The platform as ecosystem

Configurations and dynamics of governance and power

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The platform as ecosystem
Configurations and dynamics of governance and power

Het platform als ecosysteem
De configuraties en dynamieken van governance en macht
(met een samenvatting in het Nederlands)

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Preface

Acknowledgements of collaborations and co-authored publications

THIS DISSERTATION IS A MONOGRAPH, though the research that supports it was not a sole effort. I have benefited greatly from the intellectual curiosity of the wonderful colleagues I have met and worked with during the years of my doctoral research, and the multiple academic communities and institutional settings that I am fortunate to be a part of. Specifically, the body chapters of this dissertation are based on empirical and historical case studies that I have developed and carried out with colleagues from these different academic communities and settings.

At Utrecht University, I have been part of the focus area 'Governing the Digital Society' since April 2019, which is a vibrant, interdisciplinary academic community.[1] This has particularly informed my critical perspective on the social process of platformisation, and my empirical contribution to better understanding this process. At the University of Siegen, I have also been part of the Collaborative Research Centre [CRC] 1187 'Media of Cooperation' since July 2016, which is externally funded by the German Research Foundation (DFG SFB 1187).[2] My time at this centre enabled me to do the kind of novel methodological, empirical, and historical research that became an integral part of this work. And at the University of Amsterdam, I met my colleagues of the Digital Methods Initiative and the App Studies Initiative,[3] which promote methodological innovation and the empirical study of digital media, culture, and society generally. The empirical work of the current dissertation was carried out with colleagues from these different groups, sometimes in the form of data 'sprints'.[4] Because the body chapters are based on collaborations and co-authored publications, which I revised (sometimes significantly) for the purpose of this dissertation, I offer background information on each of these chapters and explain my contributions to them, starting at the beginning.

1 See: Governing the Digital Society, https://www.uu.nl/en/research/governing-the-digital-society.

2 See: DFG Collaborative Research Centre 1187 'Media of Cooperation', https://www.mediacoop.uni-siegen.de/.

3 See: Digital Methods Initiative, https://digitalmethods.net/ and App Studies Initiative, http://appstudies.org/.

4 As Venturini et al. suggest, 'Data-sprints are intensive research and coding workshops where participants coming from different academic and non-academic backgrounds convene physically to work together on a set of data and research questions' (2018: 158).

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In each of these collaborations, I have always taken on a leading role in the empirical work and in the writing, as well as in project management.

Chapter 4, 'Social media business partnerships and integrations', first of all, is based on a five-year collaboration (March 2016–2021) with Anne Helmond (University of Amsterdam, NL), leading to the publication of an article in the interdisciplinary, peer-reviewed, open-access journal *Big Data & Society* (Vol. 8, No. 1, 2021).[5] This collaborative research started with a call for papers for the *4th Internet, Politics, and Policy Conference* (IPP'16) on 'The Platform Society' (Oxford Internet Institute [OII], University of Oxford, UK).[6] At this conference, we presented the initial results of our comparative study of the digital advertising platforms of Facebook, Twitter, and other social media. This was at a time when most people were still in the dark about the considerable power of social media in this area. Subsequent iterations of this research were presented at the *9th Digital Methods Winter School, Data Sprint and Mini-Conference* (DMI'17; University of Amsterdam, NL), the *2017 Data Publics Conference* (Lancaster University/Newcastle University, Lancaster, UK), the *Consolidation of Platform Power* workshop (LSE Media Policy Project, University of London, UK) and the *Digital Platforms and Boundary Infrastructures* workshop (CRC 'Media of Cooperation', University of Siegen, DE) in 2017, the *68th Annual Conference of the International Communication Association* (ICA'18; Prague, CZ), and invited talks at King's College London, Surrey Business School (University of Surrey, Guildford, UK), and a keynote at *The Tracked Society: Interdisciplinary Approaches on Online Tracking* (ABIDA/Digital Methods Initiative [DMI], University of Amsterdam) in 2018. During *The Crisis in Political Polling and the Rise of Data Mining* workshop (Linköping University, Nörrkoping, SE) in the summer of 2017, we expanded the scope of the analysis from only popular social media to the larger marketplace of data 'brokers' and intermediaries. This workshop took place not long after Trump's rise and the Brexit vote, when we noticed data intermediaries specialised in political profiling and micro-targeting, along with dedicated resources from social media for elections. Later versions of this study were presented (including virtually) at the *2021 Annual Meeting of the Society for Social Studies of*

5 **van der Vlist FN** and Helmond A (2021) How partners mediate platform power: Mapping business and data partnerships in the social media ecosystem. *Big Data & Society* 8(1): 1–16. DOI: 10.1177/20539517211025061.

6 Helmond A and **van der Vlist FN** (2016) Big Data advertising infrastructures: A comparative study of social media ad platforms. In: *The Internet, Policy & Politics (IPP) Conferences*, Oxford, United Kingdom, 2016. Oxford Internet Institute, University of Oxford, UK. Available at: http://blogs.oii.ox.ac.uk/ipp-conference/2016/programme-2016/track-c-markets-and-labour/markets-ii/anne-helmond-fernando-n-van-der-vlist.html. See also: Call for Papers: IPP2016 'The Platform Society', http://blogs.oii.ox.ac.uk/ipp-conference/2016/call-for-papers.html.

Science (4S '21), the *22nd Annual Meeting of the Association of Internet Researchers* (AOIR '21),[7] and a keynote at the *5th 2021 SMART Data Sprint* (iNOVA MediaLab, NOVA University Lisbon, PT). Much of the empirical work that eventually became part of the published version, and of the current chapter, was carried out in January 2018—in a memorable *Ferienwohnung* with an unstable Wi-Fi network connection and in a nearby coffee shop with better Wi-Fi in Cologne. It took another three years (and multiple complete overhauls of the article manuscript) to publish the research article. I am the lead author of this publication and led the (collaborative) empirical work that led to the findings and argumentation of the study (including research design, methodology, data collection, analysis, visualisation, and interpretation). The writing occurred collaboratively (and sometimes concurrently) in Google Docs. I have modestly revised this chapter to further clarify how partnerships relate to platforms' governance and power in the larger ecosystem.

The long duration of these empirical projects (in a domain that changes so rapidly) is in most ways a difficult challenge, but also presents research opportunities for historians of the Web. Chapter 3, 'Facebook's business partnerships', is based on a three-year collaboration (September 2016–2019) with Anne Helmond and David B. Nieborg (University of Toronto, CA), leading to the publication of an article in the interdisciplinary, peer-reviewed journal *Internet Histories* (Vol. 3, No. 2, 2019).[8] This collaborative research started soon after *IPP '16*, with shared interests in the digital advertising industry, mobile apps, and the political economy of social media data. Versions of our ongoing research were presented at the *2nd 2017 Data Power Conference* (Carleton University, Ottawa, CA) and the *8th International Conference on Social Media and Society* (#SMSociety '17; Toronto, CA).[9] The empirical work (i.e., the data collection) that eventually became part of the published version, and of the current chapter, was conducted with Anne Helmond in the summer

7 **van der Vlist FN** and Helmond A (2021) Social media in the audience economy: Business-to-business partnerships and co-dependence. In: *AOIR 2021 Selected Papers of Internet Research* (SPIR), Virtual, 16 September 2021, pp. 1–4. 22nd 2021 Annual Meeting of the Association of Internet Researchers (AOIR 2021). Association of Internet Researchers. DOI: 10.5210/spir.v2021i0.12256.

8 Helmond A, Nieborg DB and **van der Vlist FN** (2019) Facebook's evolution: Development of a platform-as-infrastructure. *Internet Histories: Digital Technology, Culture and Society* 3(2): 123–146. DOI: 10.1145/3097286.3097324.

9 Helmond A, Nieborg DB and **van der Vlist FN** (2017) The political economy of social data: A historical analysis of platform–industry partnerships. In: *Proceedings of the 8th 2017 International Conference on Social Media & Society (#SMSociety '17)*, Toronto, ON, CA, 28 July 2017, pp. 1–5. ACM Publications. DOI: 10.1145/3097286.3097324.

of 2016 and the fall of 2017. Additionally, Anne Helmond and I published an article on historical platform studies methodologies in a special issue of *TMG – Journal for Media History* (Vol. 22, No. 1, 2019).[10] The methodological outlook we put forward emphasised the materiality, multiple sides, and the layers of digital 'platforms', and thus also informed the Introduction chapter of the current work. I had a leading role in the empirical work of this chapter's study (including research design, methodology, data collection, analysis, visualisation, and interpretation) and in the writing (including the original draft and editing). The writing of the published version occurred collaboratively (and sometimes concurrently) in Google Docs, with authors' names listed in alphabetical order. I significantly revised and expanded this chapter from the published version to further clarify how partnerships related to governance and power in the evolution of Facebook Platform.

Chapter 2, 'The technicity of platform governance', is based on a three-year collaboration (March 2019–2022) with Anne Helmond, Marcus Burkhardt, and Tatjana Seitz (both CRC 'Media of Cooperation', University of Siegen), leading to the publication of a working paper and an article in the peer-reviewed, open-access journal *Social Media + Society* (Vol. 8, No. 2, 2022).[11] This collaborative research started with a CAIS [Center for Advanced Internet Studies] Working Group grant to conduct a study of the relationship between the evolution of Facebook's Graph API and the data scandals and controversies that surrounded it over the years.[12] We organised two week-long data 'sprints' (2019, 2020) at the CAIS (Bochum, DE), where we carried out much of the empirical work that eventually became part of the published version and the current chapter. Versions of our ongoing research were presented at the *21st* and *22nd Annual Meetings of the Association of Internet Researchers*

10 Helmond A and **van der Vlist FN** (2019) Social media and platform historiography: Challenges and opportunities. *TMG – Journal for Media History* 22(1). Web Archaeology. Netherlands Institute for Sound and Vision: 6–34. DOI: 10.18146/tmg.434.

11 **van der Vlist FN**, Helmond A, Burkhardt M, Seitz T (2022) API governance: The case of Facebook's evolution. *Social Media + Society* 8(2): 1–24. DOI: 10.1177/20563051221086228; **van der Vlist FN**, Helmond A, Burkhardt M, Seitz T (2021) The technicity of platform governance: Structure and evolution of Facebook's APIs. Collaborative Research Centre 'Media of Cooperation' Working Paper 20. *Collaborative Research Centre 'Media of Cooperation' Working Paper Series*: 1–25. DOI: 10.25819/ubsi/9951.

12 Burkhardt M, Helmond A, Seitz T, & **van der Vlist FN** (2019). Data sharing troubles: Tracing the evolution of Facebook's Graph API [Working Group Grant]. *CAIS NRW Working Groups*, Center for Advanced Internet Studies (CAIS) GmbH, Bochum, NRW, DE. €7,600. https://www.cais.nrw/arbeitsgemeinschaften/data-sharing-troubles/.

(AoIR '20, AoIR '21).[13] The writing occurred collaboratively (and sometimes concurrently) in Google Docs. I am the lead author of this publication and had a leading role in the empirical work (including research design, methodology, data collection, analysis, visualisation, and interpretation) that led to the findings and argumentation of the study.

Chapter 5, 'Governing platform programmability', is based on a three-and-a-half-year collaboration (January 2016–2019) with Carolin Gerlitz (University of Siegen), Anne Helmond, and Esther Weltevrede (University of Amsterdam), leading to the publication of an article in the interdisciplinary, peer-reviewed, open-access journal *Computational Culture* (No. 7, 2019).[14] This collaborative research developed over the course of several week-long data 'sprint' projects at the *Digital Methods Summer and Winter Schools* (DMI'16, DMI'17; University of Amsterdam), the *1st* and *2nd Mobile Interface Methods* workshops in 2016 and 2017 (CRC 'Media of Cooperation', University of Siegen), amounting to several weeks of research time in total. I also helped design and develop software tools that were used during these 'sprints' to collect information about apps from popular app stores. The infrastructural focus of this study also inspired a special issue of *Computational Culture* that I guest-(co-)edited.[15] Versions of our ongoing research were presented at the *17th Annual Meeting of the Association of Internet Researchers* (AoIR'16; Berlin, DE)[16]

13 **van der Vlist FN**, Helmond A, Burkhardt M, et al. (2021) The governance of Facebook Platform. In: *AoIR 2021 Selected Papers of Internet Research* (SPIR), Dublin, IE, 15 September 2021, pp. 1–4. 21st 2020 Annual Meeting of the Association of Internet Researchers (AoIR 2020). Association of Internet Researchers. DOI: 10.5210/spir.v2021i0.12181; Burkhardt M, Helmond A, Seitz T, & **van der Vlist FN** (2020) The evolution of Facebook's Graph API. In: *AoIR 2020 Selected Papers of Internet Research* (SPIR), Dublin, IE, 13 October 2020, pp. 1–4. 21st 2020 Annual Meeting of the Association of Internet Researchers (AoIR 2020). Association of Internet Researchers. DOI: 10.5210/spir.v2020i0.11185.

14 Gerlitz C, Helmond A, **van der Vlist FN**, and Weltevrede E (2019) Regramming the platform: Infrastructural relations between apps and social media. *Computational Culture – A Journal of Software Studies* (7). Apps and Infrastructures. Available at: http://computationalculture.net/regramming-the-platform/.

15 Gerlitz C, Helmond A, Nieborg DB, **van der Vlist FN** (2019) Apps and Infrastructures – a Research Agenda. *Computational Culture – A Journal of Software Studies* (7). Apps and Infrastructures. Available at: http://computationalculture.net/apps-and-infrastructures-a-research-agenda/.

16 Helmond A, **van der Vlist FN**, Gerlitz C, et al. (2016) App studies: Platform rules and methodological challenges. In: *AoIR 2016 Selected Papers of*

and the *1st 2016 Annual Conference of the CRC 'Media of Cooperation'* (University of Siegen).[17] The empirical work that eventually became part of the published version, and of the current chapter, was largely conducted by ourselves in the summer of 2018. I had a leading role in the empirical work of this study (including research design, methodology, data collection, analysis, visualisation, and interpretation) and in the writing (including the original draft and editing). The writing of the published version occurred collaboratively (and sometimes concurrently) in Google Docs, with authors' names listed in alphabetical order. I thoroughly revised and expanded this chapter from the published version to include additional methodological and analytical details, and to emphasise the tensions and dynamics that unfolded between app stores, social media, and app developers.

Chapter 6, 'App stores and the pandemic response', is based on a one-year collaboration (April 2020–2021) with Michael Dieter, Nathaniel Tkacz (both Centre for Interdisciplinary Methodologies [CIM], University of Warwick, UK), Anne Helmond, and Esther Weltevrede, leading to the publication of an article in the peer-reviewed, open-access journal *Internet Policy Review* (Vol. 10, No. 3, 2021).[18] Additionally, the research design and methodology of this study are based on a longer collaboration since 2016 with the same group as part of the App Studies Initiative.[19] This collaborative research started a couple of weeks into the coronavirus disease 2019 (COVID-19) outbreak, with an ESRC/UKRI [Economic and Social Research Council/UK Research and Innovation] COVID-19 Rapid Response grant to conduct an exploratory, systematic study of the apps that were emerging to fight the global

Internet Research (SPIR), Berlin, DE, 31 October 2016, pp. 1–17. 17th 2016 Annual Meeting of the Association of Internet Researchers (AOIR 2016). Association of Internet Researchers. DOI: 10.5210/spir.v6i0.8431.

17 Gerlitz C, **van der Vlist FN**, Helmond A, et al. (2016) App support ecologies: An empirical investigation of app-platform relations. In: *1st 2016 Annual Conference of the Collaborative Research Centre 'Media of Cooperation': 'Infrastructures of Publics – Publics of Infrastructures'*, Siegen, NRW, DE, 8 December 2016. Available at: https://bit.ly/app-support-ecologies.

18 Dieter M, Helmond A, Tkacz N, **van der Vlist FN** and Weltevrede E (2021) Pandemic platform governance: Mapping the global ecosystem of COVID-19 response apps. *Internet Policy Review – Journal on Internet Regulation* 10(3). DOI: 10.14763/2021.3.1568.

19 Dieter M, Helmond A, Tkacz N, **van der Vlist FN** and Weltevrede E (2021) Multi-situated app studies: Methods and propositions. *Social Media + Society*, 5(2), 1–15. DOI: 10.1177/2056305119846486. App Studies Initiative, http://appstudies.org/.

pandemic.[20] We conducted the empirical work in the months since, with several virtual (remote) data 'sprints' at the *14th Digital Methods Summer School* (DMI '20), the *SummerPIT 2020* (Aarhus University, DK), and a self-organised *ASI/CDI Working Group data sprint* later that year, amounting to several weeks of research time in total. We presented the initial results of our exploratory study at multiple occasions, including the *5th 2020 Annual Conference of the CRC 'Media of Cooperation'*, which gave us a better sense of the value of this research. I had a leading role in the empirical work of this study (including research design, methodology, data collection, analysis, visualisation, and interpretation) and in the writing (including the original draft). The writing occurred of the published version collaboratively (and sometimes concurrently) in Google Docs, with authors' names listed in alphabetical order. The current chapter was significantly revised and expanded from the published version to include additional methodological and analytical details, to further emphasise the key role that app stores played in shaping the pandemic response that was emerging, and to discuss the tensions that unfolded between app stores, international (health) organisations, and governments worldwide.

In addition to these (open access) publications, most of the data that support the findings of the case studies included in this dissertation, as well as high-resolution versions of all figures, are openly available in the Open Science Framework [OSF].[21] This is an initiative of the Center for Open Science to support open and collaborative research practices. I am the lead creator of all these data sets and supplementary materials, as well as of all information graphics, unless stated otherwise. Google Sheets were used for collaboration and data management. Information graphics were created by myself with the help of open-source software tools, such as *Gephi* (for network visualisations and analyses), *RAWGraphs* and *D3.js* (to render different types of visualisations or charts), and *RankFlow* and *PyCatFlow* (to render different types of flow diagrams).[22] Other software tools I used and helped create in the context of this research (e.g., to scrape information, analyse text, etc.) are also openly available.[23] The full lists of data sets and software tools related to this work

20 Dieter M, Helmond A, Tkacz N, Weltevrede E, et al. (2020). COVID-19 app store and data flow ecologies [Rapid Response Grant]. *ESRC/UKRI COVID-19 Rapid Response Grant*, Economic and Social Research Council [ESRC], UK Research and Innovation [UKRI], Swindon, UK. £48,278. Grant number: ES/V004905/1.

21 Available at: https://doi.org/10.17605/osf.io/6cj5x.

22 *Gephi*, https://gephi.org/; *RAWGraphs*, https://rawgraphs.io/; *D3.js*, https://d3js.org/; *RankFlow*, https://labs.polsys.net/tools/rankflow/; and *PyCatFlow*, https://doi.org/10.5281/zenodo.5531785.

23 App Studies Initiative, ASI Tools, http://appstudies.org/tools/.

are provided in the back matter, along with further resources [▸ Data availability; Further resources]. ▾

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1. Introduction
No platform, just platform ecosystems

The 'platformisation' of digital economies and societies · *The power of 'network effects'* · *'Big Tech' have eaten the world* · Digital 'platforms' and 'ecosystems': Interdisciplinary perspectives · *Technical perspectives* · *Market-based and 'innovation' perspectives* · *Critical perspectives* · Governance and power dynamics in platform ecosystems · *Digital platforms are powerful governing systems* · *Digital platforms are multi-faceted relational constructs* · Locating governance and power dynamics in platform ecosystems · *Digital platforms' boundaries* · *The materiality of digital 'platforms'* · *The relational construction of (platform) ecosystems* · Overview of the parts and chapters · *Part I: Platform interfaces* · *Part II: Business ecosystems* · *Part III: Mobile ecosystems*

THIS DISSERTATION INVESTIGATES THE RELATIONS and material conditions of the digital 'platforms' that underpin the contemporary online digital media environment, which looks significantly different than it did some fifteen years ago. I will argue and show—empirically and historically—that it is no longer the 'platform', but the *platform 'ecosystem'* that has become the dominant technological, organisational, and governance model or configuration for today's online digital platforms. To put it provocatively: *there is no platform, there are just (platform) ecosystems*. I argue that platforms derive considerable power from these larger ecosystem structures, which I theorise and study as their larger spheres of influence. I will especially consider the implications for our understanding of platforms' governance and power, and for their potential regulation.

1.1. The 'platformisation' of digital economies and societies

It is not so long ago that 'social media' such as Facebook (founded in 2004, now rebranded as Meta since late 2021), Twitter (2006), Instagram (2010, now owned by Meta), and Snapchat (2011)—and their failed counterparts, such as Friendster (2003–2015), Google Wave, Buzz, and Plus (2009–2019), or MySpace (2003–present)[24]—were still called social networking services or 'sites' [SNSs]. People from all around the globe signed up to build social networks and relationships with other

24 While MySpace (now owned by Viant Technology) is still operational, its number of active users has declined dramatically.

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people who shared similar interests, activities, backgrounds, or 'real-life' connections. Today, 'social media' are typically called 'platforms'—by the public and by academics alike. They now constitute an intricate configuration of 'platforms', which van Dijck described as an 'ecosystem of connective media' that not only affects 'our experience of online sociality' but also a multi-faceted phenomenon that has penetrated, and transformed ('disrupted'), many different markets and sectors of society at unprecedented speed (2013: 5; van Dijck et al., 2018). Social media are not mere services for social 'connectedness' anymore but are something else as 'platforms' that exceed this original purpose.

To this day, 'platforms' remain an ambiguous phenomenon: many of their behaviours and operations are purposefully hidden and lack transparency, they continue to change or evolve continuously (many times on any single day, with many parallel-run 'A/B' ('split') tests and personalised experiences for billions of active users around the globe), they invest and pivot their business regularly to take advantage of new and emerging markets (e.g., from online digital advertising to mobile apps and games to retail to self-driving technology and vehicles), and they play a key role in many different settings (e.g., from the news to public healthcare and education to (auto)mobility, impacting how people live, work, and play). Indeed, questions such as what Google (now Alphabet), Facebook, and others even are *as 'platforms'* (e.g., Bucher, 2021), how they strategically deploy the metaphorical language of 'platforms' (e.g., Gillespie, 2010), or where the boundaries of their 'platforms' begin or end, do not have simple answers. Facebook, for instance, is many things at once: a publicly-traded holding company, a collection of Web servers and software systems, many communities of users, a variety of 'connections to the rest of the web', a large archive of content (posts, images, videos, events, etc.), and more (Bucher, 2021; Winer, 2021). Moreover, the larger economic and societal consequences are different for each (type of) 'platform'.[25] Consequently, it is not always meaningful to name Facebook, Google, and other very large 'Big Tech' companies in the same breath. As Lotz suggested, '"Big Tech" isn't one big monopoly' (2018). Additionally, it is important to know which Facebook, or which Google, is being referred to.

At the same time, while 'Big Tech' companies do and are many different things, not all of it matters to the same degree. In 2020, Apple was mostly (54.7% of

25 For example, the Digital Media and Society Series by Polity Books (Cambridge, UK), which 'takes a particular theme or phenomenon and considers the complex interplay of technologies and how they are used, in their social and cultural context', has published academic books titled *Facebook* (Bucher, 2021), *Instagram: Visual Social Media Cultures* (Leaver et al., 2019), *YouTube: Online Video and Participatory Culture* (Burgess and Green, 2018), *Twitter* (Murthy, 2018), and *tumblr* (Tiidenberg et al., 2021).

US$260 billion in total revenue) an iPhone company for customers in the Americas and Europe, just as Amazon was mostly (50.4% of US$281 billion) an online store and marketplace in the United States [USA], based on their 2019 annual financial reports filed with the USA Securities and Exchange Commission [SEC]. By contrast, Facebook and Google are undeniably advertising companies (98.5% of US$71 billion and 83.3% of US$162 billion, respectively). Only Microsoft's revenue breakdown is more diversified, led by its Intelligent Cloud server products and services (25.9% of US$126 billion).[26] Together, these 'GAFAM' companies generated almost US$900 billion in revenues, which is roughly the GDP [gross domestic product] of the Netherlands.[27] Critical scholarly research, as well as governance and regulation of technology companies arguably should be guided by these facts, such that Facebook is scrutinised as an online digital advertising giant, Apple as a mobile platform giant, and so on. This dissertation, as I will explain in this introduction, is a contribution to understanding what is behind this digital dominance, particularly how infrastructure and software development matter in the construction of platforms' governance and power.

These types of issues and concerns are at the very core of current debates around the sources and features of platforms' influence and power that take place across academic fields and disciplines, for regulators, and increasingly in society generally (e.g., Busch et al., 2021). In fact, the very ambiguity around the definition of digital 'platforms', their boundaries, and their participation in different markets and settings may have contributed to the slow response from lawmakers and regulators regarding (the negative consequences of) the growing power and monopoly position of some platforms as well as their lack of social responsibility. The question of how to conceive of and regulate digital platforms' market power in antitrust cases, for instance, hinges on the definition of the relevant market (e.g., Brandom, 2021; Maréchal, 2021). It is, then, important to address this (strategic) ambiguity of 'platforms' and to articulate and visualise their complex boundaries (and contested boundary dynamics). That is, to surface the many different relations that powerful digital 'platforms' have (and do not have, or perhaps should have) to objects, institutions, infrastructures, and the world around them.

26 'The future of computing: intelligent cloud and intelligent edge', https://azure.microsoft.com/en-us/overview/future-of-cloud/

27 American Big Tech companies are commonly grouped and called 'GAFA' (as Google (now Alphabet Inc.), Amazon, Facebook, and Apple), 'GAFAM' (inclusive of Microsoft), or 'FAAMG'/'FAANG' (inclusive of Netflix). Their Chinese competitors are called 'BAT' (as Baidu, Alibaba, and Tencent) or 'BATX' (inclusive of Xiaomi).

1.1.1. *The power of 'network effects'*

Despite this ambiguity, it is arguably no coincidence that the most powerful of the Big Tech companies, and the most popular 'platforms' they own, all offer online social networking services in one way or another, or even started out as such. Facebook, Google (with Gmail, for instance), Twitter, and others became vital to people's everyday life and practice as free-of-charge and trusted services for online communication and sociality (e.g., Pierson, 2021), after which they could more effectively leverage their established positions to generate revenue from people's online ('datafied') social actions and behaviours, most notably through online digital marketing and advertising (Crain, 2021; Turow, 2013; Zuboff, 2019). Social networks are the very core of the 'ecosystem of connective media'.

Facebook's global outage in October 2021 revealed once more that Big Tech companies are far more than their consumer-facing social networking services (e.g., websites and mobile apps). During the outage, Facebook was globally unavailable for six hours, as well as preventing anyone trying to 'Log in with Facebook' (or 'Continue with Facebook') from accessing the many third-party apps and services that rely on the platform's popular authentication and data access service.[28] The outage had a significant effect, especially in developing countries where Facebook's apps and services have become the main way people communicate or run their business. Indeed, these types of software-based systems and structures are woven into the very fabric of everyday social and economic life and practice around the globe: for many people, Facebook's 'Family of Apps and Services' is the portal to the Internet; Google's search engine and advertising technology ('adtech') is a hidden structure that influences people's social actions and behaviours, and Amazon and Microsoft's cloud services are the 'back-end' infrastructure for many of the apps and services that consumers and businesses use or need to operate (Gault, 2021).[29]

28 https://developers.facebook.com/docs/facebook-login/

29 Scholars note that Big Tech companies themselves commonly make statements of building 'social infrastructure' and of being indispensable in social life (e.g., Edwards, 2003: 187; Hoffmann et al., 2018; Pierson, 2021; Rider and Murakami Wood, 2019). For instance, Facebook's mission statement changed in 2017 from 'connecting people' to developing 'the social infrastructure for community—for supporting us, for keeping us safe, for informing us, for civic engagement, and for inclusion of all' (Zuckerberg, 2017; cf. Haupt, 2021). Vaidhyanathan contends that this change reflected Facebook's renewed ambition from being the 'operating system of our laptops and desktops' to becoming 'the operating system of our lives' (Vaidhyanathan, 2018: 99, quoted in Nieborg and Helmond, 2019: 199). As a 'social infrastructure', Facebook thus sought to become not only ubiquitous

'Network effects' are of particular significance in this respect. Network effects are powerful multipliers by which the value or utility of a tool, products, or service—or indeed, a 'platform'—depends on, and grows *exponentially* with the number of users connected (e.g., Easley and Kleinberg, 2010; Eisenmann et al., 2011; Evans and Schmalensee, 2016; McIntyre and Srinivasan, 2017; Parker et al., 2016; Rochet and Tirole, 2003). In the case of social media, they include billions of end-consumers (e.g., who signed up for a profile and to connect with friends and family), millions of small, medium-sized, and large businesses (e.g., who sign up to increase brand visibility or to 'run' digital marketing and advertising campaigns), publishers and journalists (e.g., who sign up to reach and engage with their audiences), and many additional types of users.

Many of the most valuable (publicly-traded) companies worldwide today are information technology ('tech') companies that, in stark contrast to 20 years ago, leverage such network effects (e.g., Apple, Microsoft, Amazon, Google, Facebook, Tencent, and Alibaba), most notably those enabled by large-scale computer networks and Internet infrastructure. There are different types of network effects that coalesce with social networking, including (direct and indirect) effects related to 'many-sided' marketplaces or market networks, data, and additional uses of that data. More data does not necessarily translate into more value, better technical performance improvements (e.g., faster, cheaper, easier to use), or different types of 'social' network effects (e.g., language, beliefs, social 'bandwagon' pressures to join a network) (cf. Currier, 2019; Currier, 2021). While some of these network effects are non-digital, others seem 'native' to the digital age (e.g., scale, close to zero marginal cost). In fact, Schwartzman suggests that the 'network effect' itself is fundamentally anti-competitive as it manifests itself on the Internet: in the contemporary (platformed) media environment, 'winner-takes-all'—or, more appropriately, 'winner-takes-most'—marketplaces are dominated by a small handful of Big Tech companies, which 'neutralizes the competitive market, because everyone gravitates to the dominant service' (2021; cf. Srnicek, 2016). Big Tech companies purposefully or strategically establish, integrate, and leverage powerful network effects at all levels to serve as a principal source of their economic strength, power, and influence in the larger media environment that underpins—that is, serves as the infrastructure of—today's digital economies and societies.

It is important to recognise how technology companies have set themselves up as digital 'platforms' in this respect. Specifically, this has introduced a type of developmental process where external users, stakeholders, and partners are enrolled, and which has been vital to their explosive growth and expansion and the entrench-

('to connect the world', 'building global community') but also an essential part of everyday social life and practice.

ment of their power. Andersson Schwarz noted that 'As surfaces on which social action takes place, digital platforms mediate—and to a considerable extent, dictate—economic relationships' (2017: 2). Additionally, they have solidified markets and social relationships, interactions, and exchanges into material infrastructure in ways that introduced 'platform logic', a concept to 'simultaneously acknowledge the technical capacity of unyielding local control and its consequential concentrations of global dominance by a handful of corporate actors' (Andersson Schwarz, 2017: 5; cf. Plantin et al., 2018). Drawing from this critical material perspective, I will similarly argue that large digital platforms have become powerful 'governing systems' and explain why it matters that they are organised as digital 'platforms'. Specifically, I investigate the *material configurations and dynamics* of platforms' governance and power to find an answer to my overall leading research question (to which I return later in this introductory chapter): *How are governance and power manifested in the developmental processes that constitute the ecosystems of (very large) digital platforms?* [▸ §1.5]. These developmental processes that constitute platform ecosystems, I will show, do not only involve the platform owners (or their employees), but also benefit considerably from large networks of heterogeneous users and developers. Third-party software developers, digital marketers and advertisers, and business partners all help build and extend platforms' larger ecosystems—that is, their (extended) spheres of influence.

1.1.2. *'Big Tech' have eaten the world*

Network effects explain the rapid proliferation of the 'platform' as a 'dominant infrastructural and economic model' (Helmond, 2015a: 1; Helmond, 2015b) in many different economic sectors and 'spheres of life' (Poell et al., 2019). Social media 'platforms' have leveraged network effects to the extent that they are now increasingly discussed in terms of 'public utilities', 'essential services', or critical 'infrastructures' (e.g., Alaimo and Kallinikos, 2017; Barns, 2019; Pierson, 2021; Plantin and Punathambekar, 2019; Plantin et al., 2018; van Dijck, 2021b). A small handful of core Big Tech companies increasingly perform the role of infrastructure providers to the rest of society in an 'internet-societal complex' (Flyverbom et al., 2019). In this context, Plantin et al. note that 'platform-based services acquire characteristics of infrastructure, while both new and existing infrastructures are built or reorganized on the logic of platforms' (2018: 1). Despite many waves of (social media) criticism in the wake of the June 2016 UK–European Union [EU] membership referendum, the USA Presidential Elections, the spread of misinformation, disinformation, and 'fake news', online political manipulation, threats of election interference, the Facebook–Cambridge Analytica [FB–CA] 'data scandal', the EU

General Data Protection Regulation [GDPR] and related legislation elsewhere,[30] and the global coronavirus ('COVID-19') pandemic, Big Tech companies have only further centralised and consolidated their positions of power.[31] What these criticisms have in common is that they all raise issues and concerns about the 'back-end' of social media, particularly the 'lucrative incentive structure for "fake news" publishers' (Braun and Eklund, 2019) and the 'weaponization' of digital advertising technology for social or political manipulation used by 'political and anti-democratic actors' to 'prioritize vulnerability over relevance' (e.g., Nadler et al., 2018: 6; Vaidhyanathan, 2018). Consequently, 'attribution of infrastructural power can hardly be limited to one company or one market but needs to apply to how platforms operate *in conjunction*' (van Dijck et al., 2019, emphasis in original).

The influence and power of 'Big Tech' companies is undeniable today. Big Tech are among the largest, most profitable, and most widely-used systems in history, and are now facing the biggest wave of antitrust legislation in their own history. Authors such as Moazed and Johnson (*Modern Monopolies*), Galloway (*The Four*) and Moore and Tambini (*Digital Dominance*) all recognised the power and monopoly position of Google, Amazon, Facebook, and Apple as some of the most influential companies (Galloway, 2018; Moazed and Johnson, 2016; Moore and Tambini, 2018). Additionally, business and strategic management scholars have studied the 'platform revolution' (Parker et al., 2016), the 'new economics' of 'multi-sided platforms' (e.g., Evans and Schmalensee, 2016), and the 'business of platforms' (Cusumano et al., 2019). They all share a common interest in how business, management, markets, and innovation have changed in the digital age—that is, in today's digital (platform) economies and societies—and the implications for competition, strategy, design, knowledge, and power. Furthermore, there is also more critical awareness of the broad societal consequences and the need for 'good' governance, policy responses, and and regulation regarding Big Tech and platformisation in Europe and beyond (e.g., van Dijck, 2021a; van Dijck and Rieder, 2019; Moore and Tambini, 2022). For this to be effective, it is particularly relevant that the dominant narrative of a digital economic transformation around markets,

30 E.g., 'General Data Protection Regulation (GDPR)', https://gdpr-info.eu/; 'California Consumer Privacy Act (CCPA)', https://oag.ca.gov/privacy/ccpa; and 'What is the LGPD? Brazil's version of the GDPR', https://gdpr.eu/gdpr-vs-lgpd/

31 E.g., 'Social media: Criticism, debate and controversy', https://en.wikipedia.org/wiki/Social_media#Criticism,_debate_and_controversy; 'Criticism of Facebook', https://en.wikipedia.org/wiki/Criticism_of_Facebook

competition, and innovation is expanded to include the accompanying societal, political, and cultural transformations (e.g., van Dijck et al., 2018; van Dijck, 2020; van Dijck, 2021a).

There is a (brief) history to this type of platform thinking and how the Internet, social media, and, more broadly, the media and cultural environment all came to operate under a 'platform paradigm' (Burgess, 2015; Burgess, 2021). This history involves many different fields and disciplines, which illustrates the enormous breadth and complexity of understanding this platform paradigm, and how power operates within it. To begin, Andreessen famously wrote in the *Wall Street Journal* that 'software is eating the world' (Andreessen, 2011).[32] The article has inspired a decade of software development and financial capital investments, as well as others—from investors to critical scholars—to extend the argument, including that '[m]obile is eating the world' (Evans, 2016), that 'platforms are eating the world' (Moazed and Johnson, 2016; Parker et al., 2016), or more recently, that 'software is eating the car' (Charette, 2021; Hind et al., 2022). These authors recognised the cultural, social, economic, and political significance of software in specific domains. Additionally, scholars have discussed the processes of 'Googlization' (e.g., Rogers, 2009; Vaidhyanathan, 2012), 'softwarisation' (Manovich, 2013), and 'platformisation' as processes that have profoundly transformed the contemporary media environment. This includes the open Web (Helmond, 2015a; Helmond, 2015b), mobile media and 'apps' (e.g., Aradau et al., 2019; Gerlitz, Helmond, Nieborg, et al., 2019; Goggin, 2021; Morris and Murray, 2018; Nieborg and Helmond, 2019), and media infrastructure (Plantin and Punathambekar, 2019; Plantin et al., 2018). This also includes transformations in a broad variety of markets and sectors of society, including digital marketing and advertising, Web search, cultural production, financial transactions, the news, urban transportation, healthcare, education, and automobility (e.g., van Dijck et al., 2018; Kerssens and van Dijck, 2021; Nieborg and Poell, 2018; Poell et al., 2019; Rieder and Sire, 2014; Westermeier, 2020). Furthermore, some have argued that the 'platform' is not only a recent phenomenon but also a paradigm of industrial organisation more broadly, such as for the 20th-century automobile industry (e.g., Cusumano et al., 2019; Hagiu and Wright, 2015; Steinberg, 2019; Steinberg, 2021). Finally, critical scholars in fields and disciplines across the humanities and social sciences with a common interest in 'new media' have long studied the politics and power of software, 'platforms', and computing generally (e.g., Montfort and Bogost, 2009; Bucher, 2018; Fuller, 2008; Galloway, 2004; Helmond, 2015b; Manovich, 2001; Manovich, 2013; Rogers, 2013b; Wardrip-Fruin and Montfort, 2003). These contributions add up to a better general understanding of what platforms are, why to study them, and why to be cautious of their power. With

32 Co-founder of Silicon Valley venture capital firm Andreessen Horowitz and co-developer of *Mosaic*, the first widely-used Web browser.

this dissertation, I am contributing critical empirical and historical perspectives on these matters, which, I will argue, is necessary to further advance our critical understanding of platforms' governance and power within each of these domains.

Today, the rise of the digital (platform) economy has evolved into a broader debate about a more connected and fluid digital (platform) society that recognises the many different impacts of digital platforms' power on markets and democratic societies around the globe. van Dijck et al. explain how the 'platform society' manifests itself as a 'contested concept' that foregrounds the 'struggles' that play out at different levels of society regarding the governance of platform companies, the compatibility of private and public values, the roles and responsibilities they have (and do not have) (2018: Ch.1; van Dijck, 2020; cf. Schüßler et al., 2021). These 'struggles' thus surface the conflicts and problems that arise with the platformisation—here defined as 'the penetration of the infrastructures, economic processes, and governmental frameworks of platforms in different economic sectors and spheres of life' (Poell et al., 2019)—of economies and societies around the globe.

The challenges of governing digital (platform) economies and societies in Europe and elsewhere are considerable. They cannot be considered separate from technological systems and structures, the companies that build and sustain them, and the many different communities of people that use them in everyday life and practice (van Dijck, 2021a: 10). Addressing these challenges requires an integrative understanding that involves concepts and methods from different fields and disciplines. Social and economic life has become more global and complex, which necessitates forms of private governance (e.g., platform governance by technology companies, or governance by the Internet Engineering Task Force [IETF] as a complement to public sector governance and regulation. However, it is important that they do it right given the stakes. This dissertation, therefore, is a contribution to exploring how digital platforms' governance and power configurations manifest themselves in their technological development, and how they shape social and economic relationships, interactions, and exchanges. This type of knowledge is not self-evident because of the complexity, changeability, and interdependence of today's digital media environment, yet it is impossible to intervene effectively without it.

In the remainder of this introductory chapter, I will first provide relevant background on the key concepts of this dissertation. After that, I will situate the specific focus and contribution of this dissertation [▸ §1.3]. I then explain my approach, along with the empirical and historical materials and methods I have used [▸ §1.4]. And finally, I provide an overview of the leading research (sub)questions and how I will address them in the chapters [▸ §1.5].

1.2. [BACKGROUND AND POSITIONING]

Digital 'platforms' and 'ecosystems': Interdisciplinary perspectives

Digital platform research (or Platform Studies) is a vibrant interdisciplinary research area that spans multiple fields and disciplines in the humanities and social sciences. It is an 'umbrella' that covers a range of established streams of research on online digital platforms, including within Business and Management Studies, Economics, and Information Systems [IS] research, critical Communication and Media Studies [C&MS], Information Studies, and Sociology. Definitions of the core concepts, such as 'digital platforms', 'digital infrastructures', and 'digital platform ecosystems' differ across these fields and disciplines because they have different interests. Additionally, these fields and disciplines do not necessarily draw from each other's contributions as often as they could. This section provides a detailed overview of the core concepts and features of digital 'platforms' and 'infrastructures' as understood in these different fields and disciplines. For this research, it is relevant to distinguish (1) technical perspectives, (2) market-based and 'innovation' perspectives, and (3) critical perspectives. These three perspectives are important for understanding the technical and non-technical features of platforms' governance and power, and especially the significance of the developmental processes that constitute the 'ecosystems' of platforms. While I provide a thorough overview of the relevant academic literature, it is by no means exhaustive.

1.2.1. *Technical perspectives*

Technical perspectives on digital platforms are relevant to understand the characteristics of platforms as software-based systems or as collections of software-based systems and subsystems. Here, a 'platform' is conceived as 'the extensible codebase of a software-based system that provides core functionality shared by the modules that interoperate with it and the interfaces through which they interoperate' (de Reuver et al., 2018: 126; cf. Ghazawneh and Henfridsson, 2015; Tiwana, 2014; Tiwana et al., 2010). These 'modules' are 'add-on software subsystems' (Tiwana and Konsynski, 2010) or 'pieces of software that are offered as applications, services, or systems to end-users' and are created by third-party software developers (Dal Bianco et al., 2014; Eaton et al., 2015; Ghazawneh and Henfridsson, 2013; Tiwana, 2014). Innovation perspectives often call these modules as 'complements' to a core technical platform. The digital platform thus incorporates modules that extend the core functionality already provided in some way and thereby provides opportunities for 'distributed development and recombinant innovation through modularisation' (Baldwin and Clark, 2000; Henderson and Clark, 1990; Sanchez and Mahoney, 1996; Yoo et al., 2010).

Interoperation between the modules is commonly enabled by public ('open') application programming interfaces [APIS], which are provided by platform owners along with additional development tools, regulations, and reference documentation. These interfaces are designed to allow third-party software developers to build applications and services 'on top' of a platform's extensible codebase, which contrasts with the graphical user interfaces [GUIs] that are designed for end-consumers. Given the terminology, it is relevant to note, as Burgess does, that 'public APIs [...] have been traditionally provided by platforms for commercial rather than public purposes' (2021: 30). In addition to public APIs, there are also semi-public and non-public APIs, including partner APIs exposed to (strategic) business partners and private (internal) APIs used for development purposes within companies and organisations (e.g., between departments or teams).

APIs thus enable connectivity and data traffic flows among software-based systems and subsystems and drove the shift towards the 'data-intensive' social Web with 'platforms' at the centre (Gerlitz and Helmond, 2013). Additionally, APIs serve a broad variety of purposes and user groups: they are used by individual developers and business developers, digital marketing and advertising technology ('martech' and 'adtech', respectively) developers, academic researchers, and others to build applications and services that access a platform's data or functionality. Furthermore, any given application is typically connected, or integrated with, a multitude of different software-based tools, products, and services (e.g., Dieter et al., 2019).

In addition to APIs, digital platforms typically provide software development kits [SDKs], which are collections of software development tools that developers may use or need to build applications (more effectively) 'on top' of platforms (e.g., Ghazawneh and Henfridsson, 2013; Helmond and van der Vlist, 2019). For instance, Facebook offers a variety of APIs and SDKs to assist in the development of applications for its ecosystem. There are also specific Android APIs and SDKs (by Google), iOS APIs and SDKs (by Apple) for the development of applications that 'run' on people's Android and iOS-powered mobile devices, respectively. Additional materials are often provided to communicate about these resources, including API reference documentation. Ghazawneh and other IS researchers have theorised these specific materials as platforms' 'boundary resources' [PBRs], which are the technical and non-technical ('social') tools, materials, and regulations, which are provided by platforms to leverage, control, and influence the generative capacity of third-party software app developers or other contributors in platform ecosystems (Dal Bianco et al., 2014; Eaton et al., 2015; Ghazawneh and Henfridsson, 2013). As such, PBRs serve as a key means by which the external relationships to players in the platform ecosystem are managed and controlled. As I will explain in this chapter, PBRs are also crucial to the empirical and historical approach of this dissertation, because they can be used to study how platforms govern and control their 'ecosystems' [▸ §1.4]. In other words, PBRs are vital to understanding the configurations and dynamics of platforms' governance and power.

The extent to which these PBRs support third-party modules complementing a platform's extensible codebase is considered a platform's *openness*. As such, digital platforms such as iOS (Apple's mobile operating system) and Android (Google's mobile operating system) each have different levels of openness. This openness also changes or evolves continuously because of its strategic importance for the involvement of a platform's key stakeholders (e.g., Benlian et al., 2015; Ghazawneh and Henfridsson, 2015; Ondrus et al., 2015). A digital platform 'ecosystem' is the entire collection of complements (the modules, complements, or applications) to the core technical platform (the extensible codebase); or, the software-based system plus any subsystems that interoperate with it through its programming interfaces (e.g., Blanke, 2014; de Reuver et al., 2018; Tiwana, 2014). Regardless of differences in the specific configuration of a platform's relationships, and how they are governed or regulated, a platform 'architecture' thus consists of a 'core' and potentially also a 'periphery', as well as the (programming) interfaces (Rodón Mòdol and Eaton, 2021; Staykova and Damsgaard, 2015).

de Reuver et al. have also suggested that 'digital platforms can be seen as a less complex subtype of digital infrastructure with specific control arrangements', which 'may be anchored in an organisation or consortium of companies that owns the core platform technologies' (2018: 127; cf. Constantinides et al., 2018; Hanseth and Lyytinen, 2010; Henfridsson and Bygstad, 2013; Tilson et al., 2010). Some have theorised this coalescence as the 'infrastructuralisation' of digital platforms and the 'platformisation' of infrastructure, whereby platforms acquired features of infrastructure (e.g., ubiquity, wide accessibility, reliability, etc.) and the other way round (Constantinides et al., 2018; Plantin et al., 2018). From a historical perspective, however, 'digital infrastructure evolved and took the architectural form of a digital platform as a core–periphery structure over a 20-year period' (Rodón Mòdol and Eaton, 2021).

Generative mechanisms are of specific interest in the literature on digital infrastructures because they serve to describe and explain how and why digital infrastructures change or evolve (e.g., Grisot et al., 2014; Henfridsson and Bygstad, 2013; Rodón Mòdol and Eaton, 2021; Tilson et al., 2010; Tiwana et al., 2010). Henfridsson and Bygstad distinguished four streams of research on this relationship between generativity and infrastructure evolution: (1) that there is no single source of digital infrastructure evolution but a multitude of heterogeneous actors who simultaneously enact their own goals; (2) that there are networks of human—or organisational—and nonhuman actors who translate and inscribe their interests; (3) that evolution is the outcome of the sensemaking of users or other stakeholders; and (4) that managers initiate and implement changes to increase the alignment between its systems and strategic imperatives (2013: 909–910). Additionally, they identified the mechanisms of innovation (e.g., creating new products and services through the malleability of software and the recombination of resources), adoption (e.g., through low costs, ease of use, readily available resources, etc.), and scaling or scoping (e.g., through expanding products and services, growing the user base, attracting stakeholders and partners, etc.). Taken together, these mechanisms contribute towards a better understanding of what drives digital platforms' evolution (e.g., Gawer, 2021b; Helmond and van der Vlist, 2019; [‣ Chs. 2 and 3]) or their current transformation from platforms into infrastructures (and *vice versa*) (e.g., Constantinides et al., 2018; Mackenzie, 2019; Plantin et al., 2018).

Furthermore, early 'information infrastructure' studies in this area already provided insights into power dynamics in network structures that remain relevant today. For instance, the observation that the enrollment of a growing number of actors, organisations, and institutions in the development of large technical systems, such as information infrastructures, accumulate material 'resistance against change' through such things as technical standards (Akrich, 1992: 206; Callon, 1990 Hanseth et al., 1996: 418). That is, the larger a technical system becomes, the more difficult it is to alter circumstances and adapt to change, which is a severe risk faced by larger digital platforms (Hanseth et al., 1996; Tiwana et al., 2010). Rodón Mòdol and Eaton described this kind of dynamic in platform ecosystems as one of 'generative entrenchment', where the generativity of a digital platform or infrastructure leads to the establishment of a 'core–periphery' architecture structure that entrenches (consolidates) both the peripheral modules or complements and the initial core technical platform as they come to depend on each other (2021). As I argue and demonstrate in this dissertation, this process of entrenchment through development is of particular significance to understanding the configurations and dynamics of power and governance in platform ecosystems.

To sum up, the technical perspectives provide relevant concepts and materials for studying the material (or *artefactual*) aspects that help shape and govern a digital platform's use and development cultures, its relationships with key stakeholders, its infrastructural entanglements, and the organisation of its ecosystem. I draw from these to understand the technical and infrastructural features of governance and power within contemporary platform ecosystems. Additionally, they enable more nuanced and empirical perspectives on the accumulation of power and dominance by platforms and technical systems generally, up to the point where they may become 'too big to change' (e.g., Gartenberg, 2021).[33]

33 Note that this dynamic is an important strategic motivation for 'startups' or new market entrants to 'scale quickly', particularly with the help of venture capital [VC] funds from USAbased 'angel investors' and 'startup accelerators' such as Y Combinator (e.g., Airbnb, DoorDash, Dropbox, etc.), AngelPad (e.g., Buffer, MoPub, etc.), and others. Venture capital and its political underpinnings are considered the 'backend of the digital economy' (Cooiman, 2021). Additionally, partnership strategies are also commonly

1.2.2. *Market-based and 'innovation' perspectives*

Market-based and 'innovation' perspectives on digital platforms emphasise the role of platforms as transactional intermediaries that facilitate exchanges between different 'sides' of a market (e.g., buyers and sellers, consumers and producers, etc.) or between multiple markets (e.g., Web search or social media with online digital advertising markets). Some of this foundational work from Business and Management Studies and Economics precedes contemporary research on digital platforms. Like the technical perspectives, these market-based and 'innovation' perspectives are important to understand how 'platforms' evolve, manage, and control their 'ecosystems', who participates in these developmental processes, and what kind of governance and power dynamics unfold within them.

Platforms are often conceived as 'multi-sided platforms' in this context (e.g., Abdelkafi et al., 2019). Multi-sided platforms are seen as (inter)mediating and structuring the relationships between different groups of users, such as end-consumers and advertisers or buyers and sellers of products and services. That is, they play an intermediation or a 'matchmaking' role (Evans and Schmalensee, 2016; Gawer, 2014). The related concept of 'multi-sided markets' is used when it is not a platform but a market that brings together distinct user groups, wherein the value for one user group ('side') may increase or decrease as the number of participants on the other 'side' increases or decreases (e.g., Langley and Leyshon, 2017; Rochet and Tirole, 2003). In both cases, the focus is on the intermediary role between two or multiple groups of users or market sides, which may serve to minimise 'transactions costs', shape the dynamics of competition (Rochet and Tirole, 2003), or lead to conflicts of interest and bias as in the case of search engine results (Rieder and Sire, 2014; Sundin et al., 2021).

Additionally, Cusumano et al. (2019) distinguish two types of platforms based on whether or not they facilitate innovation in new tools, products, and services: 'innovation platforms', which can be software-based or hardware platforms, and 'transaction platforms', which intermediates two or multiple market sides to facilitate interaction and exchange between them. The most powerful Big Tech companies, as owners and operators of not just one but multiple interconnected digital platforms (e.g., van Dijck, 2021b), tend to combine both types of platforms.

Furthermore, these perspectives study digital platforms as organisational or innovation configurations, comprising a 'keystone' player and any number of 'complementors' or third-party software developers (Ghazawneh and Henfridsson, 2013; Iansiti and Levien, 2004). The 'keystone' player can also be a non-digital

used to accelerate a platform's growth or market entry, as discussed in Chapters 3 and 4.

'platform', such as in Steinberg's study of 20th-century Toyotist automobile manufacture (2019; 2021). The concept of 'innovation ecosystem' is defined as 'the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors' (Granstrand and Holgersson, 2020; cf. Cusumano et al., 2019; Gawer and Cusumano, 2014). In this, there is a particular interest in the (co-)creation and capture of 'value', such as the creation of new complementary tools, products, and services (Adner and Kapoor, 2010; Ceccagnoli et al., 2012; Kapoor, 2018; Sarker et al., 2012). This also enables market diffusion of innovations created by the 'keystone' player or 'platform leader' (e.g., Bomtempo et al., 2017: 221; Gawer, 2009). What counts as innovation or value is thus shaped and controlled by the 'keystone' player. Additionally, the modularity of digital platforms is not only a software architecture style but also a crucial aspect of how platforms have distributed value creation while they centralised value capture (e.g., Barns, 2019: 5; Gawer, 2021a; Gerlitz and Helmond, 2013; Kapoor, 2018).

In this segment of the literature, 'platform ecosystems' are conceived of as 'complex ecologies of firms with individual and collective, intertwined interests, whose expansion and growth follows through the co-evolution of the digital platform core and the ecosystem participants' interests and stakes' (Haki, 2021: 243; cf. Hein et al., 2020). While these configurations are now the dominant technological, organisational, and governance model for contemporary online digital platforms, as I argue and demonstrate in this dissertation, they are not a recent phenomenon. To the contrary, these configurations have been in the making for decades. For instance, the German SAP, which is one of the largest non-American enterprise (business-to-business) software companies in terms of revenue with an ecosystem of more than 13,000 partners, states that 'reaching our full potential depends on how well we enable our partners, providing them with [the] tools they need to accelerate growth and exceed customer expectations in an increasingly complex world' (SAP Partner Edge, n.d., quoted in Hein et al., 2020: 87). IBM and Microsoft are also commonly discussed in the academic literature because of their significant business-to-business partner networks (i.e., 'partner ecosystems'), especially in the years before the rise of Google, Apple, and Facebook.[34] Today, all these Big Tech companies are configured as 'ecosystems' and, crucially, lend control and power from these configurations. For this reason, it is important that we learn to surface and understand the configurations and dynamics of governance and power that unfold within them.

34 E.g., 'IBM PartnerWorld', https://www.ibm.com/partnerworld/public; 'Microsoft Partner Network', https://partner.microsoft.com/

Haki et al. suggest that platforms and participants mutually shape 'an ecosystem of heterogeneous stakeholders that take advantage of the platform to develop innovative value propositions for their customers' (Haki, 2021: 244). As such, digital platforms facilitate—that is, (inter)mediate—the (co-)creation of value between different stakeholders in an ecosystem and they are incentivised to do so because they also derive 'much of their value' from the ecosystems they serve (Haki, 2021: 245). This process is often facilitated by a platform's (social) data, as accessed via its APIs. Consequently, scholars have explored such things as 'API ecosystems' in relation to business strategy (Evans and Basole, 2016), the 'advertising ecosystem' as a complex and interconnected set of API-based integrations [‣ Ch. 4] and as algorithmic systems (e.g., Alaimo and Kallinikos, 2021; Alaimo and Kallinikos, 2018; Broughton Micova and Jacques, 2020). Others studied 'ecosystem data' (Basole, 2020) and social media as 'data platforms' and data-based 'service ecosystems' (Alaimo and Kallinikos, 2017; Alaimo et al., 2020).

To sum up, the market-based and innovation perspectives provide relevant concepts to study the role of platforms as intermediaries that seek to balance the interests of their users, stakeholders, and partners. This is important for a critical understanding of how social media platforms are enmeshed in technical, social, and economic complexities (and how they became enmeshed to begin with), as I explain in subsequent chapters. Additionally, these perspectives provide relevant insights about the mechanisms and dimensions of platform governance, including the specific role of multi-sided platforms as *governors* or 'private regulators' who 'regulate access to and interactions around the platform' (Boudreau and Hagiu, 2009: 164; cf. Hein et al., 2020; Parker and Van Alstyne, 2018; Schreieck et al., 2018). It is also noted that further research is needed to understand how platforms help states and civil society organisations to construct and shape markets (Schüßler et al., 2021: 18), which is discussed in subsequent chapters.

1.2.3. *Critical perspectives*

Finally, there are relevant critical perspectives across fields and disciplines, including Communication and Media Studies [C&MS], Sociology, and the public discourse generally. Here, the term 'platform' often refers to the online services of content intermediaries or digital intermediaries more broadly. These critical perspectives do not necessarily draw from or engage with the technical or the market-based and innovation perspectives but may nevertheless have an affinity with them. Most importantly, they provide alternative perspectives on the various roles and responsibilities of platforms as an integral part of everyday life and practice, and of social processes more broadly, beyond mere technical (software) architecture style or business (management) model. Since the critical research on the politics and power of 'platforms' is extensive, I will at this point only mention key contributions for understanding the relationships between platforms and larger ecosystems in general terms. Additional critical perspectives (including on platform governance) are introduced in the next sections, as well as in subsequent chapters (i.e., as case-specific literature).

To begin, it is worth noting that those who operate 'platforms' are often careful to position themselves to end-consumers, developers, business, marketers and advertisers, investors, policymakers, or other user groups, by 'making strategic claims for what they do and do not do, and how their place in the information landscape should be understood' (Gillespie, 2010: 347). In 2010, Gillespie noted the ambiguity of the 'platform' concept and its use by identifying four distinct uses of the term to reveal the semantic areas and discursive politics of these 'platforms': (1) a computational meaning (as 'an infrastructure that supports the design and use of particular applications'); (2) an architectural meaning (as 'human-built or naturally formed physical structures'); (3) a figurative meaning (e.g., as 'a metaphysical [platform] for opportunity, action and insight'); (4) and a political meaning (e.g., as 'the issues a political candidate or party endorses') (Gillespie, 2010: 349–350). The 'platform' thus remains a slippery phenomenon to study, as well as govern and regulate, in part because of these multiple meanings and how they are deployed by technology companies. Surfacing the relations and material configurations of contemporary digital platforms helps to dissolve this (deliberate) ambiguity and thereby increase our ability to effectively govern and regulate Big Tech companies.

Additionally, Burgess suggests that the contemporary media and cultural environment operates under a 'platform paradigm' because of 'the penetration of economic, governmental and infrastructural extensions of digital platforms into the web and app ecosystems' (Nieborg and Poell, 2018: 4276), including any further sectors of society that rely on the Web in some way (Burgess, 2021: 22). That is, the process of platformisation and its consequences have expanded beyond the Web but cannot be understood without its reliance on the Web as infrastructure. Additionally, Burgess notes that platforms are 'powerful cultural shapers' and 'play a major role in governing the forms of creativity and social interaction that takes place through them' (2021: 24). However, these power relationships are not necessarily unidirectional: platforms may shape (govern) but they are also 'partly built, shaped and influenced by' their communities, practices, and the social norms they have developed (2021: 24; cf. Hurni et al., 2022; Schüßler et al., 2021). To locate governance and power, then, it is important to consider how platforms are enmeshed in social, technological, and economic complexities of larger ecosystems.

Furthermore, van Dijck et al. defined 'online platforms' as 'programmable architectures designed to organize interactions between users online' in everyday life (2018: 9). They stress that platforms were never neutral conduits of 'online sociality' and interactions; instead, 'they are enabled by hardware infrastructures, fuelled by data (often generated by users), automated and organized through algorithms, formalized through ownership relations and monetized via business models' (van Dijck, 2021a: 325). Moreover, they generate normative conflicts and potential conflicts of interests, such as between the commercial interests of information technology companies (as private or publicly-held companies) and the public interests of individual end-consumers, citizens, communities, governments, and societies—differences and conflicts that affect the everyday lives and practices of people, as well as institutional structures all around the globe (2021a: 325).

In addition to the above, there are also critical perspectives on ecosystems, although they are relatively uncommon. van Dijck referred to the 'ecosystem of connective media' as a system that nourishes and is nourished by social and cultural norms (e.g., 'popularity, hierarchical ranking, neutrality, quick growth, large traffic volumes, fast turnovers and personalized recommendations') (2013: Ch.8). More recently, C&MS scholars have proposed to look at 'integrated platform ecosystems' to examine 'how platforms are behaving in relation to each other, across markets, and across societal sectors' (Broughton Micova and Jacques, 2020; van Dijck et al., 2019) and have developed forms of 'cross-platform analysis' to integrate information across multiple types of media that form an ecosystem (e.g., in the study of misinformation diffusion on social media), without disregarding the 'medium specificity' of those different media (e.g., Rogers, 2021; Theocharis et al., 2021; Zuckerman, 2021).

To sum up, critical perspectives thus help to challenge what 'platforms' are to begin with, as well as foreground their involvement (e.g., as 'shapers') in different settings, including the public domain. They also identify and explore the normative challenges for researchers, citizens, policymakers, and lawmakers around the roles and responsibilities that platforms should (and should not) have. To address these issues and challenges, it is necessary to recognise that platforms operate (and thus exercise governance and power) *within a larger ecosystem* of digital platforms, where they may have many different roles at once as enmeshed in different social, technological, and economic complexities.

Taken together, these three distinct perspectives on the core concepts and features of 'platforms' complement each other in important ways and provide valuable concepts, empirical materials, and approaches for critically studying (online digital) 'platforms', such as Facebook, Google, or Apple, as powerful social, cultural, and economic shapers in different settings. They also provide relevant resources to begin situating and contextualising platforms' governance and power in platform ecosystems, as I argue in the next section. That is, it is necessary to also look beyond single platforms or technology companies (and their algorithmic systems or terms and policies) to better understand how relationships, interactions, and exchanges in digital (platform) economies and societies are (inter)mediated and shaped.

1.3. Governance and power dynamics in platform ecosystems

Next, I situate the specific focus and contribution of this dissertation in the contemporary academic debate on 'platform governance' and power. Specifically, the academic literature suggests the need for empirical approaches to enable more granular investigation and to situate and contextualise governance and power dynamics in 'platform ecosystems'. Indeed, '[p]latform ecosystems have become the dominant configuration through which innovative software products and services are co-created, marketed and distributed' (Hurni et al., 2022: 334–335). These same configurations are also the infrastructures of the digital (platform) economy and society (e.g., van Dijck et al., 2018). Consequently, it is important to consider how governance and power configurations and dynamics manifest themselves in the developmental processes that constitute platform ecosystems in practice.

1.3.1. *Digital platforms are powerful governing systems*

To begin, it is important to recognise that digital platforms are powerful 'governing systems', as Andersson Schwarz has suggested. That is, they are software-based systems that enact governance in specific ways that not only facilitate but also structure and transform the relationships, interactions, and exchanges between different groups of users, markets and industries, social structures, institutions, and infrastructures in society and the economy (Andersson Schwarz, 2017). In this dissertation, I will focus on these mechanisms and dynamics; that is, on *how* platforms then function as governing systems.

Contemporary social media, search 'engines' and mobile application 'stores' all offer localised and personalised (i.e., customised) experiences for their users or customers. Their tools, products, and services are designed and built such that observed or inferred information about people's interests, demographics, and online behaviours steers the specific content and messages that people receive, and how they appear (e.g., Alaimo and Kallinikos, 2017; Zuboff, 2019). This may improve the user experience or the return on each dollar spent on advertising ['ROAS'], but it also poses serious challenges to human behaviour and society (e.g., Wagner et al., 2021). Additionally, it raises concerns around algorithmic content discovery, curation, and moderation systems that are deployed by technology companies to handle copyright infringement, terrorism, and toxic speech at scale (e.g., Gorwa et al., 2020; McKelvey and Hunt, 2019). While workings of these systems are 'of material concern and intense interest' to a growing number of users and dependents, including content 'creators' (Burgess, 2021: 24), their architectures and operations (and changes to them) are generally difficult, if not impossible, to observe due to a lack of transparency and accountability. Rieder and Hofmann propose 'observability' as a pragmatic way forward in '[r]ealigning structural information asymmetries between platforms and society' and for 'curtailing platform power' (2020). Critical scholars also study the consequences of content moderation practices, including online speech, terms and policies, and enforcement actions of digital platforms (e.g., Caplan and Gillespie, 2020; Crawford and Gillespie, 2016; Douek, 2021; Duguay et al., 2020; Gorwa et al., 2020; Gillespie, 2018; Klonick, 2018; Roberts, 2019; Rogers, 2021; Suzor, 2019). In short, there is both an academic and a societal need to better understand how platforms exercise governance and control.

There are several ways in which the *governance of and by* platforms can be studied and that are relevant to my approach. Gorwa usefully proposed a broader definition of 'platform governance' as 'the layers of governance relationships structuring interactions between key parties in today's platform society, including platform companies, users, advertisers, governments, and other political actors' in a review of the literature (Gorwa, 2019). As such, platform governance is an interdisciplinary research area on the political effects of digital platforms (and other technical systems)—that is, how platforms govern, or *governance by* platforms—as well as the many complex challenges associated with the *governance of* platform-based technology companies and organisations (Gorwa, 2019: 855). For instance, DeNardis, Musiani, Gillespie, and others have studied 'governance by algorithms' (Musiani, 2013), 'Internet governance' by social media platforms (DeNardis and Hackl, 2015), 'governance by infrastructure' (DeNardis and Musiani, 2016), and the governance or regulation of and by platforms specifically (Gillespie, 2017; Gillespie, 2018). Hofmann et al. usefully distinguished 'governance' and 'regulation', grounding the former 'in mundane activities of coordination', and understanding the latter 'as targeted public or private interventions aiming to influence the behaviour of others' (2017: 1406). For this research, the focus is on the *governance by* platforms, although governance of platforms is also discussed tangentially.

Platform governance is also a common theme in the research areas of IS and Management Studies. For instance, they have done theoretical and empirical studies of the alignment between a platform's architecture and governance as a matter of decision rights allocation, goal convergence and coordination with app developers, and pricing policies (e.g., Tiwana, 2014: Part II). Additionally, they studied the central role of PBRs such as APIs regarding governance by platforms, which introduces a tension between the need to maintain (relational) 'infrastructural' control and the distribution of design capability to third-party software developers (e.g., Eaton et al., 2015; Ghazawneh and Henfridsson, 2013). Finally, they uniquely studied the *co-constitutive* role of architecture, governance, and ecosystem influences in a digital platform's evolution (e.g., Tiwana et al., 2010). Here, 'governance' encompasses the 'partitioning of decision-making authority between platform owners and app developers, control mechanisms, and pricing and pie-sharing structures'

(Tiwana, 2014: 291), thus recognising the distribution of governance across different parties and mechanisms. This is also key to the findings of my own empirical and historical research [▸ Chs. 2 to 6].

Additionally, Schreieck et al. conveniently summarised the challenges of governing digital platform ecosystems and distinguished the key governance mechanisms and dimensions based on a broad review of the literature (2016; 2018). They include (1) governance structure (e.g., governance structure, decision rights, and ownership status of the respective company); (2) resources and documentation (e.g., platform transparency and PBRs used to cultivate platform ecosystems); (3) accessibility and control (e.g., output and input controls or monitoring, platform openness, accessibility, and accessibility restrictions); (4) trust and perceived risk; (5) pricing strategy (e.g., pricing subsidy and revenue); and (6) external relationship management (e.g., 'inter-firm' dependency management, participation architecture and model, and technical interoperability between systems). In contrast, Kenney et al. only distinguish 'artifactual' (e.g., inscribed in software and algorithmic systems) and 'contractual' aspects (e.g., enshrined in terms and policies, partnership agreements) in their summary of the literature (2021; cf. Cutolo and Kenney, 2021). In the case of digital platform governance, the artefactual and contractual aspects are often interconnected in unique ways, as explained in subsequent chapters.

It is relevant to briefly note that the contours of this interdisciplinary debate on platform governance took shape in C&MS in the years before Big Tech companies started to face serious and ongoing criticism from regulatory authorities and the public worldwide. Of particular relevance is early research on the (inscription of) politics and power in digital media technology and data, including 'information politics' on the Web (Rogers, 2004), 'protocol politics' (e.g., Galloway, 2004; DeNardis, 2009), 'platform politics' (e.g., Bucher, 2018; Gillespie, 2010), and the culture and politics of software objects generally, including technical standards and protocols, file formats, code, algorithms, and programming languages (e.g., Fuller, 2008; Langlois et al., 2009; Manovich, 2013; Mackenzie, 2006; Mackenzie, 2010; Rieder, 2012; Rogers, 2013b; Sterne, 2012; Stratton, 2020). This early research surfaced the very material of many different software objects, which had long been left invisible, and which are so crucial to the study of how platforms govern. Critical approaches to this day often seek to render visible the hidden operations and behaviours of digital platforms and technologies generally, despite the challenges and hurdles they may have raised (e.g., Bounegru and Gray, 2021; Carter et al., 2021; Gray et al., 2018; Rieder and Hofmann, 2020). The case studies presented in subsequent chapters similarly adopt material approaches that contribute to these critical efforts.

Despite these important theoretical and critical contributions to 'platform governance' research, we know relatively little about the *configurations* and *dynamics* of how platforms govern and exercise control in practice—that is, empirically. This applies not only to the concerns around (algorithmic) content moderation systems (e.g., as faced by end-consumers or content creators) but also to the developmental 'sides' of digital platforms (e.g., as faced by app developers, marketing and advertising developers, businesses, and partners—as will be detailed in the subsequent chapters). The configurations and dynamics of governance and power can take different shapes and forms on these platform 'sides'. Additionally, it is generally difficult to observe and study these configurations and dynamics in practice to begin with due to obfuscations and a lack of transparency (or 'observability') regarding platforms' operations and behaviours. This research, therefore, makes an important methodological and empirical contribution to tackle such challenges.

1.3.2. *Digital platforms are multi-faceted relational constructs*

In addition to governing systems, it is important to appreciate that these systems manifest themselves as multi-faceted *relational constructs* that come to mean many different things to their users, stakeholders, and partners, based on what they actually do and are in practice (Schüßler et al., 2021: 9). Platforms do not only *shape and govern* but also are *shaped by* the many different communities of users, stakeholders, and partners they face on each of their 'sides'. The outcomes and dynamics of this mutual—though not necessarily equal—shaping process are of interest because they can reveal how governance and power manifest themselves in practice.

For instance, Schüßler et al. propose to conceive of digital platforms as relational structures in which social forces 'of mutuality, autonomy, and domination' operate simultaneously (2021: 9–10). As they argue, these three social forces explain how platforms are always mutually constituted through dynamics of contestation and conflict that alter the balance between mutuality, autonomy, and domination (2021: 9–13). Their suggestion is not dissimilar to how van Dijck et al. conceived of the 'platform society' as a concept that is contested on different levels of society, including at the micro-level of single platforms, the meso-level of the platform ecosystem, and the macro-level of geopolitics and international relations (2018: Ch.1). Both contributions recognise the importance—the politics and dynamics—of contestation in the way that platform boundaries are set, sustained, and modified. Pierson's study of digital platforms as 'entangled infrastructures' is also a relevant example, which points to the 'entangling' of social and private corporate-computational infrastructure (2021). Additionally, Gawer adds that technology companies make different strategic decisions about their boundaries, including about the scope of the platform (e.g., which activities are performed), the configuration and composition of the platform's sides (e.g., who can join the sides), and related to the digital interfaces (e.g., recalibrating or closing interfaces, such as APIs) (Gawer, 2021b).

Furthermore, some critical scholars have warned against deterministic narratives that '[entrench] the mystique of platforms' power' (Caplan et al., 2020). While sometimes an outcome of limited transparency or observability, deterministic narratives 'risk flattening the deeply situated and differential economic, political, and cultural conditions under which global platforms operate around the world—and under which users and institutions mediate and shape them' (Solomun, 2021). The authors instead suggest placing this power within 'relevant social, political, and economic contexts' and consider 'how institutions, individuals, and infrastructures mediate and shape platform power'. For this reason, Chapters 3 and 4 both make a significant contribution to help locating platforms' power in this way, by surfacing the larger ecosystems they are part of.

Hurni et al. (2022) similarly provide a nuanced perspective on the deterministic analysis of power dynamics within software platform ecosystems. Drawing from the academic literature, they note that power is not one but many different things and has at least four 'faces': (1) 'domination' (e.g., a platform's capacity to act as 'regulator' of its ecosystem (Boudreau and Hagiu, 2009; Parker and Van Alstyne, 2018)); (2) 'coercion' (e.g., to persuade or press actors into a certain course of action); (3) 'manipulation' (e.g., to ensure that complementor actions and behaviours remain within desired boundaries); and (4) 'subjectification' towards predefined roles or identities (e.g expectations associated with stratified partner programmes with certain rights and responsibilities) (Hurni et al., 2022: 315–316; cf. Fleming and Spicer, 2014). These different 'faces' recognise more subtle behaviours and dynamics as expressions of power and allow for more granular insights into power dynamics.

Similarly, critical scholars note that a platform's influence and power is often purposefully implicit or hidden (e.g., Carter et al., 2021), such as in layers of infrastructure.[35] In fact, infrastructure is 'powerful precisely because it is not a grand and spectacular strategy but a functional and often invisible reality' (Munn, 2020: 15; cf. Bowker and Star, 1999; Star and Griesemer, 1989). In the case of digital platforms, this 'functional and often invisible reality' is ensured by technical specifications, standards, and API-based integrations between systems that mediate governance and 'infrastructural' features of platform power (e.g., Blanke and Pybus, 2020; Busch, 2021; Busch et al., 2021; Munn, 2020), as discussed in subsequent chapters.

Hurni et al. further define a 'power paradox' in the relationship between the 'platform owner' and complementors in the platform ecosystem, where 'the technological and structural features of platform ecosystems constitute an extremely

35 In this sense, descriptive (anthropological or digital) studies of infrastructure are often critical because they bring these systems and structures from the invisible background of everyday life and practice into the spotlight.

powerful position of the platform owner, such that each complementor is at the mercy of the actions taken by the platform owner' (2022: 311; cf. Huang et al., 2013; Kude et al., 2012). However, 'despite this powerful position of the platform owner, complementors are not powerless' (Hurni et al., 2022: 311; cf. Foerderer et al., 2018; Ghazawneh and Henfridsson, 2013; Tiwana et al., 2010). The 'power paradox' thus captures the tensions that inevitably exist in platform ecosystems because platforms are relational constructs that both shape, and are shaped by, their user communities and ecosystems. As such, platform owners use PBRs to balance generativity (and the 'co-creation' it facilitates) and control (and the power it provides) (Eaton et al., 2015).

The interdisciplinary research on 'platform governance' would thus benefit from an integrative perspective on platform ecosystems that unifies the technical, market-based and innovation, and critical perspectives for empirically studying the configurations and dynamics of platforms' governance and power.

1.4. Locating governance and power dynamics in platform ecosystems

I will now situate and contextualise my thorough empirical approach for locating governance and power within platform ecosystems. This approach allows for critical investigations of the material configurations and dynamics of platforms' governance and power as they manifest themselves in specific empirical settings. As such, I will explain how we may conceive and utilise the distinct *materiality* and the *relationality* of digital platforms to locate governance and power in the developmental processes that constitute platform ecosystems. As I suggest, these developmental processes involve different types of users (including end-consumers, software app developers, business, marketers, and advertisers), each of which is addressed and governed in a different way, on a different platform 'side'. This simple observation provides opportunities for critical and empirical investigations of the material (or technological) and the relational dimensions of governance by platforms, as each of my chapters will demonstrate. Additionally, the empirical materials enable me to visualise and document platforms as part of larger ecosystems and in relation to one another. These visualisations further enable constructing and displaying these ecosystems to a larger audience and facilitate locating and analysing key 'nodes' of power—as one important contribution of this work.

1.4.1. *Digital platforms' boundaries*

Digital 'platforms' generally remain a slippery phenomenon because they are difficult to access and demarcate as objects of study: many large technology companies and platforms are designed as closed technical systems that lack transparency or observability; they are widely used, dispersed, and interconnected as infrastructures of everyday life and practice; and they are dynamic and subject to continuous change. At the same time, it is also a core research objective to address this demarcation problem; that is, to surface the relations and material conditions of very large digital platforms as a means of articulating their boundaries (and contested boundary dynamics). This is also a *critical* research objective because technology companies can easily suspend and escape liability, responsibility, and accountability through maintaining strategic ambiguity regarding their business activities; that is, whether a given 'platform' should be governed (or regulated) as a social networking service, a search engine, a technology company, a marketing or advertising company, a digital publisher, a digital marketplace, a software distributor, a computer hardware company, a public utility, and so on.

There are many different approaches to studying digital platforms. One common type of approach is to conduct semi-structured in-depth interviews to reflect on the agency (or lack thereof) of individual users, stakeholders, and partners in relation to digital platforms. Other types of approaches are more technical, policy-oriented, or involve academic–industrial collaboration (e.g., Carter et al., 2021). The ongoing platformisation of the Web, however, suggests the value of approaches that surface the many different relations and material conditions of online digital platforms that are sometimes purposefully hidden or obfuscated, including platform boundaries and boundary dynamics. The case studies conducted for the purpose of this research all involve innovative approaches and, in some cases, custom-built digital research tools that explore creative uses of the materiality of digital 'platforms'. As such, they demonstrate how the many different types of available sources and material traces left behind by platforms can be used for the critical and historical study of very large digital platforms, despite serious issues and challenges regarding their accessibility (Helmond and van der Vlist, 2019). These approaches offer research opportunities focused on how platforms operate and govern at different levels of platform architecture (e.g., interface, ecosystem, or application) and on different platform 'sides' (e.g., for developers, business, or partners).

1.4.2. *The materiality of digital 'platforms'*

The distinct *materiality* of 'platforms' is the first tenet of my empirical approach. While terms such as 'architecture', 'platform', and 'ecosystem' are all concepts and metaphors with multiple meanings (e.g., Gillespie, 2010), it is important to recognise that they are also more than that.[36] Specifically, the technical perspectives on

36 For instance, Lai and Flensburg explain that an 'ecosystem' is defined in the natural sciences as 'a complex of living organisms, their physical

digital platforms introduced earlier explain how terms like these also describe the very material form of technology companies like Facebook and Google *as online digital 'platforms'*. They describe the digital material circumstances of digital platforms as software-based systems—what software scholars originally called 'the stuff of software' (e.g., Kirschenbaum, 2003; Fuller, 2008)—that have certain technological and structural features that are a functional and invisible reality but also provide research opportunities beyond just the technological aspects. For example, I detail how they enable relational perspectives on how the different constitutive elements of a platform are interconnected as part of larger ecosystems.

How to study the materiality of platforms? Big Tech companies routinely leave material traces behind in their operations, which can be used to study aspects of their production, operations and behaviours, integrations, reception, and so on (Helmond and van der Vlist, 2019). This includes the aforementioned PBRs, which serve a unique role in the facilitation and governance of external contribution in third-party application ('app') development and ecosystem innovation generally (Eaton et al., 2015; Ghazawneh and Henfridsson, 2013). Material circumstances and traces 'for developers' may include open or closed APIs, SDKs, developer pages, reference documentation, changelogs, version histories, application development guides, best practices, debugging tools, and ad targeting fields and parameters. Additionally, material traces 'for business' may include product pages, ad management and insights tools, webinars, partner programmes and directories, certifications and awards, training courses and learning resources, application review guidelines, and help centres. Furthermore, there may be public blog archives,

environment, and all their interrelationships' and 'can be characterized by different degrees of biodiversity, understood as a richness of species, a genetic variety within species, as well as the coexistence of different ecosystems' (2021: 2303). In communication research, they add, 'media ecosystems' are similarly 'defined by their material conditions as well as by the activities and strategies of the actors who inhabit them'. Consequently, the ecological metaphor 'is frequently used as an entry point to studies of media as environments that "structure what we can see, say, and do"' (Scolari, 2012, quoted in Lai and Flensburg, 2021: 2303). Specifically, it draws attention to the material aspects of communication, the different features and functions that apps have (and have in common), their relationships and (co-)dependencies, and their positions in the larger media environment. As in the natural sciences, it is the task of the researcher to determine what those relationships and environments are. In short, the 'ecosystem' metaphor (and related metaphors, including 'evolution') offers many productive avenues for digital platform and infrastructure research going forward (e.g., van Dijck, 2021b; Zuckerman, 2021).

technical reports, research publications, patent applications, developer conferences and meetings, partner summits, earnings releases, SEC filings, court documents and filings, occasional 'leaked' documents, GitHub code repositories, public statements, Facebook or Twitter posts from founding members, LinkedIn staff member profiles, business information databases, technology blogs, and other available materials to use. In short, there are many different types of available materials that can be explored and used to surface the relations and material conditions of digital platforms and to articulate their boundaries and boundary dynamics in the platform ecosystem.

Additionally, a material approach provides unique opportunities for writing the histories of digital 'platforms' and applications that are often ephemeral and change or evolve continuously. There are many relevant (yet underutilised) Web sources about social media platforms and mobile apps that are in fact archived and relatively well-preserved by public Web archiving initiatives and organisations, including by the American Internet Archive and European national Web archives [▸ Appendix A: Figure A 1.1(a) and (b)], as I have argued elsewhere (Helmond and van der Vlist, 2019; Helmond and van der Vlist, 2021).[37] The case studies presented in Chapters 2 and 3 use archived sources taken from these public Web archives and, crucially, would not have been possible in the same way without them.

It is relevant to note that such a material approach is distinct from many others that seek to unravel the 'inner workings'—that is, to peer into the 'black box'—of specific technical or algorithmic systems, including search ranking systems, social media ranking algorithms (e.g., Facebook News Feed, Twitter's top Tweets, etc.), content discovery and recommender systems, or algorithmic moderation systems (e.g., Bucher, 2018; Eriksson et al., 2019; Gorwa et al., 2020; McKelvey and Hunt, 2019). It is also different from 'API-based research', which is a popular approach across the humanities and social sciences 'based on the extraction of records from the datasets made available by online platforms through their application programming interfaces' (e.g., Venturini and Rogers, 2019). Instead, my approach helps surface the relations and material conditions of platforms in ways that reveal how they are embedded in larger ecosystems, which, in turn, is necessary for studying platforms' governance and power within these larger ecosystems.

1.4.3. *The relational construction of (platform) ecosystems*

The *relationality*—or the *relational construction*—of (platform) ecosystems is the second tenet of my empirical approach. I am especially interested in the role of external user groups, including third-party software app developers, digital marketers and advertisers, and business partners for they are the ones who build platform ecosystems in practice.

37 E.g., https://resaw.eu/

To deal with the limitations of existing approaches for studying (social media) platforms, Carter et al. proposed 'investigation' as a critical approach for researchers to not '[lose] access to the full, social and technical, scope of these phenomena and greatly limit their ability to critique and articulate visions alternative to the current state of information technology' (2021: 9). They specifically highlight the need for stories such as those about the social construction of (large) technological systems, such as the electrical grid, rapid transit systems, or classification systems in Science and Technology Studies [STS]-related research from the 1980s–1990s (e.g., Bowker and Star, 1999; Bijker et al., 2012; Latour, 1996; Pinch and Bijker, 2012). Carter et al. thus propose considering the larger systems and structures that platforms are inevitably part of, similar to my own proposal to investigate digital platforms as part of larger ecosystems. However, they note that such stories are difficult to write in an environment where technology companies maintain tight control (Carter et al., 2021: 10). The challenge, then, is not only surfacing the *material conditions* of 'platforms', but also their *relations* (or better yet, their relationship structures).

To study the making (or relational construction) of these relationship structures by third-party software app developers, business, marketers and advertisers, and other types of users, it is especially relevant to draw from STS-related research. In fact, the technical perspectives on digital platforms and infrastructures I introduced [▸ §1.2] draw from this same tradition of STS-related research. The concept of PBRS, which is central to my own material approach, draws from 'boundary objects' theory (Star and Griesemer, 1989) and has been influential in the research on collaboration and coordination between different social groups (i.e., the research area of Computer-Supported Cooperative Work [CSCW]). For instance, Ghazawneh specifically studied PBRS as a means of creating and governing third-party application development (Ghazawneh, 2012; Ghazawneh and Henfridsson, 2013). Similarly, the 'interpretative flexibility' of technologies has been studied to learn how a particular technological artefact, such as a bicycle or a contemporary digital platform, may have associated with them many different meanings and interpretations relative to different groups in society. The different 'relevant social groups' of a technological artefact may include any user and stakeholder groups, such as end-consumers, producers, as well as businesses, developers, journalists, politicians, and so on (e.g., Oudshoorn and Pinch, 2003; Pinch and Bijker, 2012). Because of this interpretative flexibility, it is important to facilitate design flexibility to allow for the construction of those different meanings and interpretations by the relevant social groups. Today's digital platforms facilitate this flexibility by providing PBRS for application development to third-party software developers and business, amongst others. Chapter 5 employs these concepts in a case study of the complex boundary dynamics that manifest themselves between platform owners and third-party software app developers, who explore (and seek to exploit) this flexibility.

Other chapters, such as Chapters 3 and 4, draw from these concepts to identify platforms' relevant user groups, and to explain how they are not just users but active participants in the relational construction of 'platforms' as part of larger ecosystems.

Once the relevant social groups are identified, they can be described in more detail, including regarding power and economic strength. In empirical terms, then, the research objective is to study (the construction, or developmental process of) a complex technological artefact such as a digital platform regarding each of the relevant groups (e.g., a platform's 'sides'), and to avoid general statements about, say, consumers or producers (cf. Pinch and Bijker, 2012: 28). This is crucial to recognise when, as Hurni et al. suggest, 'power resides in the social construction processes between' different actors, and is thus not only held by platform owners (2022: 314; cf. Hardy and Leiba-O'Sullivan, 1998). As such, Chapter 4 finds that power dynamics in platform ecosystems are often more complex and subtle, such as (inter)mediated and shaped by business partners and infrastructures they build.

Finally, problems and conflicts may arise either between the developers of a technological artefact and its users, or between the different relevant groups. The larger the technological system is, the more complex the problems and conflicts that arise, as also suggested by the aforementioned research on the platform society as a 'contested concept' (van Dijck et al., 2018: Ch.1; Schüßler et al., 2021). This is one important reason why the overrepresentation of Big Tech companies in the critical academic literature and in the public debate is arguably justified, even though the impacts of 'datafication' and 'platformisation' are not limited to these technology companies. In fact, there are many additional powerful digital platforms that also deserve attention from critical scholars, as Chapters 3 and 4 suggest.

To conclude, a critical 'investigation' of digital platforms, and the Big Tech companies who own them, may explore creative uses of the distinct materiality and the relationality of digital platforms, which are combined in unique ways. Such an approach offers unique research opportunities: To begin with, it affords empirical studies that appreciate how specific platform architectures (inter)mediate and structure the relationships, interactions, and exchanges that occur on, or pass through them. It also affords approaches that help situate and contextualise platforms' governance and power in larger ecosystems. Finally, it affords historical studies of platforms, which is of particular importance to historicise and denaturalise the present dominance of Big Tech companies.

Most of the data that support the findings of the case studies are openly available in the Open Science Framework [OSF] to support open and collaborative research practices.[38]

1.5. Overview of the parts and chapters

This last section introduces the organisation of the body of this dissertation, which comprises five chapters and a conclusion. Each subsequent chapter covers an empirical case study and a methodological contribution to the study of digital platforms as part of larger ecosystems.

The overall leading research question of this dissertation [RQ] is: *How are governance and power manifested in the developmental processes that constitute the ecosystems of (very large) digital platforms?* [▸ Table 1.1]. Specifically, how do they manifest themselves in practice, as observed in the actual relationships and interactions between platform owners and their communities of third-party software app developers, marketing and advertising developers, and official business partners who all help in collectively constructing the platform ecosystem?

Table 1.1. Overview of the leading research (sub)questions per chapter.

No	Research (sub)questions	Ch(s).
RQ	*How are governance and power manifested in the developmental processes that constitute the ecosystems of (very large) digital platforms?*	
RQ1	How are governance and power manifested in the capacity of 'core' technical platforms to decompose and recompose their infrastructure for different types of development?	2 [Part I]
RQ2	How are governance and power manifested in the developmental processes of:	3 and 4 [Part II]
	(a) Facebook's business ecosystem integrations since the launch of its Development Platform?	3
	(b) the business ecosystem integrations of contemporary social media platforms generally?	4
RQ3	How are governance and power manifested in the developmental processes of:	5 and 6 [Part III]
	(a) social media-related mobile app ecosystems for Android (Google Play) and iOS (App Store)?	5
	(b) the COVID-19-related mobile app ecosystems emerging in the initial stages of the global pandemic crisis (also for Android and iOS)?	6

38 Available at: https://doi.org/10.17605/osf.io/6cj5x. See also: https://www.uu.nl/en/research/open-science.

The chapters are organised in three thematic parts that address the distinct aspects of the overall leading research question: first, the 'technicity'—or, the material-technological features—of governance through *platforms' interfaces*, including their evolutionary dynamics and significance for the developmental processes that constitute platform ecosystems [Part I]; second, the making of the larger *business (partner) ecosystems* of contemporary social media platforms, including the dynamics of governance and power within this larger ecosystem [Part II]; and third, the making of the larger *mobile application ('app') ecosystems*, including the layered dynamics of governance and power between platform owners, app developers, and app 'stores' [Part III]. In short, if Part I investigates the 'core' technical platform, then Parts II and III each investigate the 'peripheries' of platforms' larger ecosystems—which, as I argue, cannot be considered separate from their 'core'. Ultimately, this dissertation thus argues and shows that—empirically—there is no platform, there are just (platform) ecosystems (cf. Kaldrack and Leeker, 2015).[39]

Each of the case studies thus explores the configurations and dynamics of governance and power as they manifest themselves in specific empirical settings. In each of these empirical settings, I surface the relations and material conditions of platforms' governance and power. This type of study involves designing innovative research methods and tools, including for the collection and visualisation of different data forms. At the same time, these methods and tools pave the way for future empirical and historical studies of the larger ecosystems of platforms, beyond studies of single (specific) platforms or (mobile) apps. This shift of focus, I argue, is vital for situating and contextualising platforms' governance and power, especially in empirical or historical terms.

I will briefly overview the three parts of this dissertation and the key points of the chapters they contain.

1.5.1. *Part I: Platform interfaces*

Application programming interfaces [APIs] are the material foundation—or infrastructure—of digital platform ecosystems. They are also the core mechanism by which platform owners facilitate and govern external contribution in third-party application development and ecosystem innovation generally. The leading research subquestion in Part I [RQ1] is: *How are governance and power manifested in the*

39 Kaldrack and Leeker posited that 'There is no software, there are just services' to describe the shift into the software as a service [SaaS] model for business, whereby software was dissolving into 'a cascade of services that organize access to data and its processing' (2015: 10). With this shift, ownership of software became obsolete, replacing 'goods as property through services use'.

capacity of 'core' technical platforms to decompose and recompose their infrastructure for different types of development?

Chapter 2, 'The technicity of platform governance', argues that APIs are central to understanding how governance and power dynamics manifest themselves in platform ecosystems. It does so through a case study about the history of Facebook as a platform for software application development since the launch of 'Facebook Development Platform' in 2006. Specifically, it reconstructs the platform as an 'assemblage' of tools, products, and services–including APIs–to account for the material ways in which the platform has decomposed and recomposed itself for developers of software applications. Such foundational accounts are necessary to understand the key role of third parties in the 'peripheries' of digital platform ecosystems, and indeed, the process of platformisation generally. It uses a large corpus of original historical Web sources about Facebook' PBRs (i.e., APIs) to surface these relations and material conditions of the platform for different groups of developers from 2006–2020. Importantly, it examines the 'technicity'—or the material-technological features—of how APIs shape (govern) and are shaped by external pressures in Facebook Platform's evolution, such as social, competitive, and regulatory pressures to change. Overall, the study challenges what Facebook even is *as a 'platform'*, which is crucial to understand its unique position of power in the larger ecosystem. The chapter shows that instead of a single monolithic 'platform', Facebook is a complex layered and interconnected configuration of components that change and evolve continuously.

1.5.2. *Part II: Business ecosystems*

Chapters 3 and 4 both explore the importance of (strategic) partnership strategies and mergers and acquisitions (M&As) for establishing and managing external relationships with companies and organisations, including direct competitors, that constitute platform ecosystems. Managing these organisational relationships is one of the core governance dimensions that has led to an increasing stratification of the larger ecosystem and has amplified power dynamics. Both case studies use openly available PBRs and information about partner programmes, including directories that list the names of current partner companies and organisations, to reveal the larger business (partner) ecosystems that formed around social media platforms. The leading research subquestions in Part II [RQ2(a) and (b)] are: *How are governance and power manifested in the developmental processes of:* (a) *Facebook's business ecosystem integrations since the launch of its Development Platform* [▸ Ch. 3]; and (b) *the business ecosystem integrations of contemporary social media platforms generally* [▸ Ch. 4]*?*

The two chapters in this part are especially about online digital marketing and advertising technology, a global industry that comprises thousands of interconnected platforms, including all major social media platforms. Digital advertising powers (and provides the infrastructure for) large swathes of the digital economy and has given businesses and publishers worldwide new ways to 'monetise' and find and reach people at a low cost. This all runs 'on top' of material foundations—or infrastructures—that are accessed through APIs. Facebook, Google, and social media generally offer sophisticated programmatic and self-serve advertising tools and inventory and are uniquely positioned as custodians of vast amounts of social data. Additionally, their (advertising) revenues depend considerably on partnership strategies. Partners use the exclusive application and development PBRs offered by digital platforms like Facebook to build and maintain the digital infrastructures that they need to profit from marketing and advertising. Specifically, this infrastructure underpins the growing ecosystem of programmatic (API-based) forms of marketing and advertising, where advertisements ('ads') and audience commodities are automatically traded and served across media distribution channels and geographic regions in mere milliseconds through complex real-time bidding auctions. As such, partnerships are deployed to govern (limit) access to these exclusive PBRs, which have led to the emergence of a particular kind of business ecosystem around social media.

Chapter 3, 'Facebook's business partnerships', builds upon the historical groundwork laid out in Chapter 2 with a case study about the evolution of Facebook's (technical and business) integrations and its embedding in the larger business ecosystem in 2006–2019. It uses historical Web sources about PBRs to reconstruct the way that Facebook's platform boundaries have evolved towards an increasing variety of users, stakeholders, and partners. The rapid expansion of Facebook's platform boundaries is directly linked to its meteoric rise to power from its founding in 2004 into one of the world's most profitable businesses in history in a mere decade. The chapter shows how Facebook's partnership strategy and strategic M&As were pivotal in this rise to power, especially to accelerate the platform's entry in the digital marketing and advertising industry. Partnerships generally remain understudied yet are crucial to recognise the infrastructural features of Facebook as a 'platform-as-infrastructure' that has accrued both technological and organisational dependencies.

Chapter 4, 'Social media business partnerships and integrations', further argues that platform's business-facing APIs and business partnerships are essential for understanding how platforms accrue considerable strategic and infrastructural power from their larger ecosystems. It provides a comprehensive, large-scale study of the (technical and business) integrations and dependencies of the 20 most-used social media to the larger business ecosystem around them. As such, it is one of the most comprehensive views of the digital (platform) economy so far. It uses a large corpus of original sources about each platform's PBRs and official partner programmes to chart (or 'map') the entire business (partner) ecosystem of social media—that is, the complex technological and organisational relationship structures that comprise the digital economy as centred around social media. Crucially, this business (partner) ecosystem is not limited to social media but also involves many other types of digital platforms, and thus uniquely reveals the complexity and interconnectedness—that is, the structural particularities—of the larger ecosystem. Therefore, these charts are important to situate and contextualise platforms' unique positions of power, how they are constituted and different in subtle ways, and help to locate strategic and infrastructural 'nodes' of power in larger ecosystems.

1.5.3. *Part III: Mobile ecosystems*

Chapters 5 and 6 both focus on the ecosystems of mobile applications regarding governance and power. Most people today do not use 'desktop' computers to access social media anymore; instead, they use smartphones or other mobile (device) platforms. With this shift, many different types of 'apps' have become embedded in everyday life and practice. This has not only changed how people use social media but has also introduced different governance and power dynamics in the developmental process of mobile apps. The leading research subquestions in Part III [RQ3(a) and (b)] are: *How are governance and power manifested in the developmental processes of:* (a) *social media-related mobile app ecosystems for Android (Google Play) and iOS (App Store)* [‣ Ch. 5]; and (b) *the COVID-19-related mobile app ecosystems emerging in the initial stages of the global pandemic crisis (also for Android and iOS)* [‣ Ch. 6]*?*

From a methodological perspective, studying the ecosystems of mobile platforms and apps poses a different set of research challenges compared to studying the ecosystems of (Web-based) social media platforms and apps. These differences are the result of distinct governance mechanisms, and the powerful role of app stores in (inter)mediating and structuring the relationships between end-consumers of apps on one 'side', and developers of apps on the other. End-consumers can easily find and purchase these apps, as well as download software updates for them, while developers use these 'stores' to distribute and monetise their mobile applications (and games). These developers include individual developers and business developers, as well as large social media platforms, governments, and international organisations, who all distribute apps via such app stores. This poses an important research opportunity: in contrast to third-party applications or services built 'on top' of social media, which cannot be collected via central directories, the mobile apps built 'on top' of popular *mobile (device) platforms* are listed in central application directories, catalogues, or repositories. That is, we can find all approved Android Apps in Google Play and iOS apps in Apple's App Store. The two chapters in this part thus provide a novel approach that makes use of app stores to demarcate and surface specific app ecosystems, enabling critical investigations of the configurations and dynamics of governance and power in larger ecosystems.

Just as the chapters in Parts I and II, both chapters use PBRs to study the relations and material conditions of platforms' governance and power. However, the chapters in Part III additionally advance innovative empirical approaches for studying the relations and material conditions of mobile platforms and apps (including app stores and app infrastructures). These approaches draw from 'digital methods' by employing the medium-specific affordances of mobile apps and app stores for research purposes (Dieter et al., 2019; Gerlitz, Helmond, Nieborg, et al., 2019; cf. Rogers, 2013b).

Chapter 5, 'Governing platform programmability', surfaces the complex interactions (and contested boundary dynamics) that manifest around the 'programmability' of platforms—that is, around platforms' capability to change or adapt in response to app developers' needs. Specifically, it studies how this programmability is governed not only by platform owners, but also by app stores, and is routinely challenged by app developers. It presents a detailed study of the mobile (Android and iOS-based) application ecosystems that have emerged around popular social media platforms, such as Facebook, Instagram (also owned by Facebook), Snapchat, and Twitter. It shows how third-party software developers build applications to appropriate social media in ways that do not always comply with their terms and policies, probing the limits of platforms' capacity to change or adapt in response to developers' needs, while platform owners seek to maintain control. It thus elaborates on the fact that not only the platform owners, but also third-party app developers hold power, and shows how this tension manifests itself in these social media-related app ecosystems.

Chapter 6, 'App stores and the pandemic response', demonstrates how Google and Apple (as 'gatekeepers' of the mobile ecosystem) reconfigured their platform governance, as well as their relationships to international (health) organisations, governments, and civil society organisations in the initial stages of the global coronavirus (COVID-19) pandemic crisis. It offers a comprehensive, multi-level analysis of the mobile (Android and iOS-based) apps that have been created in response to the global pandemic, including the types of response apps, the actors who built them, and aspects of their development. This helps to surface the relations and material conditions of platforms' governance and power in this empirical setting, which involve mobile platforms and app store owners with private interests on the one hand, as well as international (health) organisations, governments, and citizens with public interests on the other hand. Notably, it shows how Google and Apple both adapted their governance in the light of the 'unprecedented' nature of the pandemic crisis with increased editorial intervention because the societal stakes were high. Such reconfigurations may also have important societal consequences in the longer term.

Taken together, the five case studies of this dissertation contribute unique empirical and historical insights, as well as innovative methodologies for studying the relations and material conditions of platforms and apps, and their implications for understanding governance and power dynamics in larger platform ecosystems. These insights help to understand the unique features of platforms' governance and power as part of larger ecosystems, especially in terms of their relations and material conditions. In the Conclusion chapter [▸ Ch. 7], I synthesise the insights from these different case studies and reflect on the value of the ecosystem concept. I also outline a proposal for an interdisciplinary theory of (platform) ecosystems that is grounded in the distinct materiality and relationality of digital platforms. ▾

I. Platform interfaces

2. The technicity of platform governance

Evolving Facebook's application programming interfaces

Application programming interfaces [apis] provided by many digital platforms are the material-technological infrastructures that enable the emergence of larger ecosystems 'on top' of those platforms. They are also the core mechanism by which platform owners facilitate and govern third-party app development and ecosystem innovation generally. This makes it especially relevant to investigate how platforms' apis are configured, how those configurations have changed and evolved over time, and what that means for development 'on top' of the platform. Therefore, this chapter asks [rq1]: *How are governance and power manifested in the capacity of 'core' technical platforms to decompose and recompose their infrastructure for different types of development?*

This chapter thus unravels the material-technological features of platform governance. This provides an understanding of platform governance that is foundational to the case studies of the subsequent chapters, which all investigate the relationships and interactions between these material-technological infrastructures and the larger ecosystems they uphold and govern.

2.1. Introduction to the case study

Researchers, policymakers, and competition and regulation authorities worldwide recognise application programming interfaces [apis] for their role in datafication and platformisation processes as a way to 'dominate the digital world' (van Dijck, 2021b; ft Reporters, 2020; Iyer and Getchell, 2018). apis serve as the *lingua franca* for the exchange of data and functionality between companies and are of strategic importance for Big Tech companies like Facebook or Google. This is in part due to

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the Web becoming more data-intensive with the rise of the 'platform' as its dominant technological and business model (Helmond, 2015a). APIs have become the core elements of digital infrastructure, underpinning today's digital (platform) economy and society. Consequently, Iyer and Getchell (2018) warn that regulators should not only focus on the market dominance of Big Tech companies but also on their 'data dominance'—specifically, how Big Tech companies use APIs to share data or services with third parties. Competition authorities and regulators in Europe and the United States [USA] increasingly scrutinise anti-competitive uses and potential misuses of data centred around Facebook's APIs and the platform's monopoly power (CMA, 2020: Appendix J; FTC, 2020). In 2019, the USA Federal Trade Commission [FTC] fined Facebook US$5 billion for violating consumer privacy rights by providing third-party developers access to users' friends data via its APIs and for not properly reviewing third-party developers and their apps (Fair, 2019). The FTC also ruled that application ('app') developer Aleksandr Kogan and Cambridge Analytica CEO Alexander Nix used deceptive data-gathering practices to harvest personal information from Facebook users and their friends through a quiz app that exploited the Facebook Graph API [GAPI] (Albright, 2018; FTC, 2019). These accounts suggest the need for a better understanding of the role of APIs in the digital (platform) society.

APIs enable programmatic communication and the exchange of data and functionality between software-based systems such as digital platforms. They are 'powering digital transformation' (e.g., Sawers, 2021) and serve as the core infrastructural elements that underpin the large ecosystems of apps and services (or 'complements') created by third parties and partners (or 'complementors'). APIs play a key role in the capture and movement of personal data, the interconnections between software apps and services, and bring about 'the formation of platform monopolies' through the decentralisation of their services (Blanke and Pybus, 2020). Although APIs may be perceived as 'microscopic' technical objects, they are nonetheless significant because they comprise the *material infrastructures* of platforms and apps and articulate and shape the processes of datafication (e.g., programmatic data-sharing) and platformisation (Helmond, 2015a; Pybus and Coté, 2021). APIs are more than technical objects designed and deployed by platforms at a given moment; they are increasingly complex layered and interconnected technical objects that govern a platform's data and functionality and are prone to constant change due to both internal and external pressures. Particularly, this study finds that APIs evolve through the interactivity between a platform and its communities of use, app development, and monetisation by businesses, as well as through pressures originating from a platform's competitive and regulatory environments.

Despite broad recognition of their importance in the digital (platform) society, there is no comprehensive understanding of social media platforms' APIs as complex technical objects that change and evolve continuously. As such, critical scholars argue that '[r]egulatory fixes require detailed insights into how technology and business models work' (van Dijck et al., 2018: 158) and call for the 'observability' of platforms as an explicit means of regulation (Rieder and Hofmann, 2020). Further, very little is known about the historical relationality between platforms' APIs, governance, and power. Big Tech companies design and change their APIs to facilitate third-party app development in ways that influence (or 'orchestrate') the evolution of their ecosystems (Tiwana et al., 2010). These ecosystems typically comprise multiple user and stakeholder groups connected to the same core technical platform using one or more of its APIs, including (small, medium-sized, and large) app development ventures, businesses, digital marketers and advertisers, and academic researchers. In today's digital (platform) society, APIs enable and control the possible relationships and interactions between these different users and stakeholders and thus serve as a core technical dimension of 'platform governance' (Gorwa, 2019: 854). Accordingly, Big Tech companies like Facebook and Twitter have responded to public controversy, criticism, and external social pressures not only with feature and policy changes (Barrett and Kreiss, 2019) but also with amendments to their APIs. After the Facebook–Cambridge Analytica [FB–CA] data scandal, Facebook made changes to certain terms and policies and implemented restrictions on API data access and sharing.

This chapter is the outcome of an empirical study of the structure and evolution of Facebook's APIs and their relation to platform governance to highlight the *technicity*—that is, the technical dimension and dynamics—of what, how, and whom platforms like Facebook seek to govern. It explores how governance and power is configured and how it manifests itself in the decomposition and recomposition of Facebook Platform as an 'assemblage' (Blanke and Pybus, 2020) of tools, products, and services—and a *material foundation* for app and business development around the globe. The analysis is focused on Facebook's APIs, which have been among the most popular, widely used, and most controversial for over a decade (Albright, 2018). Specifically, I consider the co-evolution of Facebook Platform and its APIs and modes of platform governance on three levels: (1) the structure of Facebook's entire API architecture; (2) core API objects in terms of their properties, connections, and parameters; and (3) their associated permissions, as handled through Facebook apps and Facebook Login specifically, using both current and archived developer pages. I provide original empirical materials for further historical platform research to better understand the evolutionary dynamics between API design and platform governance (e.g., Helmond and van der Vlist, 2019; Nieborg and Helmond, 2019; [‣ Ch. 3]).

Building upon prior research, the analysis reconstructs how Facebook's APIs have evolved from a simple programming interface for development into a complex layered and interconnected *governance configuration* wherein technical API specifications serve to enforce (changes to) platform policy and strategy. I thus contend that platform governance is about more than a platform's content moderation, terms and policies, or corporate governance structure; it also involves the design and reconfiguration of technical API specifications that govern and control the possibilities for the exchange of data and functionality between software-based systems and organisations. As such, this study makes an empirical–historical contribution to the ongoing debate on 'platform governance' within the literature on digital platforms and social media (e.g., Caplan and Gillespie, 2020; Gillespie, 2018; Gorwa, 2019; Gorwa et al., 2020; Medzini, 2021; Schreieck et al., 2018). I focus specifically on the technicity of Facebook's platform governance as enforced through APIs, which, as scholars note, 'are an important source of infrastructural power in the platform society' (Busch, 2021; cf. Blanke and Pybus, 2020; Munn, 2020). In fact, this 'infrastructural power' is one of the identified 'blindspots' in the European policy debate on 'platform power' (Busch et al., 2021). The contribution emphasises that APIs are neither simple nor stable technical objects but complex governance configurations that continuously change and evolve, which is crucial to gaining an understanding of how APIs tie into platforms' power, particularly the *infrastructural aspects* of that power.

In the next section, I first provide an overview of the contemporary academic literature on APIs and platform governance to position the contribution in these research areas. Second, I detail the empirical-historical approach to examining Facebook's API governance against this background, highlighting aspects of the platform's infrastructural power, and describe the method of data collection.[40] Third, I present the empirical case study of the structure and evolution of Facebook's APIs. Finally, I discuss the implications of the historical analysis, which highlights the importance of technical perspectives on the *governance of and by* APIs as a major source of platforms' infrastructural power within the ecosystem.

2.2. [BACKGROUND AND POSITIONING] **API studies meet platform governance**

2.2.1. *Streams of API-related research*

APIs have been studied by scholars across multiple disciplines and fields, including Communication and Media Studies [C&MS], Information Systems [IS] research, and software engineering. This section identifies relevant streams of research on the historical relationality between APIs and governance to contextualise the analysis of the technicity of platform governance.

40 The data that support the findings of this study are openly available in the Open Science Framework [OSF] at https://doi.org/10.17605/osf.io/wfxyp. Data collection was conducted until February 2020.

First and most relevant for the purpose of this research, APIs have been described as mechanisms of generativity and control. APIs enable third-party app developers to interact with a platform to access and exchange data and functionality through a standardised information exchange that ensures interoperability (Bodle, 2011; Tiwana, 2014: 7). They coordinate development work between platforms and third parties (cf. de Souza et al., 2004), which means that platform governance through APIs is also a practical matter of facilitating collaboration. Platforms stimulate generativity by inviting third-party app developers to create new apps and services 'on top' of a platform by using its APIs. This generative dimension of platforms has previously been understood as a form of participatory 'remix' or 'mashup' culture, as platform appropriation or reimagination, and as a value-adding activity (Bucher, 2013; Evans and Basole, 2016; Hogan, 2018; Werning, 2017; [‣ Ch. 5]). At the same time, there is a 'paradoxical relationship' between generativity and control because platform owners must maintain economic, social, and technical control over their platforms, the external contributions of third-party app developers, and the platform's evolution (Eaton et al., 2015; Ghazawneh and Henfridsson, 2013). As such, APIs provide access to data and functionality in exchange for control (Eaton et al., 2015; Evans and Basole, 2016). Protocological technical objects like APIs serve as 'conduits for governance'—or as artifacts of governance'—where control is enabled on the level of API code (Bucher, 2013; Musiani, 2013; Snodgrass and Soon, 2019). Control over programming interfaces 'amounts to control over the platform and its evolution' and the platform's complements and complementors (Tiwana et al., 2010: 680). APIs thus facilitate infrastructural dependencies between platforms and apps, which I argue represents a source of infrastructural power and provides control over the platform's ecosystem.

Second, the rise in popularity of (proprietary) APIs over open Web development standards to enable generative practices has transformed the fabric of the open Web and beyond. As Web APIs and social plugins began to promote a more 'social' experience of the Web in the early 2010s, new forms of API-based connectivity emerged to underpin today's 'data-intensive' Web (Gerlitz and Helmond, 2013). As Langlois and Elmer suggest, platforms are increasingly 'weaving themselves in a new distributed infrastructure of life in all its forms' (2019: 6) in which APIs enable new 'connected viewing environments' in the television industry (Lahey, 2016) and new 'data seams' in the urban fabric of cities (Raetzsch et al., 2019). These developments are centred on the role of APIs as the standard mechanism for interconnectivity, embeddedness, and scale growth. However, they also raise concerns around power through platformisation (Blanke and Pybus, 2020; van Dijck, 2021b) and 'infrastructuralisation', whereby platform-based services acquire the characteristics of infrastructure (Plantin et al., 2018; [‣ Ch. 3]). The outcome is that these new data-intensive fabrics are no longer open or public but are instead privatised and governed by Big Tech companies.

Third, APIs structure and 'datafy' social and commercial processes. Social media platforms use APIs to create and temporarily stabilise digital identities for consumption by external apps (Pridmore, 2016). On the consumer 'side' of their platforms, social media companies like Facebook are infrastructuring online sociality for the eventual monetisation of targetable audiences (Alaimo and Kallinikos, 2019). On the developer 'side' of these platforms, 'webmasters' and developers implement APIs to ensure the seamless integration of their content and pages by making them 'platform-ready' (Helmond, 2015a). However, as social media companies seek to create an 'advertiser-friendly atmosphere of connectivity', their APIs are 'largely blind to acts of disconnectivity, such as unfriending and unliking', thereby only datafying commercially relevant types of sociality (John and Nissenbaum, 2019).

Fourth, APIs have been pivotal to the business models and strategies of platforms and the commercialisation of the Internet in general. IS researchers have studied the economic and business dimensions of the API ecosystem as an API 'economy'. In such an economy, Big Tech companies strategically provide data access through APIs to stimulate the development of API 'mashups' to capture the value produced by these complements (Evans and Basole, 2016). APIs also facilitate the distributed capture of datafied user engagements on third-party websites and apps, giving rise to Web economies such as the 'like economy' of the social Web (Gerlitz and Helmond, 2013). The logic of participation thus became heavily commercialised. Some researchers have traced TripAdvisor's evolution into a diversified ecosystem of data-based services wherein complementors assemble around new data forms to create additional services governed through APIs (Alaimo et al., 2020); others have mapped extensive API-based business-to-business (data) partnership networks that integrate social media platforms within the global digital advertising market [‣ Ch. 4]. Further, the strategic role of APIs in collecting new types of valuable data has been studied to understand the evolution of data and the business strategies of platforms (Bechmann, 2013; Wilken, 2014) by comparing API ecosystems (Evans and Basole, 2016). In short, APIs are not merely technical objects for software and app development but an integral part of a platform's data and business strategy.

Finally, APIs are commonly used and reflected upon as tools for academic research. Some researchers have examined the use of APIs for data extraction purposes and the role of API-based research software tools as 'data makers' (Rieder, 2013; Vis, 2013). Similarly, others have considered the technicity of APIs as they intervene in empirical research by shaping their objects or phenomena of study (e.g., Rieder et al., 2015). As far as Facebook is concerned, research uses are just another app type: they use the same APIs as other third-party app developers but for different purposes.[41] However, even minor API changes can have significant research implications. Newly imposed data limitations may introduce potential biases that undermine the representativeness of data studies (Ho, 2020). Such API-based studies can arguably only be interpreted and replicated alongside historical information about how the APIs used have changed and evolved. After the FB–CA data scandal and the subsequent 'APIcalypse' (Bruns, 2019), platforms like Facebook and Twitter severely restricted their API data access and sharing practices. This impacted critical academic research into phenomena such as online abuse, hate speech, and disinformation campaigns that employed APIs for data collection purposes. Consequently, the conditions of platform observability through APIs have worsened (Rieder and Hofmann, 2020). How platform APIs are governed raises questions around fair use and the need to look for alternative research methods suitable for a 'post-API environment' (Freelon, 2018; Perriam et al., 2020; Venturini and Rogers, 2019).

2.2.2. *Co-evolution of API design, governance, and strategy*

While these streams of API-related research all provide important insights into the politics of social media platform APIs, they have not necessarily focused on the evolutionary dynamics of APIs and their complicated role in how platforms govern app and business development. On the one hand, Communication and Information Studies have emphasised governance concerning end-consumers and content, including platforms' policies and their terms and conditions (e.g., Gillespie, 2018), the technical challenges and politics of algorithmic content moderation (Gorwa et al., 2020; Rieder and Skop, 2021), and governance by algorithms (Musiani, 2013). To this end, platforms enact governance by making certain design choices in their technical infrastructures, app features, and other architectural elements (DeNardis and Hackl, 2015; Duguay et al., 2020). On the other hand, IS researchers and software engineers have conducted empirical studies on APIs and their documentation to understand structural platform changes and how they are communicated and impact development (e.g., Medjaoui et al., 2018; Sohan et al., 2015). They have also theorised how a platform's evolution is influenced by the co-evolution of its architecture, governance, the 'environmental dynamics' of its ecosystem (Tiwana et al., 2010), and the challenges of governing digital platform ecosystems (Schreieck et al., 2018). In studying the technicity of platform governance, I draw from each of

41 Facebook has launched several (controversial) API-based initiatives since 2018 to build academic partnerships and improve transparency, including SOCIAL SCIENCE ONE, the Facebook Ad Library (formerly Ad Archive), and the FORT Pages API.

these strands. Governance of and by APIs concerns a platform's developer and business communities (and indirectly, its end-consumers), and involves its terms and policies, API design, and strategy.

Furthermore, the empirical-historical approach foregrounds the ability of a platform to shape—through governance and strategy—the evolution of the ecosystem around it in ways that impact certain outcomes, social, cultural, economic, or otherwise. For instance, these may include forms of 'platform envelopment' (or 'capture'), where a platform owner leverages power asymmetries over dependents to move into another's market (e.g., Eisenmann et al., 2011; Partin, 2020), or 'path dependency' and proprietary 'lock-in' effects, where a platform benefits from continued use by consumers, developers, or businesses based on historical preference or specific use (e.g., Alaimo et al., 2020). Previous technical design choices, strategic decisions, and advantages thus often sustain an enduring influence on the present.

2.3. [MATERIALS AND METHODS] Investigating API evolution and governance

2.3.1. *The material conditions of app development*

Platforms such as Facebook leave many forms of material traces that document their operations; these can subsequently be used to observe platforms' behaviours (Rieder and Hofmann, 2020) and reconstruct a platform's means of governance and strategy throughout their evolution. These material traces include information about the platform's APIs and other software (development) tools located on dedicated websites for developers (developers.facebook.com) and businesses (facebook.com/business). Because these websites have been well-archived in online archives, they are particularly suitable for empirical and historical Platform Studies that leverage the materiality of 'platforms' (Helmond and van der Vlist, 2019; [▸ Ch. 1: §1.4]).

Just as APIs are not stable objects but are prone to continuous changes, so does their imagined utility for third-party development evolve. Moreover, platform owners, complementors, and other actors collectively shape and reshape the evolution of a platform's 'boundary resources' [PBRs] in a process of 'distributed tuning', revealing the dualistic logic of generativity and infrastructural control (Eaton et al., 2015; [▸ Ch. 5]). In this process, a platform's reference documentation serves both a functional and strategic role by 'optimizing the developer experience' in working with the API (Medjaoui et al., 2018) while acting as 'a conspicuous form of political communication' that enacts 'specific social roles' (Moschini and Sindoni, 2021); for instance, in shaping the meaning of 'privacy' (Greene and Shilton, 2018). They provide important information and contain traces of API governance—that is, governance of and by platforms through their APIs. The amount of detail provided in the

API reference documentation thus enables granular empirical analysis of the material conditions of third-party app development and how those conditions have changed and evolved. These material conditions shape data flows and the kinds of interactions that are supported by a platform, which enable and constrain development and business opportunities. This study provides detailed empirical evidence to learn how API governance operates and how it evolved over the years.

The Facebook for Developers website covers the reference documentation for Facebook Platform.[42] This includes technical information about each of its open (i.e., public-facing) APIs, instructions on how to use them (e.g., how to read or write information to Facebook), and additional information about versioning, access levels, and rate limits, as well as specific data fields, edges, parameters, and permissions (specifying which data and functionality can be accessed under which requirements). Within the API reference documentation, Facebook currently refers to API objects, which represent information on Facebook, as 'nodes' or 'endpoints' (e.g., the /user, /photo, /event, and /page nodes). The properties associated with a node are 'fields' (e.g., 'name' and 'birthday' are fields of the /user node) and some fields require permissions from the user (e.g., the 'location' field). Connections between the nodes are called 'edges' (e.g., /(user-id)/feed returns any posts and links shared by a specified user-id on their profile). Although there are many distinctly named APIs, they can mostly be accessed through the same base URL (i.e., graph.facebook.com). These 'nodes' and 'edges' thus correspond with what end-consumers can see and do on Facebook's 'front-end' consumer interface, although the API (programming interface) offers different affordances (and sometimes more detailed information than the consumer interface) for development purposes.

Developers can use these nodes and edges ('endpoints') to access Facebook data and functionality. When developers request data from a node (e.g., /user), it typically returns not one but many data points about that node (i.e., its properties, such as 'birthday' or 'gender'). Further, when they connect to an edge, they can retrieve all the nodes associated with that edge. Since Facebook Platform's 'beta' launch in 2006,[43] a complex layered structure of access controls, app permissions, and app review guidelines has evolved to govern and restrict API data access for

42 Facebook Platform is 'the set of APIs, SDKs, tools, plugins, code, technology, content, and services that enables others, including app developers and website operators, to develop functionality, retrieve data from Facebook and any other Facebook Products, or provide data to us' (FD-2021O).

43 Software developers typically release (public) 'beta' versions when a software product is 'feature complete' and the development is done, to test the product with a large group of users and under 'real' use conditions (e.g., to identify 'bugs'). Today, most software tools, products, and services are kept in a 'perpetual beta', where new features are continuously added and tested, without the user necessarily knowing.

most nodes and edges. Finally, we make use of Facebook's archived Platform Terms and Developer Policies, which explain how the Platform should (and should not) be used (FD-2021o; FD-2021a).

2.3.2. *Archived developer pages and API reference documentation*

The empirical analysis of this chapter is based on Facebook's developer pages as retrieved from the 'live' Web and the Internet Archive. My co-authors and I downloaded 3,394 'live' Web pages from developers.facebook.com (2019–2020) and retrieved 1,960,901 archived developer pages from the Internet Archive's Wayback Machine [IAWM], going back to the initial launch of Facebook's beta API (August 2006 – February 2020).[44] Because Facebook does not provide an archive of its developer website, these independently archived sources provide an important means to analyse the observability of the platform. We combined multiple strategies to explore this large corpus of Web sources because APIs are complex composite technical objects that demand analysis at the different levels at which they occur and operate. Therefore, we analyse the evolution of Facebook's APIs on the level of the entire API architecture, of individual API objects, and app permissions.

On the larger level of the API architecture, we derived the link structure of 63,027 (combined 'live' and archived) reference documentation pages that describe Facebook's APIs. Each page describes a specific node and any associated fields, edges, and parameters, and details the data or functionality that is available to third-party developers. As such, the link structure embedded in the reference documentation reflects the API architecture. We derived and charted the link structure as it evolved with each new version. Additionally, we created a corpus of 178,972 Web pages with annual 'snapshots' of archived URLs anywhere on the Facebook for Developers site to visualise the complexity and diversity of the APIs and to examine their naming conventions. We further analysed the associated 'changelogs' (FD-2021g; FD-2021c), which document all versioned API changes and include information about newly introduced, changed, and deprecated nodes and edges as well as information about permission changes. A changelog addresses third-party app developers and communicates implemented or planned API changes and their implications. In some cases, they also reveal how Facebook Platform has responded to public controversy and external social pressures or made changes to its business and data strategies.

44 Available at: https://web.archive.org/web/*/developers.facebook.com/* (2006–2020) and https://web.archive.org/web/*/wiki.developers.facebook.com/* (2007–2011). This count only includes those 'snapshots' with a HTTP 200 OK success status response code, which indicates that the request has succeeded.

On the level of individual API objects, we examined one of the core (and most connective) nodes in the entire reference documentation: the Graph API User object (FD-2021i). The User object represents a user on Facebook (i.e., an account that represents a person). This object is at the core of Facebook's social network, which is structured around people's user-profiles and friendship connections and is also central to its advertising-based revenue model, which lets paying customers find and reach those users with targeted messages. Additionally, the User has long been the central focus of critical scholarship around online data privacy, which means that the evolution of its governance is of particular interest. We thus reconstructed how the User object evolved as a data object (in terms of its descriptive properties) and as a *relational* data object (in terms of its connections). The User and Page objects—the latter representing businesses, organisations, and public figures—are the two nodes that can authorise API access tokens for apps to allow data access. Other data objects are typically linked through the User object in some way. We further examined the evolution of targeting options for finding and reaching Facebook users with the Marketing API [MAPI], which is a distinct subcomponent of the GAPI used by Facebook Marketing Partners to develop digital marketing and advertising tools and services. The same targeting options are available through Facebook's self-service advertising tools, enabling me to examine how the targetable user has been governed through the MAPI (FB-2021).

Finally, we examined app permissions; these provide a way for apps to access data from Facebook (FD-2021l) and have become an increasingly important governance mechanism. We analysed the structure of these permissions and when specific nodes or edges require permission from the user in the first place. Facebook currently distinguishes between 'Basic' and 'Extended' Permissions for accessing its data and functionality. Any app can, by default, access ('read') the data fields that belong to a User's 'public_profile', including their 'name' and 'picture'. When an app requires access to additional data or to publish ('write') data to the platform, it needs to request extended permissions from the respective user(s).

To contextualise the observed changes on all levels, we consulted (read) Facebook's own Developer Blog and News sections (where Facebook communicates about important changes to developers using the Platform), as well as external technology journalism blogs, interviews and testimonies by CEO Mark Zuckerberg, and 7,000 pages of documents leaked during Facebook's litigation with app developer Six4Three in court [▸ Appendix B: Table B 2.1] (FL-2019a). We thus used a variety of primary (i.e., Facebook) sources and external sources that provide important contextual information about specific changes. Finally, we used visualisations to support the analysis and communicate a sense of the complexity of Facebook's APIs.

Taken together, the multilevel approach thus provides a comprehensive view of the evolution of Facebook Platform as a whole, and how its APIs became an increasingly complex arrangement of governance mechanisms.

2.4. [ANALYSIS] The structure and evolution of Facebook Platform

This section presents the results of a multilevel analysis of the structure and evolution of Facebook's APIs in terms of what, how, or whom it governed; that is, we trace the emergence of Facebook's API governance configuration beyond its mere programming interface across three levels. To begin with, the architecture level reveals how changes to Facebook's core APIs were central to the platform's evolution and how they became objects of governance. Additionally, the object level shows how Facebook represents its users as data objects, determining what counts as user data and how it may be accessed. Finally, the permissions level shows how Facebook articulates more granular access controls organised as an additional layer atop the API. Taken together, they provide important insights into how changes made to Facebook's APIs relate to the platform's governance and (data) strategy, especially regarding the orchestration of (asymmetric) relationships with complementors in the ecosystem (cf. Tiwana et al., 2010).

2.4.1. *The API architecture level*

At the API architecture level, we find that Facebook Platform has evolved from a single programming interface into a Web of interrelated API components; that is, collections of API endpoints around core platform products (e.g., Messenger, Instagram Platform's APIs, etc.). Initially (2006–2010), the platform only included the Facebook API, which provided data access to Facebook's core platform products (e.g., Profile, Friends, Photos, and Events). This enabled developers 'to add social context' to their Facebook apps (FD-2007). This so-called 'RESTful' API (i.e., designed according to open Web standards[45]) grew with the addition of further API functionality, reflecting Facebook's evolution as a social network. With the launch of the current GAPI (2010), this API architecture style was redesigned on the logic of the (social) graph, which modelled Facebook's social network entirely in terms of 'nodes' (objects) and 'edges' (connections). Since then, the graph model has codified and datafied any kind of relationship between people and those between people, objects, and activities both on and off the platform (FD-2021h).

45 REST (representational state transfer) is a software architectural style that uses HTTP-based methods for requests and responses (e.g., 'GET', 'POST', 'DELETE', etc.). It is commonly used to create interactive apps on the Web.

2.4.1.1. *Core API components: Cycles of diversification and integration*

Since 2010, many new core APIs have been introduced and integrated, reflecting the different tools, products, and services that Facebook has created (e.g., the Marketing API, Messenger Platform, Workplace, etc.) or acquired (e.g., Instagram, WhatsApp, Atlas, etc.) over the years. Under each of these core API components of Facebook Platform, we find more specific API endpoints that provide access to individual data objects and functionality components. Figure 2.1 presents the evolution of the entirety of the architecture of Facebook's APIs, including core components and specific endpoints as well as their interrelations. This API architecture grew not only in size and complexity but also became increasingly interconnected as Facebook evolved from a social network into a multi-sided platform for development, underpinning a large ecosystem of data-based apps and services (Alaimo et al., 2020; [‣ Ch. 3]). Here, governance manifests in the strategic diversification and integration of Facebook's APIs and the ongoing design and reconfiguring of API components. It also manifests in tiered API access levels and rate limits, which control API access for different users and limit the number of API (data) requests that can be made within a given time.

Evolution of Facebook's Graph API Reference, until v6.0 (2006–2020)

Based on 'live' and archived developer pages and API reference documentation

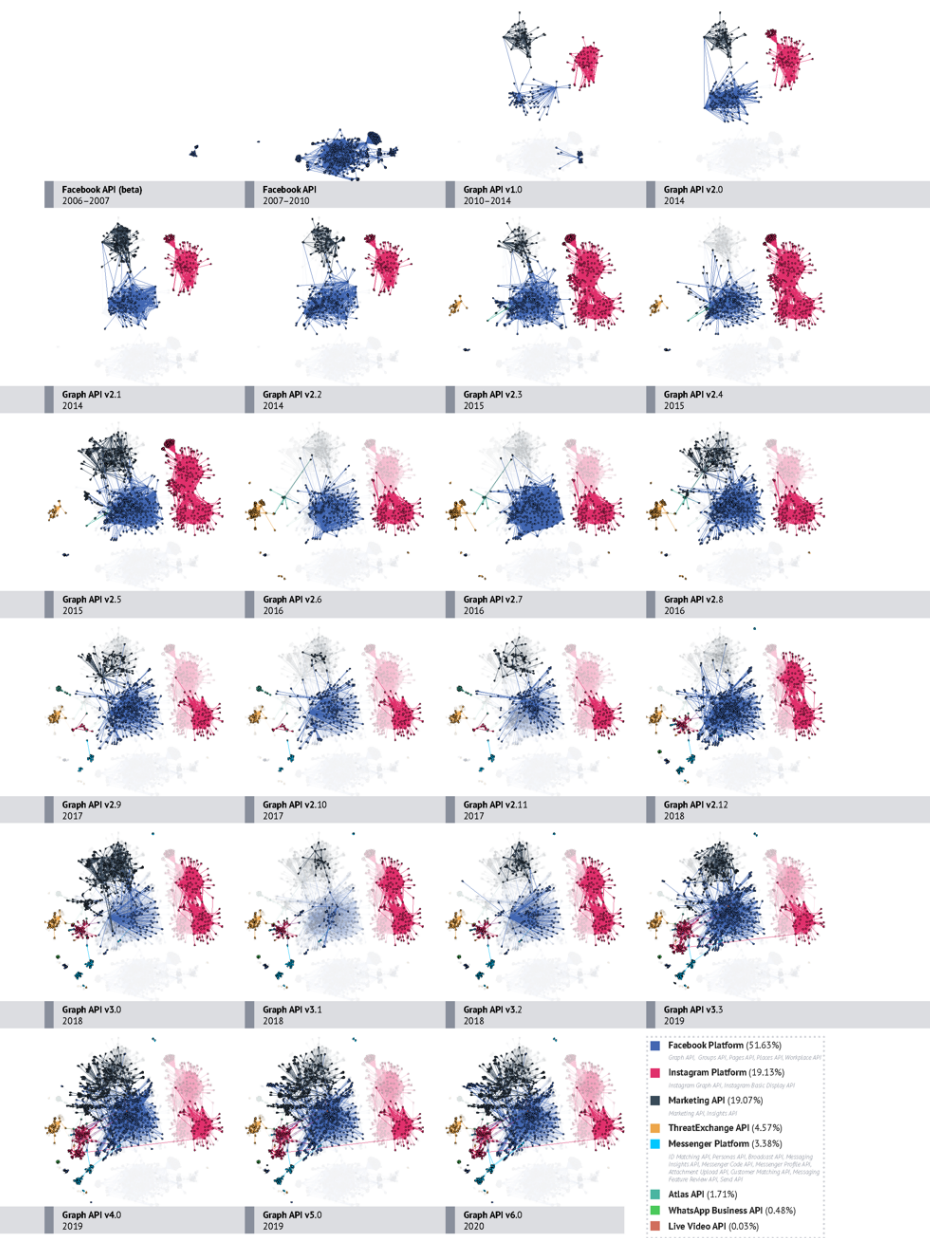


Figure 2.1. The evolution of Facebook's API Reference until v6.0 (2006–2020) [dynamic network diagram, small multiples]. Each tile represents the entirety of the API architecture for one API version (i.e., cumulative link structure of the entire API reference documentation), while the 'legacy' architectures from all previous versions up to that moment are rendered transparent in the background.

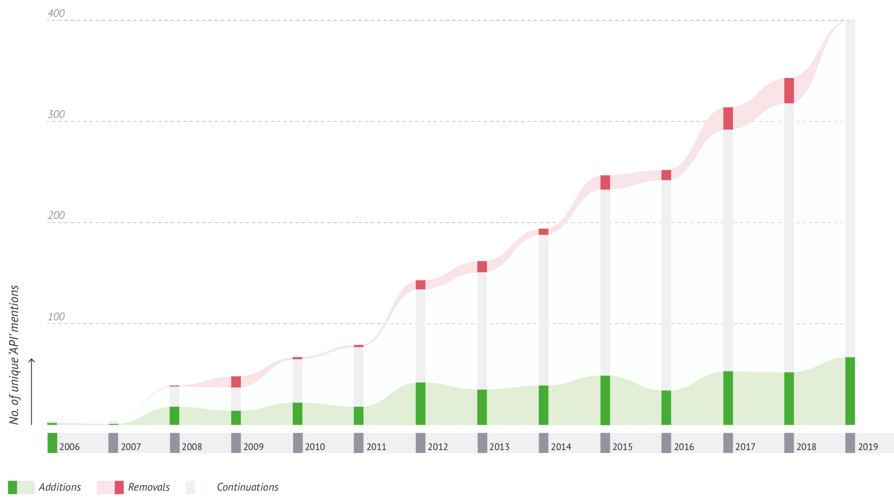
Nodes: individual pages within the API reference documentation (where each page documents a single API object, such as the User object, and all its features); edges: the detected link structures between those pages. Colour-coding: by API component (brand colour). Data: Internet Archive. High-resolution figures are openly available in OSF at https://doi.org/10.17605/osf.io/wfxyp.

Since 2014, the MAPI has increasingly merged (i.e., technically integrated) with the GAPI, sharing more and more of the same API objects, methods, and documentation. As such, Facebook's advertising platform became part of its core development platform rather than remaining separate. While Facebook's own self-built and acquired platforms—Facebook's 'family of apps'—have remained separate for end-consumers, we see that they have long been interconnected in the back-end for business users (Nieborg and Helmond, 2019). These changes were slowly rolled out throughout several API versions. When Instagram (2012) and WhatsApp (2014) were acquired, their back-ends initially remained entirely separate from the rest of Facebook Platform. They later migrated to Facebook's data centres to 'ease the integration with other internal Facebook systems' by unifying 'their underlying technical infrastructure' to further 'increase Facebook's utility and keep users highly engaged inside the company's ecosystem' (Isaac, 2019; IE-2014).

The longer-term evolutionary trajectory of Facebook's API architecture is characterised by stages of explosive growth (a diversification of API endpoints) combined with an ongoing integration process of the platform's core API components. These changes are as much discursive as they are technical: we find a proliferation of distinct APIs mentioned and documented in the API reference documentation. 'The Facebook API', as it was originally called, gradually evolved into a complex and interrelated structure comprising hundreds of distinct APIs to address more specific development needs.

Figure 2.2(a) and (b) lists all the entities referred to by Facebook as 'APIs' between 2006–2019. We identified 446 unique APIs in total, comprising both individual and collections of endpoints. The vast majority encapsulate very specific GAPI and MAPI data and functionality that enable developers to build tools, products, and services more securely and efficiently. These special-purpose APIs can be 'in name only', merely repackaging API functionality to promote particular use cases and enable targeted and subtle forms of governance. As such, the developer pages do not only contain technical information but also have a communicative function for developers by signalling specific use cases (cf. Dal Bianco et al., 2014). Because of this dual role, we see Facebook's evolution reflected in the reference documentation and in how its API architecture is presented and described.

Evolution of 'API' mentions within Facebook's Graph API Reference (2006–2019)
Based on 'live' and archived developer pages and API reference documentation



2006 Facebook API Generic API

2007 Facebook Platform API

2008 Action API Association Data Access API Association Data Definition API Batch API Batch Run API Batching API Client API Data API Data Store API Facebook Rest API Feed API Object Data Access API Object Data Definition API Permissions API Platform API Rest API SMS API User Preference API

2009 Application API Comments API Connect API Demographic Restrictions API Events API Facebook Platform Connect API Facebook Platform Rest API Facebook Restful API Open Stream API Page API Places API Restful API Search API Stats API

2010 Admin API Ads API Core API Dashboard API Facebook Status API Graph API Groups API Inbox API Insights API List API Marketplace API Messages API Migrations API Notifications API Open Graph API Platform Dialogs Graph API Real Time API Realtime API Rest Graph API String API Subscriptions API Time API

2011 Async API Backend API Backwards API Chat API Credits API Credits Graph API Dialog API Frontend API Games API Marketing API Messaging API Monetization API Page Graph API Payment API Requests API Scores API Sponsored Stories API Thread Graph API

2012 Achievements API Ads Preview API Ads Rest API Asynchronous API Audio API Batch Graph API Camera API Client Side API Credits Order API Dashboard Rest API Facebook Scores API File API Fql API Graph Batch API Graph Rest API Group Graph API High Score API Linter API Login API Medium Graph API Medium Insights API Message Graph API Milestone API Mobile Device API Navigation Timing API Network Information API Offers API Open Graph Photos API Open Graph Search API Orders API Page Post Visibility API Payer Promotion API Payments Reporting API Post API Real Time Updates API Reporting API Reports API Sponsored Results API Subject Graph API Test User API Time Updates API Updates API

2013 A/B Testing API Access Tokens All Graph API Ad Account API Apps API Domain API Friends API Game Groups API Gamorlive API Graph Insights API Id API Insights Graph API Message API Mobile API Object API Page Locations API Pages Marketing API Parse API Pay Dialog API Payment Graph API Places Search API Preferred Currency API Preview API Profile API Public Feed API Push Status API Response API Role API Send API Shortcut API Stream API Tag API Trial Pay API Trial Pay Offers API Upload API Video API

2014 Ad Report Stats API Ads Insights API Ads Reporting API App Events API App Insights API App Links Hosting API App Links Index API Atlas API Audience Network Native API Behaviors API Business API Business Mapping API Conversion Pixel API Custom Audiences API Disputes API Facebook Tag API Friends Graph API Games Achievements API Geo Targeting API Hashtag Counter API Hosting API Index API Instagram API Invitable Friends API Inviting API Keyword Insights API Mobile Hosting API Mobile Measurement API Native Ads API Page Feed API Place Picker API Social Context API Taggable Friends API Tagged Places API Topic Feed API Topic Insights API Topic Search API Trending API Trends API

2015 Ad Label API Ad Tag API Ads Activity Log API Ads Management API Aggregated Instant Articles API App Development API App Link API App Link Index API Audience Management API Audience Network Reporting API Business Manager API Buying API Custom Audience Pixel API Custom Audience Pixel Stats API Data Model API Device Login API Embedded Video Player API Game Groups Tutorials API Game Request API Game Services Tutorials API Geocoding API Inline Page Post API Insights Page API Instagram Ads API Instant Articles API Instant Articles Insights API Labels API Mapping API Measurement API Media Solutions API Minimum API Mutual Friends API Page Insights API Page Videos API Pixel Stats API Prediction API Reach And Frequency API Reach Estimate API Reachestimate API Refunds API Report Stats API Share API Sharekit API Showcase API Source API Story API Targeting Search API ThreatExchange API Xmpp Chat API

2016 Account Management API Accountkit API App Events Export API Asset Management API Audience Network Native Ad API Business Asset Management API Business Management API Catalog API Crossposted Videos API Device Share API Devices API Dynamic Post API ID Graph API Instagram Ads Post Moderation API Lead Ads API Live API Live Video API Messenger API Messenger Platform API Offline Conversions API Page Instagram Accounts API Product Catalog Preferences API Reactions API Recommendations API Rights Management API Rights Manager API Send/Receive API Three Degree Mutual Friends API User Profile API Video Edit API Video Upload API Webhooks API Wit.Ai API Workplace Account Management API

2017 Account Preferences API Accountkit Graph API Accountkit Rest API Actiontag API Ad Copy API Advanced Measurement API Advertiser API App Marketing API Atlas Reporting API Attachment Upload API Audience API Audience Create API Audience Network API Campaign API Checks And Quality API Checks API Company API Conversations API Crowdtangle API Current Place API Customer Matching API Detailed Targeting API Export API Games Ads API Id Matching API Instagram Platform API Instagram Stories Ads API Jobs API Marekting API Marking API Messaging Insights API Messenger Code API Messenger Profile API Page Messaging Insights API Pass Thread Control API Paymentrequest API Place Information API Placement API Places Graph API Preferences API Product Catalog API Product Feed Rule API Product Feed Rules API Product List API Publisher API Quality API Resumable Upload API Rules Engine API Split Testing API Suggested Rules API Take Thread Control API Thread Settings API Workplace API

2018 3D Posts API Add Instagram API Ads Marketing API Broadcast API Business Discovery API Business Management Asset API Catalog Batch API Certificate Transparency API Collection API Comment Moderation API Contacts API Content Publishing API Conversation Graph API Current Place Feedback API Destinations Marketing API Facebook Live API Game Switch API Handover Protocol API Hotel API Hotel Room API Hotel Rooms Batch API Information API Instagram Graph API Instant Articles Transformer API Instant Games API Lead Ads Retrieval API List Batch API Media Solutions Live API Media Upload API Mentions API Messaging Feature Review API Messenger Expressions API Messenger Send API NLP API Page Change Proposals API Page Scoped Id API Page Upcoming Changes API Pages Categories API Payment Dispute API Payment Request API Psid API Public Figure API Query Event API Register Account API Rules API Shops API Sponsored Message Ads API Store Visits Custom Audience Eligibility API Thread Control API Thread Owner API Whatsapp Business API Workplace Graph API

2019 Ad Creative API Ad Keyword Stats API Ad Library API Ad Rules API Ad Video Library API Ad Volume API Adcampaign API Ads Insights Edge API Ads Manager App API Basic Display API Bot Subscription API Business Onboarding API Canvas Ads API Canvas API Categories Management API Commerce API Commerce Payout API Commerce Platform API Connected Player API Credit Allocation API Custom Labels API Custom Update API Direct Feed Upload API Direct Upload API Document Interaction API Dynamic Ads API Finance API Fundraiser API Generation API Hashtag API Hashtag Search API Home Screen Shortcut API Instagram Basic Display API Instagram Content Publishing API Lead Retrieval API Leaderboard API Leadgen API Leads API Live Polls API Managing Pages API Marketing Leads API Matchmaking API Messenger User Profile API Onboarding Clients At Scale API One Time Notification API Order Management API Page About Story API Page Messaging API Particle System API Persona API Player Stats API Product Catalog Batch API Product Feed API Real Time Batch API Remaining Ads API Send And Receive API Sequence Sampler API Split Testing And Lift API Static Recommendations API Store Visits API Subscriptions Syncing API Support API Targeting API Tax Override API Whatsapp API Whatsapp Business Management API Workplace Live API

Figure 2.2(a) and (b). The evolution and overview of 'API' mentions within Facebook's reference documentation, 2006–2019 [stacked bar chart]. The upper chart includes all 'API' mentions (and whether they are newly mentioned or removed), while the lower timeline only lists newly mentioned APIs.

Colour-coding: first-mentioned/launched (light green), continuations (light grey), or last-mentioned/deprecated (light red). Data: Internet Archive. High-resolution figures are openly available in OSF at https://doi.org/10.17605/osf.io/wfxyp.

2.4.1.2. *Changelog: The transition towards a stable platform*

Developers require stable (reliable) platforms on which to build and maintain their apps and services.[46] Indeed, any dependent apps and services would immediately break without timely and clear communication and instructions (documentation) about upcoming API changes (Sohan et al., 2015). Reversely, the platform owner risks losing its technical integrations and embeddings in other competitive markets, industries, and sectors of society.

At first, Facebook did not systematically communicate its API changes and only documented some of them on its Developer News page (FD-2006a). This is reflected in Facebook's internal motto at the time to 'move fast and break things', which impacted dependent app developers. Consequently, due to mounting criticism, Facebook started publishing a Developer Roadmap (2010) to 'help developers plan for changes' (FD-2010d). This roadmap was part of Facebook's 'Operation Developer Love' (2010–2011), which was intended to ease tensions with developers requesting improved communication about changes to the platform to increase reliability (FD-2010a). Before this, Facebook would primarily use its Developer Terms of Service to govern app development. For instance, the increasing popularity of 'social games' built using Facebook's APIs led to the so-called 'News Feed spam wars' as developers tapped into the possibilities of Facebook's APIs to virally distribute their apps and games (Levy, 2020: 165). After user complaints about these 'spammy' game apps, Facebook immediately restricted developers' API access to the News Feed and notifications, citing their terms of service. This event would kickstart a 'push-pull between Facebook and its developers', where 'Facebook would change the rules and developers would figure out how to get around those rules' (Levy, 2020: 165).

46 'Stable' (also called 'production' and 'final') version releases are verified and tested thoroughly (e.g., to identify bugs), and are thus as reliable as possible. The 'stable' version typically comes last in the development process (i.e., software release life cycle), after the 'alpha' and 'beta' version releases.

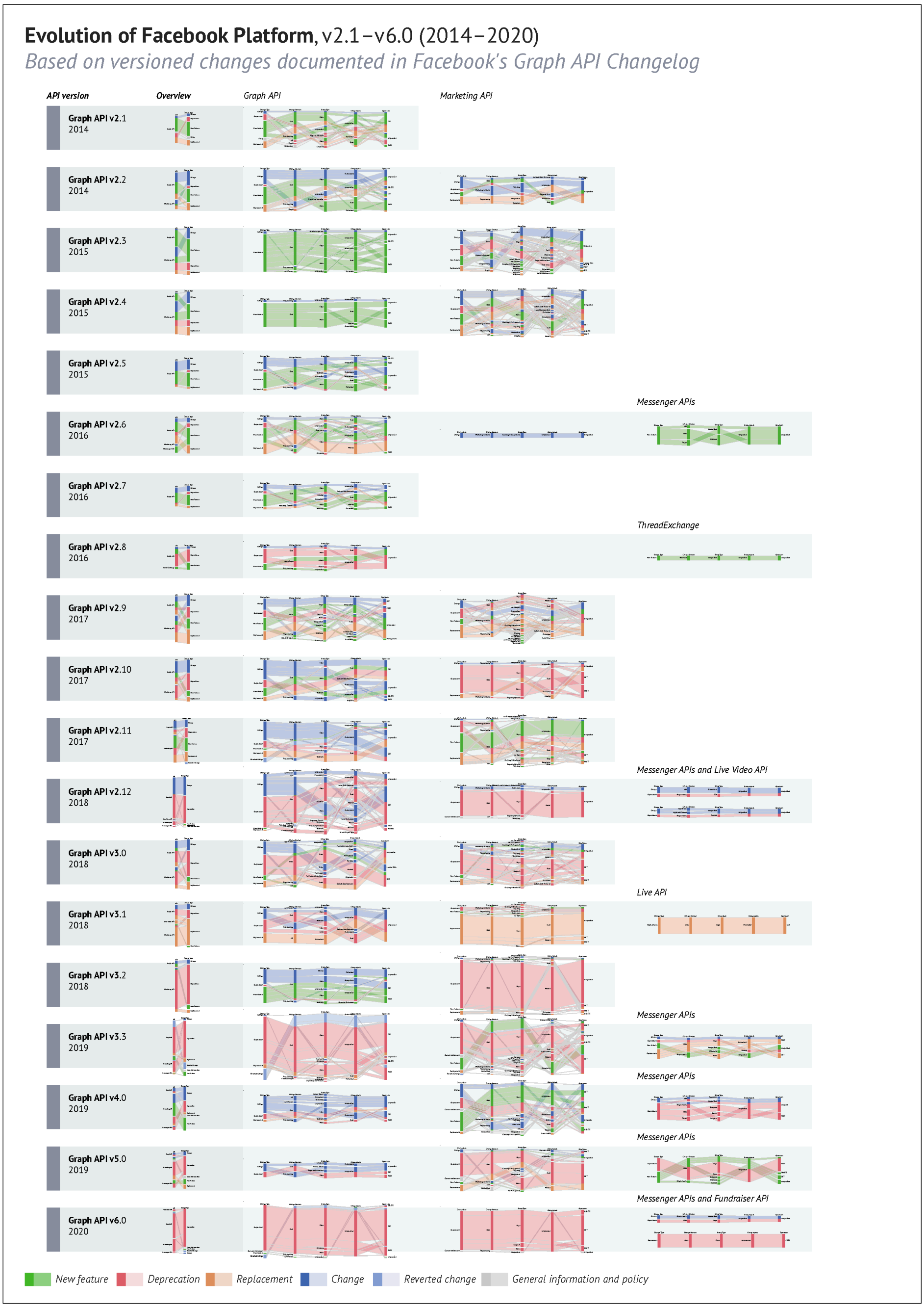
The operation eventually led to stability improvements when the reference documentation became more frequently updated and a 'breaking change policy', signalling API changes that would cause an app to malfunction in advance, was introduced (FD-2011a; FD-2011b). Facebook later started posting weekly updates on upcoming platform changes on its Developer Blog (formerly Developer News), marking its transition towards becoming a more 'stable platform' (2010–2014) (FD-2010a; FD-2011a). This transition from an experimental to a stable development platform has been critical in Facebook's acquired infrastructural scope and scale [▸ Ch. 3] because it reduced or minimised development risks for complementors, particularly businesses.

With the release of GAPI v2.0 (2014), Facebook made several key changes to announce and document API changes: it introduced 'versioning' (and retrospective version numbers) to manage the multiple (consecutive or parallel) releases of an API as well as to communicate upcoming changes, provide a transition period to provide ample time to address them (to avoid 'breaking'), and make a stability guarantee for developers. Moreover, Facebook introduced the changelog to announce and document any changes to the GAPI (FD-2014a). Concurrently, Facebook changed its internal motto to 'move fast with stable infrastructure' (Levy, 2020: 243), signalling the Platform's maturation with a commitment to supporting third-party app development and improving app (performance) quality (e.g., less bugs). The platform further introduced versioning to the Ads API (now Marketing API) and aligned its versioning and release cycles with the core GAPI soon after (FD-2014b). Both developments paved the way for Facebook's explosive growth as a digital marketing and advertising business in the subsequent years [▸ Ch. 3].

The shift Facebook made from its continuous trajectory of development and releases (with concomitant unpredictability) to scheduled and versioned release cycles mark an important step in the platform's evolution. Communication between Facebook and third-party developers was further standardised through developer pages and reference documentation. Since then, changes to the GAPI and MAPI have been documented in the changelog because of its important communicative function, namely that it informs developers (and other complementors) about whether, how, and when they should update their tools, products, and services to comply with a new API version (along with an Upgrade Guide). The updated policy assured a two-year transition period for developers to upgrade their apps. Consequently, so-called 'breaking' API changes became an important aspect of API governance because these changes either take effect immediately or on short notice (called '90-day breaking changes'). Here, API governance serves to ensure platform stability and predictability in app development for Facebook's growing community of complementors—developers, businesses, marketers, and researchers worldwide—and its growing app ecosystem. This type of platform stability (reliability) is crucial for the further 'infrastructuralisation' of Facebook Platform, such that third-party software app developers and businesses are willing to establish relationships and dependencies on Facebook's platform [‣ Ch. 3].

Figure 2.3 shows the evolution of Facebook's APIs as documented in the changelog going back to v2.1 (2014). The changelog documents the addition of any new features, changes, deprecations (removals),[47] as well as the introduction of App Review requirements, affected nodes (or their fields, edges, parameters, permissions, etc.), and affected API methods (for reading, creating, updating, or deleting Facebook data). As such, it is useful for determining the temporality of API evolution and governance.

47 'Deprecation' refers to the (scheduled) removal of nodes or edges, even if replacements were introduced simultaneously. In the latter case, we use the label 'Replacement' instead.



Evolution of Facebook Platform, v2.1–v6.0 (2014–2020)
Based on versioned changes documented in Facebook's Graph API Changelog
API version
Overview
Graph API
Marketing API
Graph API v2.1
2014
Graph API v2.2
2014
Graph API v2.3
2015
Graph API v2.4
2015
Graph API v2.5
2015
Messenger APIs
Graph API v2.6
2016
Graph API v2.7
2016
ThreadExchange
Graph API v2.8
2016
Graph API v2.9
2017
Graph API v2.10
2017
Graph API v2.11
2017
Messenger APIs and Live Video API
Graph API v2.12
2018
Graph API v3.0
2018
Live API
Graph API v3.1
2018
Graph API v3.2
2018
Messenger APIs
Graph API v3.3
2019
Messenger APIs
Graph API v4.0
2019
Messenger APIs
Graph API v5.0
2019
Messenger APIs and Fundraiser API
Graph API v6.0
2020
New feature
Deprecation
Replacement
Change
Reverted change
General information and policy

Figure 2.3. The evolution of Facebook's Graph API Changelog, v2.1–v6.0 (2014–2020) [alluvial diagrams, small multiples]. The changelog documents any versioned changes to the Graph and Marketing APIs, and any of Facebook's products or services that rely on them.

Flows and colour-coding: by change type (e.g., New Features, Changes, Deprecations, etc.) and by API component (e.g., GAPI, MAPI, etc.). Data: Internet Archive. High-resolution figures are openly available in OSF at https://doi.org/10.17605/osf.io/wfxyp.

Between 2014–2017 (GAPI v2.1–v2.4; MAPI v2.2–v2.4), Facebook's business side became significantly more professional in its orientation. Many additions to the MAPI were made in this period, significantly expanding the data and functionality accessible to the platform's business developers and marketing partners. Further, new components such as the Messenger Platform were gradually included in the changelog, reflecting their integration with Facebook's core technical platform.

We observe many changes to the GAPI and MAPI in the wake of public controversies and criticisms of the platform's role regarding the 2016 United Kingdom [UK] EU-membership referendum, the subsequent USA presidential election, and the FB–CA data scandal (FD-2018c). Facebook introduced additional restrictions on their use, deprecating many available fields, permissions, ad targeting options, and legacy APIs to improve data protection and permission requirements.[48] Additionally, the EU General Data Protection Regulation [GDPR] came into force in May 2018, imposing stricter data protection obligations on Facebook and other companies and organisations that target or collect data related to people in Europe—and which we found mention of in the reference documentation (e.g., about the Marketing API 'Targeting Specs', or the instructions that determine who will be shown an ad).

The changelog thus also captures how recent stages in Facebook's API evolution were guided by the platform's responses to intensifying pressures from public scrutiny and regulations. So far, these responses have led to changes related to specific API objects but did not alter the internal structure of the API architecture. Many of these changes ended up as 'breaking changes' and were announced on a separate (dedicated) page next to the changelog. These breaking changes occur outside of the regular API version release schedule and, as such, they momentarily disrupt the platform's stability. They require the urgent action of app developers who rely on the respective API endpoints. Consequently, breaking changes provide an immediate way for platforms to govern their relationship with developers through their

48 While we found some examples of this, it is not always the case that API changes due to regulations such as the GDPR are explicitly motivated in the reference documentation. Instead, their context is typically provided in separate accompanying posts on Facebook's Developer Blog.

APIs, although it remains difficult to know exactly what the implications are because that would require a better (empirical) understanding of individual developers' experiences with such specific changes [▸ Ch. 5]. In 2018–2019, we see that further external pressure demanded additional immediate responses by Facebook and led to many breaking changes. This time, they were related to concerns around discriminatory ad targeting, the FB–CA scandal, and the GDPR preventing Facebook from using third-party audience data for its self-service advertising tools, which is further discussed in relation to app permissions [▸ §2.4.3].

2.4.2. *The API object level: The Graph API User*

At the API object level, we see how Facebook Platform defines and represents—that is, datafies—entities as data objects with certain properties ('fields') and connections ('edges'). Object-level API design underpins all of Facebook's apps, including Instagram, WhatsApp, Messenger, and Workplace, because they have all been integrated into the same unified 'data infrastructure' (Nieborg and Helmond, 2019). Object-level design decisions shape how an app can interact with the User object. Moreover, they also impact the platform's business side because a data object's fields and edges also serve as targeting options for Facebook's suite of (both self-service and programmatic) advertising tools, products, and services. As such, Facebook's API design and governance are entangled with the platform's data strategy.

Figure 2.4 presents the evolving composition of the GAPI User object in terms of its fields and edges between 2006–2020. Between 2006–2010 (before GAPI v1.0), the User is one of seven available API objects, together with the Events, Friends, Messages, Photos, Pokes, and Wall endpoints. The fields of the User object were user-defined inputs that corresponded to the information presented on that user's profile page (e.g., 'about_me', 'gender', 'movies', 'political', etc.). The number of fields slowly increased during this period, as did the number of edges linked to the User.

The release of GAPI v1.0 (2010–2014) marked a turning point for the platform's data structure because Facebook Platform was subsequently reconfigured according to the logic of the (social) graph. With this new graph-based data model, data objects such as the User came to be defined by their connections to other data objects, thus forming relationship networks. The User's fields (properties) are mostly defined by the users themselves, while its edges (connections) emerge through the user's online activities, behaviours, and friendships (e.g., /likes for a user's liked Pages, /friends for a user's friends). Due to this new data-structuring logic, API changes tend to concern an object's edges more than its fields. Further, the new graph-based data model also impacted app development and data use (i.e., data access and sharing). It represented Facebook's vision of a 'social' Web wherein its users are not only connected to other Facebook data objects but also to data objects outside of the platform's boundaries. It was during this time that Facebook appealed to third-party app developers to implement its social buttons on their websites and released the Open Graph protocol (2010) to standardise data formats on the Web. This was a strategic move that helped make a wealth of external (i.e., unstructured) data sources 'platform ready' to integrate them into Facebook's data infrastructure, wherein Facebook was the *de facto* standard infrastructure for online social networking. The new data model was a pivotal moment in Facebook's evolution from a profile-centric social networking site into an 'identity service' (centred around Facebook Login [‣ §2.4.3]) (FL-2019d) and a graph-based data infrastructure that could support more than just its own social network.

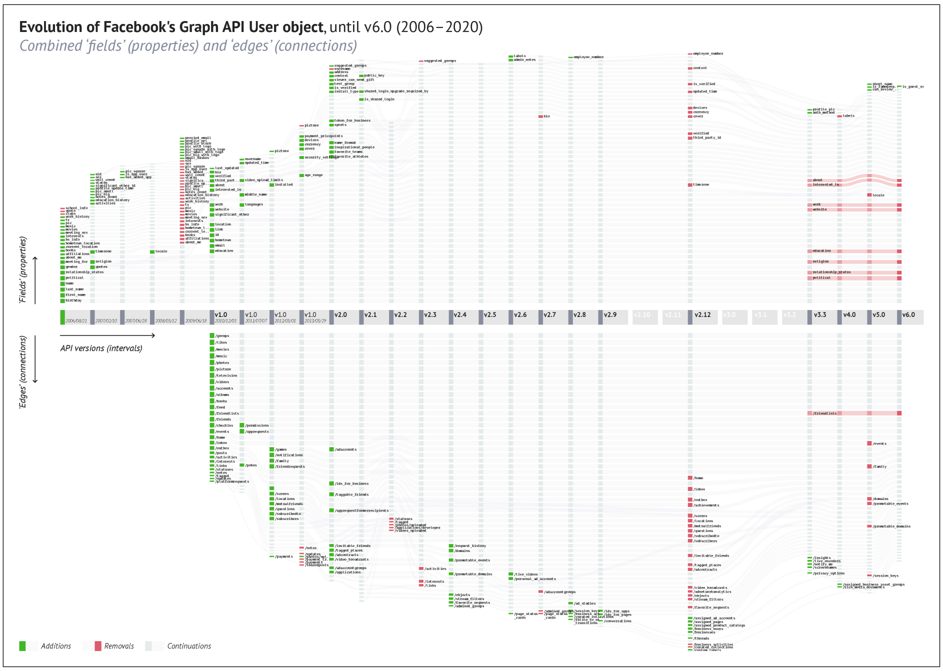


Figure 2.4. The evolution of Facebook's Graph API User object until v6.0 (2006–2020) [flow diagram]. The User object represents a user on Facebook as a combination of properties ('fields') and connections ('edges'). Each vertical slice displays the fields and edges of the User object for one API version.

Nodes: available fields (upper segment) and edges (lower segment); flows: continuities and breaks between API versions. Colour-coding: first-mentioned/launched (light green), continuations (light grey), or last-mentioned/deprecated (light red). Data: Internet Archive. High-resolution figures are openly available in OSF at https://doi.org/10.17605/osf.io/wfxyp.

Most changes to the User object between 2014–2018 (GAPI v2.0–v2.12) were minor, such as renamed fields and edges. Some of the new edges represent then-launched platform products or features (e.g., /games, /locations, /taggable_friends, and /live_videos). Additionally, new fields and edges were introduced for business users and advertisers when the Ads API and GAPI were streamlined in 2014. These new edges thus reflect the User's evolution from a consumer with a profile page to a critical connective node with potentially multiple roles within Facebook's ecosystem (e.g., the user as an app developer, app user, business owner, advertising account holder, advertising account manager, etc.). In short, the User node became the central gateway through which all the user's roles are governed by the platform.

In some cases, API objects are governed on the microscopic level of data fields. In early 2018, we first observe that the User's 'interested_in' field was no longer available in the MAPI for targeting people in France 'due to local laws'(FD-2016) and then in Europe for the same cited reason (FD-2017c) and it was later completely removed (FD-2018a). Similarly, in 2016, *ProPublica* reported that the 'ethnic_affinity' field targeting option could be used to create discriminatory housing ads by excluding specific groups, despite this being prohibited according to Facebook's advertising policies (Angwin and Parris Jr, 2016; FP-2021a). Facebook initially updated its policy but later removed the field entirely from the MAPI after ongoing social pressure and multiple lawsuits from civil rights organisations (FD-2017a; FD-2017b; FD-2018h). The issue of discriminatory advertising (or targeting in general) continued for several years, and it was not until 2019, as part of a settlement with civil rights organisations, that housing, employment, and credit ads became a 'special ad category' with fewer available targeting options in compliance with USA non-discrimination laws (FNe-2019a; FP-2021b; FD-2021k). Nonetheless, a year later, *The Markup* reported that targeting 'multicultural affinity categories' was still possible, after which Facebook announced it had removed them in service of 'simplifying and streamlining our targeting options' (FB-2020). In short, we witness how the User, as a *targetable* data object, has evolved within the MAPI reference documentation in response to external social and regulatory pressures.

GAPI v3.0 (April 2018) was the first version to implement major changes on the User object level in the wake of the FB–CA data scandal disclosed in March 2018. Facebook deprecated many of the fields associated with the User's profile and restricted the data that apps could access without going through App Review (FD-2018c). However, we see that several fields and edges were not immediately removed or deprecated after the scandal; instead, they would no longer return any data effective immediately (e.g., 'about', 'education', 'interested_in', 'political', 'relationship_status', 'religion', 'website', and 'work' fields; /friendlists, /taggable_friends, and /mutual_friends edges). Since their immediate removal would break current app distributions that rely on those endpoints, they were not immediately deprecated. Notably, some of these deprecated fields and edges (e.g., demographics, education and workplace, locales, relationship statuses, etc.)

remained available as audience-targeting options in Facebook's self-service advertising tools and programmatically through the MAPI (FD-2021j). In other words, while app developers could no longer access certain data through GAPI endpoints, advertisers, marketers, and certified marketing partners could still use them to target users via MAPI endpoints.

Since 2018 (GAPI v3.1–v6.0), there have been no notable changes to the User object except for additional deprecations (e.g., /family, /tagged, /threads, and /notifications edges) 'as part of [Facebook's] ongoing commitments to privacy and security' (FD-2020). More importantly, app permissions and the app review process matured as part of Facebook Platform's core governance mechanisms in this period. As I detail next, the User serves a central role in this configuration.

2.4.3. *The app permissions level*

At the app permissions level, we see how Facebook Platform governs its relationships with complementors (app developers, businesses, academic researchers, etc.) through its APIs. The permissions mediate and structure the relations between platforms and apps, which involve distinct access controls and privileges (e.g., 'read-only' to access data, 'read/write' to access or modify data, etc.) for different app and user types. Most app permissions are now requested through Facebook Login [‣ Figure 2.5].

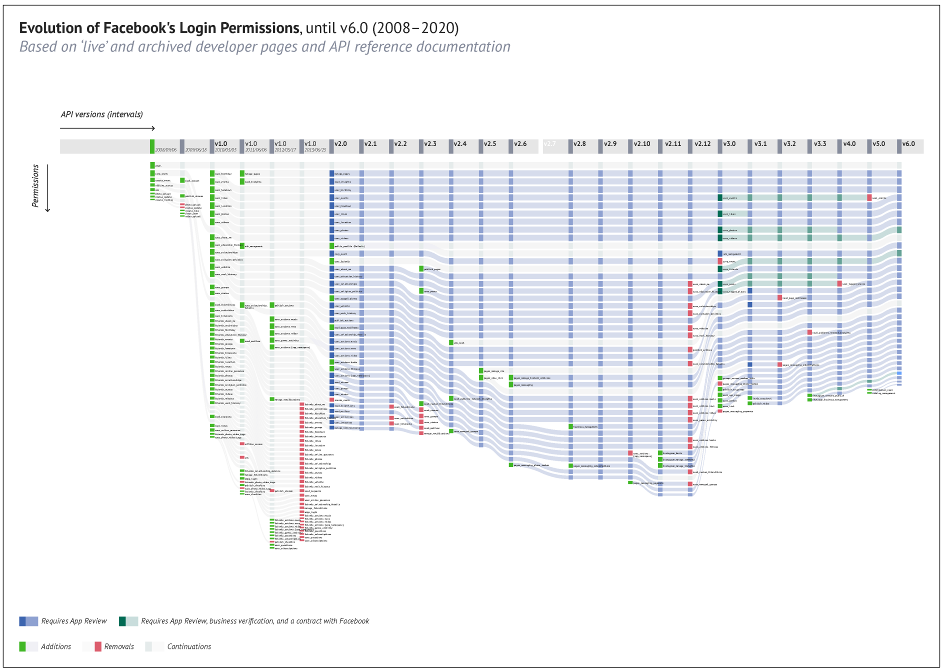


Figure 2.5. The evolution of Facebook's Login Permissions until v6.0 (2008–2020) [flow diagram]. Permissions provide a way for apps to access data from Facebook and are mostly requested through Facebook Login. Each vertical slice displays the permissions requested through Facebook Login for one API version.

Nodes: available permissions; flows: continuities and breaks between API versions. Colour-coding: first-mentioned/launched (light green), continuations (light grey), or last-mentioned/deprecated (light red); permissions that require App Review (dark blue); and permissions restricted to a limited set of partners (that require App Review, business verification, and a contract with Facebook) (dark green). Data: Internet Archive. High-resolution figures are openly available in OSF at https://doi.org/10.17605/osf.io/wfxyp.

Permissions for apps did not exist until 2008. Instead, developers had access to 'your profile info (excluding contact info), your photos, your events, and most importantly, your friends' by default (FD-2006b). If Facebook users did not want an app—or the apps of their friends—to access their user data, they needed to proactively opt out in their privacy settings. As such, data access was governed on the consumer side with opt-out privacy settings and not on the developer (or app) side with opt-in permission requests. Extended permissions to access further data were introduced in 2008 for 'certain use cases' that 'require a greater level of trust from the user' (FD-2008). The extended permissions provided API access for publishing data to the platform on behalf of the app's user (e.g., to send emails, upload photos or videos, or RSVP to Events). Permissions thus governed the relations between the platform and its connected apps and services, allowing developers to write data to the platform. In 2009, Facebook introduced an optional Application Verification Program [‣ Ch. 3] to verify an 'application's commitment to providing a trustworthy user experience that is secure, respectful and transparent' (FD-2009). Developers were requested to provide basic business information and an explanation of their data requests and data use cases. In return, apps received 'verified badges', priority ranking in Facebook's Application Directory, and Facebook advertising credits (FD-2009).

With the release of GAPI v1.0 (2010), Facebook changed the way permissions were granted on the platform, 'moving to a model where apps must list all the pieces of data they need to access from a user's profile rather than having all that data available automatically' (FD-2010f). A distinction was introduced between a user's basic (public) profile information (i.e., a person's name, profile picture, gender, username, and friend list), which is visible to all Facebook users and accessible to all apps through the API by default, and a user's private profile information (e.g., 'user_likes', 'user_religion_politics'), which now required apps to request extended permissions from the user via the new permissions dialogue (FD-2010c; FD-2010e). Consequently, it became more difficult for apps (and app developers) to access users' 'sensitive' personal data (a special category under the GDPR).

The platform further reconfigured its extended permissions into separate /user and /user/friends permissions 'to protect the privacy of users who have not explicitly authorized [an] application' (FD-2010b). In the new permissions model, apps could access the basic profile information of a user's friends via the User object without their explicit permission although access to additional friend information required extended permissions. This change also meant that the earlier extended permissions, which initially focused on publishing data to the platform, were expanded with user and friend 'data permissions'. In other words, on an individual level, permissions now controlled which apps could read or write data to the platform and which apps could access user and friends' data. The increasing number of data fields associated with the User object in this period, including new Open Graph API actions, led to a sharp increase in the number of extended permissions—from eight to 49 (2008–2010) to 72 (May 2012). Between 2011–2012, there were also new permissions that referred to the Ads API Business User (/business-user) for the first time, reflecting the integration of Facebook's development and business platform governance at the permissions level (part of the larger integration of both core API components intended to streamline the platform as it continued to expand and evolve [▸ §2.4.1.1]).

Several notable changes occurred between 2014–2018 (GAPI v2.0–v2.12). First, the platform restricted access to users' friends' data in response to mounting concerns over users' data and privacy. The friend list no longer belonged to the set of basic permissions and Facebook now required apps to request extended permission from each app user (FD-2014c). Additionally, whereas the GAPI User Friends (/user/friends) endpoint in v1.0 returned lists of users' friends, v2.0 only returned lists of friends who had also installed the app and had given the required permissions. Second, Facebook also launched its current App Review process to ensure that any information obtained by an app is directly connected to a relevant data use case. Moreover, most permission requests now require developers to undergo App Review as well. Facebook informed the UK Competition and Markets Authority [CMA] that this was 'aimed at safeguarding users' information against data misuse, leaks and bad actors' (CMA, 2020: Appendix J9). Third, a new version of Facebook Login was introduced to handle these app permission requests. The Login Review process was launched to ensure that apps request only those permissions they need (FD-2014a; FD-2021f; FD-2021e). As such, Facebook Login is now used for *authentication* (for users to sign in) as well as for *authorisation* (for handling permission requests from apps to access users' information) (FD-2021d). All existing apps needed to comply with the new platform policy, or their API access tokens would be revoked, representing a powerful form of 'gatekeeper' power. Facebook Login—as a digital passport of sorts—also ties into Facebook's online digital advertising system as one of the world's largest and most valuable 'identity graphs' [▸ Ch. 4].

The new Facebook Login enabled users to make more granular choices about the types or categories of data they wanted to share with third-party apps. However, it also enabled Facebook to evaluate whether the apps submitted for review would add value to the platform's ecosystem. These changes were not only meant to provide more granular privacy controls for Facebook users but were the outcome of internal reassessments at Facebook about the business value of its data-sharing practices with third-party app developers and businesses. This reassessment operation was internally called 'protect the graph' (FL-2019e; FL-2019f). As was later revealed, by limiting and reconfiguring API access to user and friends data in these ways, Facebook intended to undermine any competitors who used friend data and to reward complementors who added value to Facebook Platform (FL-2019a). Internal documents revealed that App Review was used to determine 'the appropriate level of reciprocity' (FL-2019e). Facebook's 'reciprocity' principle ('take data, give data') demands that apps 'share back to Facebook' so that it is not only 'good for the world' but also 'good for us' (FL-2019e). In short, there were now two competing accounts in explaining these API changes: on the one hand, Facebook reports that App Review is a proactive measure for protecting user trust and privacy; on the other hand, it limits competitors' access to valuable Facebook data (e.g., by reconfiguring the permissions model, revoking API access to friends' data, and launching App Review). This is one example of governance by platforms' APIs and may also help policymakers and regulators to regulate the infrastructural aspects of platforms' power. In Facebook's own words, App Review represented 'just another product feature to improve quality', while the API-level changes were meant to 'protect the business/model/data' (FL-2019g). As such, the various changes to Facebook's app permissions and the new privacy controls for users in this period served to implement and enforce Facebook's new strategic platform policy (to improve privacy controls and restrict competitors) while monitoring app development. Conversely, as head of Facebook Platform Justin Osofsky wrote: 'Historically, we've treated policy enforcement as a secondary function of platform' (FL-2019h).

With the release of GAPI v3.0 (2018), the number of permissions decreased for the first time from 47 to 36. These permissions (e.g., 'user_religion_politics', 'user_relationships', 'read_custom_friendlists', and 'user_education_history') were deprecated as a response to the FB–CA data scandal (FD-2018c; FD-2018f). Further, an increased number of permissions (e.g., 'user_friends', 'user_likes', and 'user_photos') was now restricted to a limited set of partners, not only requiring App Review but also requiring 'business verification' and a contract with Facebook (FD-2018d; FD-2018f; FD-2021b; FD-2021c). Facebook Login received its own Changelog to document changes to permissions as it had become the core authentication service for both end-consumers and app developers as well as a powerful control point for governing app development (FD-2021c). Facebook further increased control over its platform through additional verification processes for individual developers and business entities and required external business-to-business technology providers (i.e., partners) to sign a supplemental terms contract to restrict data usage (FD-2018d; FD-2018g; FD-2018e). Additionally, the tiered MAPI access structure for partners and businesses was simplified (FD-2018b). In short, while it may appear as if Facebook Platform only expanded over the years, it also underwent significant reconfigurations at crucial moments in (partial) response to external social and regulatory pressures from the public and competitive dynamics in the digital (platform) economy generally.

Since 2020 (GAPI v8.0), these permissions have been further streamlined. All permissions were moved onto a separate Permissions Reference page (FD-2021l) and are requested (and thus governed and controlled) through Facebook Login. Permissions other than a user's 'public_profile' and email address now require App Review 'so that Facebook can confirm that the app uses the data in intended ways and safeguards user privacy' (FD-2021n). This also concerns permissions related to Facebook's other platform instances (e.g., WhatsApp, Messenger, and Instagram apps) and applies to developers, businesses, and creators alike. Only Instagram apps for end-consumers that require 'read-only' access rights to basic profile information, photos, and videos need to request separate Instagram Permissions (FD-2021m). The distinct treatment of these app types, we suggest, reflects Facebook's dual governance strategy for business users and creators on the one hand and for end-consumers on the other.

2.5. [DISCUSSION] Governance of and by Facebook's APIs

Based on this analysis of Facebook's evolution, we can derive some general features of *governance of and by* APIs as a contribution to the contemporary academic literature on platform governance (e.g., Gillespie, 2018; Gorwa, 2019; Gorwa et al., 2020). These features illustrate the ways in which the technicity of platform governance provides control over a platform's ecosystem.

Regarding governance *by* APIs, we must first identify what is governed. Facebook provides several distinct APIs, including those dedicated for (app) development around its core products as well as for digital marketing and advertising. These distinct interfaces reflect what Facebook's APIs are or are not intended for and how those intended uses have changed and evolved. Furthermore, we may distinguish how those things are governed. Facebook Platform has a variety of access controls that serve as additional layers of API governance. These include distinct access levels, rate limits, App Review, verification processes for business and individual developers, and app permissions for distinct app types (e.g., consumer apps, business apps). Furthermore, we may discern who is governed. Facebook offers distinct programming interfaces for its user groups, including the developers of apps, games, and digital marketing and advertising technology. The distinct user and app types, the App Review process, and permissions provide additional controls over specific (individual) users and uses. Finally, we may determine when governance or control is exercised by APIs. Most changes to Facebook's APIs are now versioned and documented, including any breaking changes, which can go into effect either immediately or after 90 days and later, giving developers some time to update their app infrastructure or accept that their app (or business) is no longer viable. The developer documentation and blog posts typically contextualise these changes, explaining why they are happening according to Facebook.

Regarding governance *of* APIs, we observe that API changes can be the outcome of both internal (e.g., policy changes and strategic decisions) or external pressures (e.g., social, competitive, or regulatory). The aforementioned significant events were followed by many changes to Facebook's APIs, especially on the object and app permissions levels. Similarly, ongoing social and regulatory pressures from civil rights organisations and journalists regarding discriminatory ad targeting and the introduction of new regulatory frameworks such as the GDPR led to observable API changes. Finally, leaked files from app development firm Six4Three's lawsuit against Facebook revealed how the social platform allegedly implemented API changes and App Review to 'protect' its business model while strategically controlling and closing down competitors (FL-2019g).

These features of governance of and by platforms through APIs are by no means comprehensive. However, they illustrate how APIs are not merely technical objects used by developers to access or retrieve a platform's data and functionality. Because of their strategic importance, APIs like those of Facebook, have evolved into complex layered and interconnected governance configurations that shape the conditions for app and business development in often subtle ways through coordination, managerial, and control mechanisms (e.g., Eaton et al., 2015; Stratton, 2020). These mechanisms govern the platform's many different types of users and uses, including business and academic research. In this way, Facebook's API governance shares similarities with what Caplan and Gillespie described as a 'tiered governance' strategy in the case of YouTube, where different users face different rules, material resources, and procedures (2020: 6). Subsequent chapters also identify tiered modes of governance, particularly in social media partnership strategies [‣ Chs. 3 and 4] and in app stores [‣ Ch. 6].

In the following, we discuss the implications of the analysis concerning API governance and platforms' infrastructural power. The observation that APIs have evolved into complex governance configurations and function as more than technical objects for data access or retrieval prompt a discussion into the relationship between the technicity of platform governance—governance of and by APIs—and the material conditions of a platform's power.

2.5.1. *API evolution, governance, and infrastructural power*

Significantly, API governance targets the conduct of a platform's complements and complementors in the platform's ecosystem more so than the conduct of its end-consumers. As such, the analysis augments the literature on platform governance, which often focuses on governance (and power) over end-consumers (e.g., content moderation, algorithms, policies, etc.) or content producers, and may or may not involve an interest in a platform's technicity (e.g., Caplan and Gillespie, 2020; Gillespie, 2018; Gorwa et al., 2020; Medzini, 2021). However, APIs are a critical part of platform governance because they constitute the material conditions of platforms and apps (cf. Blanke and Pybus, 2020; [▸ Chs. 4 and 5]). They allow third parties to develop apps and services 'on top' of a platform while enabling the platform to maintain infrastructural control over those apps and services, thus concurrently enlarging a platform's operational scale and scope while consolidating its position of power within the ecosystem.

This analysis traced how Facebook's APIs have evolved from a relatively simple technical object (programming interface) into a complex configuration of technical objects, specifications, terms and policies, and review and verification processes to govern the platform's diverse users and uses in different ways. App permissions do not only enable distinct and approved data transactions between a platform and its complementors (Pybus and Coté, 2021) but also govern those transactions and complementor relationships in increasingly granular ways. Additionally, increasingly granular governance mechanisms, including App Review and verification processes for individuals and businesses, may improve privacy or security but are also used to block 'bad actors' and unwanted competitors. In short, APIs are far more than mere developer tools; the more granular this governance configuration becomes, the more we need to caution against potential uses (and abuses) of a platform's power in the ecosystem. The reality is that most of these changes instill more (and not less) control and power in the respective platform, which may have as an additional consequence that barriers to competition are raised.

If platforms like Facebook exert a powerful influence over their ecosystem, then we need to consider the implications for those affected. We observe that platforms like Facebook do not only shape their own evolution [▸ Ch. 3] but also shape (or 'orchestrate') the evolution of their ecosystem through API design, governance, and strategy. It is because APIs are governance configurations, more than mere programming interfaces, that platforms can set, shape, and alter the material conditions of development on their different 'sides', such as for app development by individuals, marketers, or advertisers. These conditions directly influence, often in subtle ways, what can and cannot be built, sustained, or thrive in the ecosystem.

This shows that the boundaries of platforms are unstable, and continuously reconfigured through the collective development work of platforms' different groups of users [▸ Chs. 3 to 6]. Platforms' different boundary resources play a central role in this because they establish the material conditions of participation and control. On an infrastructural level, API design shapes what is technically feasible on a given platform, while a platform's governance shapes what is allowed, encouraged, or technically and economically viable for those within that ecosystem. With Facebook, we note that certain uses of its data and functionality were allowed and encouraged (e.g., building 'rich social apps'), whereas other uses were eventually discouraged or restricted (e.g., 'data export tools').

Platforms also control how, when, and for whom these conditions change, which they can enact as they see fit, often without risking their position of power. Although Facebook Platform may allow diverse user and stakeholder groups to participate in its ecosystem, it also ensures that those complementors are not equal in their ability to influence the platform owner or other complementors, resulting in asymmetries and different degrees of agency (Eaton et al., 2015: 219). Any change may cause disturbances or ripple effects across the entire ecosystem of apps and services relying on an API, potentially impacting the viability of all apps and services supported or sustained by it, including those of businesses and academic researchers. When Facebook changed API access to friends' data in 2014–2015, this severely impacted the business models and apps of complementors as well as academic research tools, causing shutdowns across the ecosystem (e.g., Constine, 2015; FL-2019b).

This dimension of a platform's power, which puts special emphasis on the material or infrastructural conditions of development, may be conceptualised as an evolutive aspect of the 'infrastructural power' of digital platforms (cf. Busch et al., 2021). We thus suggest that the analysis of platforms' governance and power needs to take into account a specific focus on their unique ability to influence or 'orchestrate' not only their own evolution but also the evolution of the larger ecosystem (Boudreau, 2010; Boudreau, 2012; Eaton et al., 2015; Stratton, 2020; Tiwana, 2014). Powerful platforms can unilaterally change the competitive conditions 'on' a digital platform and in a platform ecosystem because they define what is (and what is not) afforded, as well as how offerings are presented, received, and rated in the case of app stores [▸ Chs. 5 and 6]. While one may study how individual platforms or APIs change and evolve, we suggest considering how powerful platforms like Facebook also *wield* API evolution as a tool for governance and control. Evolution concerns not only inevitable changes but also strategic considerations.

This strategic dimension is perhaps most clearly visible on the API architecture level: Facebook's APIs went through multiple cycles of diversification and integration with the continuous addition of new endpoints and the consolidation of new API components into its core technical platform, respectively. While some of these new components and endpoints originated from Facebook's own internal development (e.g., Messenger), others notably originated either from mergers and acquisitions (e.g., Instagram, WhatsApp, Atlas Solutions, LiveRail, etc.) or from Facebook's marketing partnership strategy (e.g., the Marketing APIs) [▸ Ch. 3]. These different components were all eventually integrated into Facebook's core technical platform, although the process took several years. Integrations initially occurred in the 'back-end', enabling developers and businesses to reap the benefits of a consolidated, unified data infrastructure. Meanwhile, Facebook to this day has maintained a fragmented front-end for end-consumers: it offers a 'family of apps' wherein each one speaks to a different segment of the platform's user population or accommodates a different set of user practices.[49] The consolidation of these different apps and services 'from FACEBOOK', including their different APIs, may also make it increasingly difficult to break up the platform (an important implication for policymakers and regulators). Additionally, the diversification and integration processes tie into 'platform capture' (Partin, 2020). Facebook has leveraged these asymmetries in its complementor relationships, demanding that complementors not only 'take data' but also 'give data' back to Facebook when using its APIs. Finally, this diversification process has enabled large platforms like Facebook and Google to decompose and recompose themselves into what Blanke and Pybus describe as 'service assemblages'. This process has led to 'a much deeper technical integration' of application ecosystems, enabling Facebook and Google 'to shift the dynamics of competition and monopolization in their favour' (Blanke and Pybus, 2020: 2). In sum, the ongoing processes of diversification and integration provide important starting points for further analyses of platforms' evolutive and infrastructural power.

2.6. Concluding remarks

This chapter asked [RQ1] how governance and power are manifested in how 'core' technical platforms decompose and recompose their infrastructure for different types of development.

To address this question, it traced the evolution of Facebook's APIs, which evolved from a relatively simple programming interface for data access into a complex layered and interconnected governance configuration that links API design,

49 Consequently, many users are unaware that Facebook also owns Instagram, WhatsApp, and other popular apps. From November 2019, the company's rebranded 'from FACEBOOK' tagline made Facebook's ownership of all these apps much more evident (Constine, 2019; FNe-2019b).

governance, and strategy. Since its launch in 2006, Facebook Platform has provided many different APIs that both facilitate and govern the material conditions of app development and the social and economic processes they sustain. As observed, APIs have played many different roles, not only as developer tools but also as a means of enforcing platform policy and strategy and influencing the evolution of the larger ecosystem in often subtle ways. Studying the co-evolution of API design and governance thus provides important insights into determining how platforms secure and maintain infrastructure control and how this is operationalised or evolving over time. As such, this study is an empirical-historical contribution to begin understanding the infrastructural power 'blindspot' in the academic and policy debates on platform power (Busch et al., 2021).

Previous reports stressed the need for better understanding the infrastructural aspects of platform power, and for further research on this topic. I have argued that the material conditions and evolution of APIs can be analysed to develop such a better understanding of the infrastructural aspects of platform power. Specifically, I have demonstrated that APIs are not a single or monolithic source of power, but a complex arrangement of many different governance and control mechanisms that, together, represent a key source of infrastructural power. These mechanisms target many different uses and user groups, including third-party app developers, businesses, and partners. They also provide centralised and unidirectional hierarchical control over large numbers of apps and services—and the developers who build and maintain them— built 'on top' of the platform's APIs. Moreover, they represent a source of power over the evolution of the platform's ecosystem, which, in the case of Facebook, comprises millions of complements and complementors.

Additionally, this study gives a unique view of the ways in which platform governance and power are configured, and continuously reconfigured (Eaton et al., 2015), in the configuration of Facebook Platform as a complex 'assemblage' of tools, products, and services (Blanke and Pybus, 2020). This continuous decomposition and recomposition towards app developers underpins Facebook's platformisation and is crucial to understand the role of third parties in the 'peripheries' of platform ecosystems. Specifically, third parties and business partners have been vital to Facebook Platform becoming the 'core' of a large ecosystem of artefacts and relationships dependent on its 'assemblage' of tools, products, and (micro)services. Chapter 3 explores this involvement in detail with another case study of Facebook's evolution—this time focused on the co-evolution of Facebook's platform architecture and partnership strategy.

The multiple levels of analysis that I distinguished illustrate the complexity of APIs as technical objects regarding the technicity of platform governance. Many of the different features and mechanisms of governance and coordination found across these levels are subtle: they are 'powerful precisely because it is not a grand and spectacular strategy but a functional and often invisible reality' (Munn, 2020:

15). They shape the material conditions and evolution of apps and services connected to Facebook Platform in specific ways. Given this significance, it is important to continue to consider how large platforms like Facebook evolve and how they negotiate external pressures to change and reform on the level of the technical platform. Independently archived developer pages and API reference documentation provide necessary empirical materials for this purpose, and can help address the current lack of observability regarding complex technical systems and digital platforms (Rieder and Hofmann, 2020). This may also help policymakers and competition and regulation authorities by providing insights into Facebook's data-sharing practices with different types of third parties.

Furthermore, the approach enables studying what Facebook, as one of the most popular social media platforms, is built and intended *for*, and how this has changed and evolved over the years. Specifically, I have demonstrated the value and utility of archived Web sources for reconstructing exactly how Facebook has decomposed and recomposed itself as a platform for developers, enabling a comprehensive view of the platform as a 'service assemblage' (cf. Blanke and Pybus, 2020). Moreover, such a comprehensive view is difficult, if not impossible, to obtain otherwise due to the many serious issues and challenges faced by social media and platform historians and archivists (e.g., Helmond and van der Vlist, 2019).

The large corpus of developer pages and API reference documentation used in this study may guide and inspire further research into the history, evolution, and importance of APIs in relation to a platform's governance and infrastructural power. Specifically, I recommend further research on APIs and (the technicity of) platform governance to further explore the material conditions and evolutionary dynamics of powerful platforms like Facebook who occupy a unique position of power within the ecosystem. We encourage scholars to use similar approaches to study the evolution and material conditions of platform governance and how APIs tie into platforms' infrastructural power. For instance, comparative studies of APIs and their evolution may provide relevant insights into the distinctive governance arrangements they represent. Further research could investigate how the API mechanisms that I identified compare across different platforms and how they figure into broader theoretical discussions about infrastructural power.

We also need more comprehensive views of the application ecosystems that are connected to platforms' APIs (and thus impacted by their exercise of governance and infrastructural power). Chapters 4 and 5 both explore the complex dynamics between popular social media platforms, including Facebook and Instagram, and the external contributions of complementors. They appropriate the data or functionality of social media platforms to discover what social media can be employed or repurposed *for*, while the platform owners seek to maintain control—in part through complex governance configurations like the one described in this chapter.

Additionally, popular APIs are prone to cause large-scale 'ripple effects' and potential infrastructure breakdowns, which may extend throughout the entire ecosystem of apps and services and the various social and economic processes they support or sustain. Finally, it is worth noting that Web archives play a vital role in preserving the material traces necessary to reconstruct a platform's evolution or history, despite the laborious challenge of studying platforms and APIs that continuously change and evolve. ▲

II. Business ecosystems

3. Facebook's business partnerships

Evolving platform boundaries and ecosystem integrations

Part I of this dissertation has provided a foundational understanding of the material conditions and the role of application programming interfaces [APIs] in facilitating and governing different types of development. It also showed why digital platforms, such as Facebook, cannot be understood as a single monolithic entity. Instead, Facebook Platform evolved into a complex layered and interconnected governance configuration, whose components are changing and evolving continuously to enable and encourage (and disable) specific types of development. The two chapters in Part II both examine how this 'technicity' of platform governance relates to platforms' *business ecosystems* by investigating the relationship between (API-based) development and business partnership strategies. In both cases, this research focus surfaces social media's business integrations with the digital marketing and advertising industry, which is by far the largest and most significant industry for social media and the Internet generally. Therefore, the chapters in Part II [RQ2(a) and (b)] ask: *How are governance and power manifested in the developmental processes of:* (a) *Facebook's business ecosystem integrations since the launch of its Development Platform* [▸ Ch. 3]; and (b) *the business ecosystem integrations of contemporary social media platforms generally* [▸ Ch. 4]*?*

The current chapter thus also investigates the evolution of Facebook but focuses on different aspects of its development into one of the world's largest and most powerful businesses. As I argue, Facebook's integrations with the larger business ecosystem have been vital in this regard.

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3.1. Introduction to the case study

Digital advertising has become the dominant business model of the internet, including the Web and social media, mobile, and internet-enabled devices generally. However, it is a business model driven by the proliferation of digital technologies deployed to collect, process, and use massive amounts of data to monetise, predict, and influence or manipulate people's actions and behaviours, even without their knowledge or explicit consent (e.g., Nadler et al., 2018; Zuboff, 2019). There is also an immense amount of concentration and consolidation of market power in the marketing and advertising industry. In 2021, Google (27.5%) and Facebook (25.2%) alone—known as the online digital advertising 'duopoly'—accounted for over half of the entire digital advertising market worldwide, calculated by net digital advertising revenue share around the globe (eMarketer, 2021). Alibaba (9.5% of total digital ad spending), Tencent (7.1%), and especially Amazon (from 0.8% in 2016 to 7.1% projected share in 2023) are gaining some territory (Cramer-Flood, 2021). The dominance of Big Tech companies in the digital marketing and advertising industry—and their entrenchment in the 'ecosystem'—raises the need to better understand the technological development of powerful platforms alongside their exponential growth as some of the world's largest and most profitable businesses in history, serving a growing number of users, stakeholders, and partners around the globe.

This chapter is the outcome of an empirical study of the history and evolution of Facebook. Specifically, it traces the evolutionary trajectory of Facebook's technical and business integrations and its embedding in the larger business ecosystem around it. As such, this study builds upon the historical groundwork laid out in Chapter 2, which already established that Facebook Platform is inherently unstable—prone to constant change due to both internal and external pressures—at all levels of its platform architecture and governance. In this study, I detail how third-party app developers and business partners were vital to the 'infrastructuralisation' of Facebook Platform (cf. Plantin et al., 2018), including the formation of a 'core–periphery structure' (Rodón Mòdol and Eaton, 2021) that came to characterise the architecture of Facebook's platform's ecosystem. In short, this study traces the evolution—and the historical relationality—between Facebook's platform architecture, governance (particularly regarding external relationships, resources and documentation, and platform accessibility), and ecosystem integrations. It extends the analysis of Chapter 2 to better understand how governance and power manifest themselves in the construction of Facebook's business platform ecosystem, which has evolved 'on top' of the platform's business-facing APIs. Consequently, it also uses different methods and (archived) sources [▸ §3.3].

Similar to Chapter 2, this study contributes to the emerging literature on the evolution of digital platforms and infrastructures (e.g., Henfridsson and Bygstad, 2013; Rodón Mòdol and Eaton, 2021; Tilson et al., 2010; Tiwana et al., 2010), particularly the co-evolution of platform architecture, governance, and power (e.g., Kovacevic-Opacic and Marjanovic, 2020; Rietveld et al., 2020; Tiwana et al., 2010; [▸ Ch. 2]). The specific focus on the business platform ecosystem is a unique contribution to this literature. Additionally, it contributes to both journalistic and academic efforts to historicise and contextualise Facebook's exponential growth and its rapid rise to power (Brügger, 2015; Goggin, 2014; Kirkpatrick, 2010; Vaidhyanathan, 2018).

Digital platforms commonly use partnership strategies to connect and integrate their software-based systems with those of other companies and organisations, as well as to rapidly enter other markets, industries, and sectors of society. Business partners are typically treated differently from other types of third parties, such as software app developers, because of their strategic importance to the business of platforms. This study traces how this differential treatment evolved, which is important regarding the understanding of the configurations and dynamics of governance and power. In the case of large online digital platforms like Facebook, those partner companies and organisations are often leaders in specific markets and industries, complementing the platform in terms of technology capabilities, languages, countries or regions, and so on [▸ Ch. 4]. Despite Big Tech companies' many partnerships, as well as mergers and acquisitions [M&As], we know relatively little about the roles and significance of *business partnerships*, what they entail, how they serve mutual interests, or whether they veil asymmetric (or extractive) power relationships, for instance. Additionally, it is unclear how partnerships—and the efforts of the partner companies and organisations—tie into the process of 'platformisation' generally (Helmond, 2015a; Poell et al., 2019). This study explores how Facebook's partnership strategy ties into the platform's evolutionary trajectory (and fundamental transformation) from a social networking service or 'site' [SNS] in 2004 to one of the most powerful Big Tech companies and a platform leader—specifically, a 'duopolist'—in online digital marketing and advertising within a mere decade (i.e., by the mid-2010s). This fundamental transformation is characterised by *incremental modifications*, which thus underscores the value of evolutionary metaphorical language in writing the histories of platforms: that is, the value of platform evolution over 'platform revolution' discourse (e.g., Parker et al., 2016).

By focusing on the co-evolution of Facebook's platform architecture and business partnerships, we gain a unique perspective on the developmental dependencies and how the interdependencies between the core and periphery of Facebook's platform ecosystem—which lend Facebook significant 'infrastructural control'—evolved (cf. Rodón Mòdol and Eaton, 2021: 3). As such, they are particularly significant to understand how exactly Facebook became embedded—and 'generatively entrenched', as it came to act as the basis for other components (Rodón Mòdol and Eaton, 2021: 6)—in specific markets and industries in the first place, including in the digital marketing and advertising ecosystem. Moreover, Rodón Mòdol and Eaton observed that 'greater entrenchment yields greater stability' regarding a system's evolution (Rodón Mòdol and Eaton, 2021: 5). Specifically, Facebook's incremental reconfiguration as a 'platform' *for development*—more so than as a social network for end-consumers ('end-users')—enabled the company to 'become the core component of an ecosystem of artifacts and relationships dependent on its products and services' (Moschini and Sindoni, 2021: 3). This transformation thus captures the essence of Facebook's developmental or evolutionary trajectory: from a social network ('transaction platform'), to an 'innovation platform' that offers PBRs for its different user groups (Bonina et al., 2021: 26; Cusumano et al., 2019), to what Plantin et al. called a 'platform-as-infrastructure' that exhibits some characteristics of infrastructure (Plantin et al., 2018: 307). It also concerns the very form of Facebook, described by its platform architecture and 'partly built, shaped and influenced by' its different communities of app developers and businesses (Burgess, 2021: 24; cf. Bucher, 2021). Consequently, we witness the *boundary-work* that Facebook does by configuring its 'programmability' towards specific users and uses, which is reflected in the platform's architecture and how it changes and evolves (e.g., Mackenzie, 2019; [▸ Ch. 2]).

The empirical-historical approach involves two complementary lines of enquiry. In the first line of enquiry, I trace the evolution of Facebook's platform architecture—but on a different level than in Chapter 2. Specifically, I consider the configuration of Facebook's *programmability*—as an 'extensible codebase' (e.g., de Reuver et al., 2018: 126)—and how it changed and evolved to serve different groups of users, stakeholders, and business partners. In the second line of enquiry, I trace the evolution of Facebook's ('strategic', 'preferred', and other) business partner relationships, which describe Facebook's integration in the business ecosystem. Taken together, they offer insights into the co-evolution of Facebook's platform architecture and business ecosystem integrations—and how artefactual (technological) and contractual (organisational) dimensions of governance and power (e.g., Kenney et al., 2021) are interrelated.

In the next section, I first position the contribution in the literature on 'platform evolution' and Internet histories generally. Second, I detail the empirical-historical approach to tracing Facebook's platform boundaries and describe the methods of data collection and analysis.[50] As in Chapter 2, I use a set of 'platform boundary resources' [PBRs] to conduct the historical analysis. This includes archived Web

50 The data that support the findings of this study are openly available in the Open Science Framework [OSF] at https://doi.org/10.17605/osf.io/47zyc. Data collection was conducted until November 2018. Please note that any names of companies and organisations, particularly their parents, may have changed since then (e.g., due to M&As).

sources about Facebook's many different application programming interfaces [APIs], software development kits [SDKs], and associated reference documentation, as well as partner programmes, partner badges and certifications, and additional information about Facebook's business partnerships. Third, I present the two lines of enquiry. Fourth, I discern four stages in Facebook's longer-term evolutionary trajectory and present these in the form of a periodisation, beginning in 2006 with the launch of Facebook Platform (i.e., two years after Facebook was founded in 2004). Overall, the evolutionary perspective enables empirical-historical studies of digital platforms in ways that recognise their entanglements as part of larger technological and organisational environments. This includes the larger business ecosystems of social media platforms, which is the focus of Chapter 4.

3.2. [BACKGROUND AND POSITIONING] Platform evolution and Internet histories

Like websites that are subject to 'fluctuation' as they are editable and reproducible (Brügger and Finnemann, 2013), digital platforms change and adapt continuously. Typically, changes are not systematically documented by platform owners, nor do they offer comprehensive archives of historical materials, which poses challenges to writing digital platform histories and Internet histories generally [▸ Chs. 1: §1.4 and 2]. Consequently, a key challenge for platform historians is 'to find useful sources that enable them to understand the evolutionary processes in the first place' (Bruns and Weller, 2016: 186; Helmond and van der Vlist, 2019). In the field of Communication and Media Studies [C&MS], multiple approaches have been employed to write platform histories (Brügger, 2015; Burgess and Green, 2018; Elmer, 2017; Gerlitz and Helmond, 2013; Goggin, 2014; Hoffmann et al., 2018; van Dijck, 2013; Rogers, 2013a; Rogers, 2013b). These approaches typically focus on the evolution of single digital platforms and commonly employ secondary sources, such as industry blog posts and screenshots, to chronicle their history or evolution. However, as others have argued, digital platforms evolve via a complex interplay among users, technologies, infrastructures, organisational structures, and various social, cultural, and economic practices (e.g., van Dijck, 2013).

This study differs from existing historical Platform Studies in several ways [▸ Chs. 1: §1.4 and 2]. First, it moves from histories of single (specific) platforms to an ecosystem-level view of their histories, which considers the larger environments within which those digital platforms operate. Second, the historical analysis draws from a unique set of primary historical sources: archived PBRs made accessible in the Internet Archive (cf. Helmond et al., 2017; Helmond and van der Vlist, 2019; Nieborg and Helmond, 2019). Third, the approach mimics the foci and language in the adjacent fields of IS research and Organisation Studies. In these fields, 'platform evolution' is studied conjointly with the evolution of digital infrastructures and inter-organisational networks (Constantinides et al., 2018; Kovacevic-Opacic and Marjanovic, 2020; de Reuver et al., 2018; Tiwana et al., 2010). Like C&MS scholars, Organisation Studies scholars have adopted biological models and metaphors to conceptualise the dynamics of organisational structures (e.g., Mars and Bronstein, 2018). For instance, as digital platforms transform, their architectures, integrations with partners, governance frameworks, and environmental contexts co-evolve (e.g., Rietveld et al., 2020; Tiwana et al., 2010). Collectively, these dynamics determine digital platforms' 'evolutionary trajectories', particularly in terms of 'composability' (or modularity) and 'malleability', which are the two key shorter-term evolutionary dynamics in a platform's programmability (Tiwana et al., 2010). As I detail, these two features describe the incremental changes of a platform's programmability and the ability of third-party developers and business partners to extend—or build 'on top' of—existing platform data and functionality without compromising the platform's integration within the larger platform ecosystem. In short, they capture a platform's technical adaptation to changing or evolving user needs, technological innovation, market competition, and other 'environmental dynamics' (Tiwana et al., 2010) as they play out in the larger ecosystem of digital platforms.

Building upon the notion of evolutionary trajectories, the fourth way this study deviates from historical Platform Studies is the level of temporal granularity. In the empirical analysis, we can distinguish between longer-term and shorter-term evolutionary dynamics. Platform histories are more likely to study the former for practical reasons, offering broad-stroke histories based on key events or leadership decisions impacting a platform's overall design and governance, particularly insofar it relates to the end-consumer experience. These developments cover annual or multi-year periods. I complement such accounts by studying the shorter-term dynamics that take place on a monthly or quarterly basis [‣ §3.3]. This reveals the incremental modifications in platform architecture and PBR design that ultimately underpin or accumulate as the longer-term evolutionary dynamics (e.g., achieving corporate entrenchment, envelopment of competing platforms, derivative mutations such as dating or messaging platforms). As Alaimo et al. observed in a case study of TripAdvisor, the 'evolutionary patterns' underpinning social media reveal their evolution in cumulative, 'path-dependent' ways from social networking 'sites' focused on end-consumers and user-generated content to 'multi-sided' platforms that accommodate diverse user groups around their particular data and functionality (Alaimo et al., 2020). Taken together, these dynamic adaptations are critical for understanding the evolving programmability of platforms insofar as they facilitate diverse external user and stakeholder groups, including developers, advertisers, marketers, and publishers. Specifically, these trajectories reveal how platforms, through technical and partner-oriented PBRs, govern and control platform boundaries and openness to external contributions.

3.2.1. *Platform boundaries and integrations*

Platform evolution, I argue, is best observed through minor changes traced over longer periods of time, which in the fast-paced digital economy means years or even quarters, not decades. Therefore, in the historical approach, I suggest including a platform's archived app development PBRS to allow for a longitudinal investigation of changes in a platform's programmability. I build upon the work by C&MS scholars who examine the underlying mechanisms and logics that structure a platform's extensions into other markets, industries, and sectors of society. Examples of such extensions include 'plug-ins', 'social buttons', and other API-based connections that extend platform boundaries by integrating data and functionality into third-party websites, software, and apps (Gerlitz and Helmond, 2013; Helmond, 2015a).

PBRs, such as APIs, are important mechanisms to realise platform extensions as they provide 'a set of interfaces' that enables third-party websites, platforms, and apps 'to communicate, interact, and interoperate with the platform' (Tiwana, 2014: 6). Consequently, they allow third-party app developers, such as marketing agencies, to build 'on top' of a platform's core infrastructure, thereby extending its functionality. Relatedly, SDKs are important PBRs that facilitate and streamline the app development process by providing developers with a set of software tools, developer libraries, APIs, documentation, code samples, and guides.

PBRS are an important way for digital platforms to stimulate generativity while maintaining infrastructural control over their external relationships with third parties. On the one hand, digital platforms change continuously and evolve alongside competitors, partners, and external contributors who integrate data and functionality into their own software tools, products, and services. On the other hand, as Chapter 2 argued, there is an incentive for digital platforms to maintain stability and standardise their PBRS for third-party app development (Tiwana et al., 2010; [‣ Ch. 2: §2.4.1.2]). For instance, stability and standardisation ensure that apps built 'on top' of the platform continue to function reliably. The ability to define platform architecture and governance is indicative of what Bechmann, in following of Suzor's critique of interoperability, called an 'economy of data intraoperability' (Bechmann, 2013; cf. Sutor, 2011), in which digital platform owners strategically establish asymmetrical external relationships such as with their partners. Tracing the evolution of Facebook's PBRs helps us grasp not only how the platform's architecture changed and how its functionality became embedded in other markets, industries, and sectors of society, but also the evolution of organisational dependencies by third-party companies and organisations.

3.2.2. *Business partnerships and exponential growth*

Compared to more traditional companies in the information and communication industries, one of the defining economic and organisational properties of digital platforms is their programmability. That is, they operate 'multi-sided' markets by bringing together different 'sides', as explained in the previous chapters (Gawer, 2014; Tiwana, 2014; [‣ Chs. 1 and 2]). In the context of 'multi-sided' markets, users can be end-consumers and a wide variety of organisations, including but not limited to non-profits, governments, businesses, content developers, and advertisers. A platform's ability to thrive within an ecosystem hinges on its ability to aggregate users (i.e., market sides) and facilitate seamless interactions and transactions among them.

Most of the 'multi-sided' market research is rooted in the fields of Business and Management Studies and Economics, which theorise how companies can gain a competitive advantage by leveraging the externalities associated with networked markets (McIntyre and Srinivasan, 2017; de Reuver et al., 2018). Network externalities or 'effects' describe how users accrue (or lose) value by other users joining (or leaving) a platform [‣ Ch. 1]. From an economic perspective, platform businesses can grow exponentially if they can grow all sides in the market as this leads to Cross-side network effects. For example, the more end-consumers join a market, the more plentiful and valuable the transactions become for other sides in the market. From a strategic management perspective, a platform's 'competitive advantage' hinges on its ability to entice users to join a platform. Growing the pool of end-consumers is typically an issue of scale: the bigger the pool, the higher the demand. Conversely, growing organisational sides introduces supply-side economies of scope: heterogeneous organisations that partner with platforms not only offer products or services to end-consumers, but also are positioned as 'collaborative innovators' (Gawer, 2014: 1243). In this role, they can introduce a larger variety of platform services and extend a platform's core features. In the case of Facebook, this means that business partners, such as marketing and advertising companies, can contribute technology, data, or services that complement Facebook's own products and services.

The scholarship on business partnerships is closely related to questions about platform evolution and platform boundaries. Scholars studying 'multi-sided' markets emphasise the dynamic nature of platform design and how partners and technology are managed. They argue that platform owners are incentivised to facilitate organisational alignment and integration among the various sides of a platform. As I noted, platform owners can accommodate business partners by offering a standardised, stable, core technology (Tiwana, 2014). The fact that this is not always the case demonstrates that the process of forging and sustaining organisational relationships is fraught with tension, risk, and uncertainty. Because of the inherent power asymmetries in platform ecosystems and the unbridled growth driven by network effects, the emergence of 'platform capitalism' has drawn the attention of critical political economists (e.g., Bechmann, 2013; Crain, 2021; Srnicek, 2016; Zuboff, 2019). I align with these critical perspectives and concur that business partnerships are inevitably entwined with questions of power. Additional business partnerships solidify a platform's infrastructural position and is one step closer to a more dominant position not only in the platform ecosystem but also in broad and far-reaching markets, industries, and sectors of society.

3.3. [MATERIALS AND METHODS] Tracing platform boundary evolution and ecosystem integrations

To study Facebook's evolving programmability and platform boundaries, my co-authors and I developed an empirical-historical approach that uses archived Web sources to reconstruct platform history. As one of the most popular and prototypical social media platforms, the case of Facebook illustrates how processes of 'platformisation' and 'infrastructuralisation' became increasingly interrelated in the period between 2006–2018. Moreover, Facebook and Twitter, I argued, are particularly suited for historical platform research given the broad availability of archived Web sources related to their platforms 'for development' (Helmond and van der Vlist, 2019; [▸ Ch. 1]).

For the purpose of this study, as in Chapter 2, we only retrieved and used the archived Web sources from the Internet Archive, which is the largest publicly-accessible Web archive, containing over 344 billion 'snapshots' from archived Web pages since 1996. We also draw from Facebook's blog archives and trade publications [▸ Appendix C: Table C 3.1]. The data set starts in 2006 with the launch of the Facebook Development Platform and ends in November 2018. In the analysis, we partitioned the dataset into 14 intervals (avg. = 1.4 intervals per year) to compare different materials and moments. These intervals are based on prior exploratory research (Helmond et al., 2017) that offered insights into key moments when changes occurred in these sources (e.g., in developer, business, or partner materials). Additionally, to further contextualise the historical analysis based on the archived Web sources, we conducted semi-structured, 30–60-minute background interviews with a small number of Facebook's marketing partners from 2013 to 2016. We interviewed founders and business development executives of large partner organisations, such as App Annie, AppsFlyer, Fiksu, Grow Mobile, and TUNE, on-site or at industry events. We draw from these interview materials to contextualise the analysis by including partners' perception of the role and dynamics of Facebook's partnerships. Finally, we rely on information visualisations to present the historical reconstructions and the outcomes of the analysis. Figures 3.1 to 3.5 all use identical temporal axes and intervals to enable comparison of all parts of the empirical analysis.

The empirical analysis proceeds along two main lines of enquiry. First, we systematically retrieved archived snapshots of Facebook's developer materials to trace the evolution of Facebook's programmability and relationships with different kinds of developers. We then reconstructed changes in Facebook's PBRs, their retrospective versioning, and the conditions under which third-party app development and external relationships evolved. Second, we collected archived business and partner materials to trace the evolution of Facebook's relationships with partner organisations. Using archived snapshots of partner programme directories, which list all partnerships, we took stock of all partners' names and details. Partner programmes signal integrations with officially approved or certified partner organisations who provide services or implement platform data and functionality that augment Facebook's reach and scale.[51] We then characterised these partnerships by examining the official partner badges, which have a longer history online and typically function to mark 'authority, expertise, experience, and identity' (Halavais, 2012: 356–357). These badges are created by Facebook to describe the specialities of business partners. In the case of Facebook, these badges detail the particular capabilities and expertise by which partners complement the platform (FB-2018b). We employed these materials to trace the changing composition of Facebook's ecosystem of marketing partners who have been adjudicated on their 'demonstrable expertise' and capacity to develop apps that complement and extend Facebook's own tools, products, and services.

In short, these materials allow us to reconstruct Facebook's embedding within larger technological, economic, and organisational structures. They highlight Facebook's ability to leverage cross-side network effects to expand the scale, scope, and reach of its technical and business operations through business partnerships. Neither PBRs nor partner programmes are typically included in historical Platform Studies as conducted by C&MS scholars.

3.4. [ANALYSIS] The evolution of Facebook Platform

51 While business partnerships are generally based on contractual agreements between both parties, these contracts are not publicly available in the way that these other resources are. Consequently, the focus of this study is not to analyse specific partner relationships but to determine the role and dynamics of partnerships in Facebook's evolution more broadly.

In the first line of enquiry, we traced the evolution of Facebook's programmability and platform boundaries and visualised this over time [‣ Figure 3.1].[52] Launched in 2004 as a social networking 'site', Facebook became programmable when it started inviting third-party app developers to integrate with Facebook: first with the beta launch of 'Facebook Development Platform' (2006), followed by 'Facebook Platform' (2007) (FNo-2006; FNe-2007; [‣ Ch. 2]). To facilitate third-party app development, Facebook offered a set of PBRs, which exposed the platform's architecture and offered developers guidance on how to access platform data and functionality to build their own apps.

In these formative years, Facebook Platform primarily focused on having third-party app developers build 'social apps' inside Facebook's domain and 'on top' of its 'social graph', which represents 'the network of connections and relationships between people' in the Facebook API (FNe-2007). At the F8 Developer Conference in 2010, Facebook announced the first major iteration of their developer platform, dubbed 'v1.0', which featured a new 'Graph API', formerly known as the 'Facebook API.' Since then, the platform has employed API versioning and so-called versioning schedules to introduce regular updates and mark the deprecation of previous API versions (FD-2018e). The launches coincided with the introduction of several SDKs to help developers build mobile apps for Facebook, signalling its ambitions to expand into the emerging mobile ecosystem (FD-2010b).

52 Monochrome gradient bars are applied in these visualisations to demarcate the four stages of the proposed periodisation, which is presented after the analysis [‣ §3.6.1].

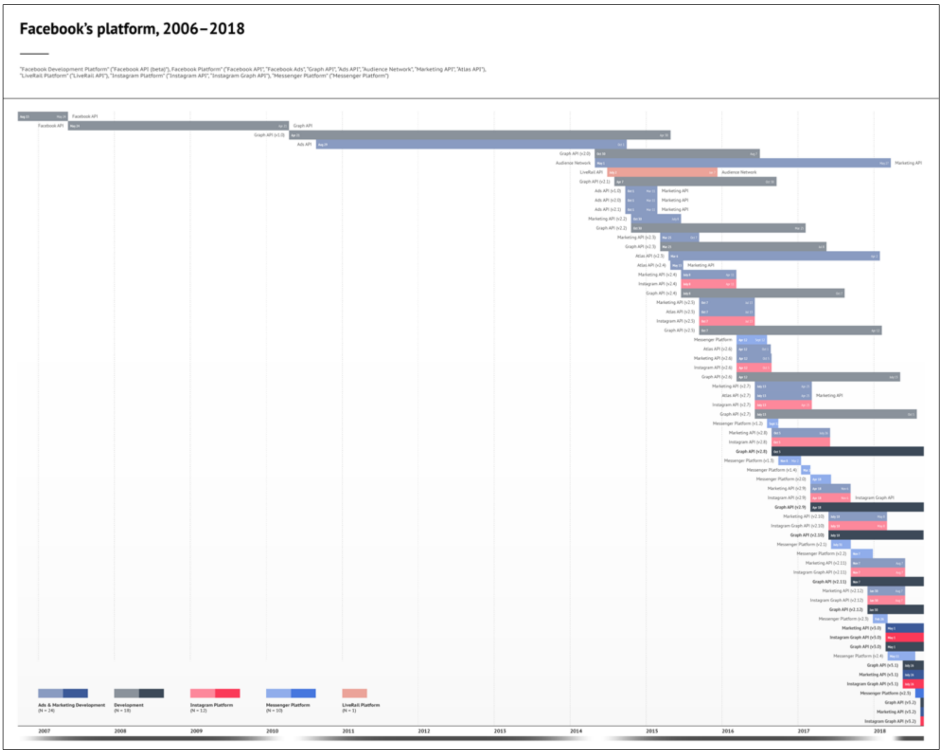

Figure 3.1. The evolution of Facebook Platform components, 2006–2018 [Gantt diagram]. Each horizontal bar represents a platform component version (e.g., Graph API (v1.0), Marketing API (v2.0)).

Bar length: by start and end date; groups and colour-coding: by platform type (e.g., 'Ads & Marketing Development', 'Development', etc.). Data: Internet Archive. High-resolution figures are openly available in OSF at https://doi.org/10.17605/osf.io/47zyc.

In mid-2010, the development platform was firmly in place, which paved the way for the platform's orientation towards businesses and advertising technology ('adtech'). The introduction of Facebook's 'Ads API' meant that developers could build their own business and technology 'on top' of Facebook's programmable platform (instead of app development for its own sake, or as a hobby). The Ads API was available to selected 'tools vendors' and marketing agencies to create and manage their 'ads on Facebook programmatically' (FD-2010a). It offered partners deeper levels of technology integration by enabling them to connect their own tools with Facebook's advertising products, allowing partners to automate and manage ads on Facebook. As such, the rollout of the Ads API demonstrates an important transition and expansion of Facebook's development platform by accommodating advertisers not only as customers, but also as a new group of development partners [‣ Ch. 4].

In 2013–2015, flush with momentum and capital from its initial public offering [IPO] in 2012, Facebook made several high-profile M&As to expand its user base and advertising development platform, including Instagram (2012, US$1 billion), Atlas Solutions (from Microsoft in 2013, US$100 million), WhatsApp (2014, US$19 billion), Oculus VR (2014, US$2 billion), and LiveRail (2014, US$400–500 million). These M&As are reflected by the increasing number of PBRs and the growing pace of API updates. In 2013 and 2014, Facebook acquired Atlas, a programmatic advertising platform, and LiveRail, a video advertising platform (FNe-2013; FNe-2014). Although both services were eventually discontinued, certain components of these platforms, such as the Atlas API, were integrated into Facebook's core advertising platform. Furthermore, Facebook expanded its focus on mobile advertising by launching 'Facebook Audience Network' (2014), which included a set of PBRs that enabled 'advertisers to extend the scale of their Facebook campaigns beyond Facebook and into other mobile apps' (FB-2014), allowing advertisers to find and target audiences beyond the platform's boundaries. These M&As and the subsequent integration of external PBRs indicate how Facebook followed larger developments in digital marketing as the company oriented itself towards programmatic advertising, video, and mobile advertising (Crain, 2019).

In 2015, Facebook officially rebranded the Ads API into the Marketing API [MAPI], which can be seen as an effort to further broaden the scope of Facebook's advertising ambitions by explicitly hailing it as a platform for marketing development. In this context, marketing refers to a larger set of corporate activities centred on promoting and selling services, and typically includes market research and advertising. Together with Facebook's Audience Network for mobile advertising, foregrounding the MAPI's development marked a key moment in Facebook's evolving programmability as it enabled the development and integration of marketing apps. Finally, in 2018, Facebook again redesigned and consolidated its technical PBRs for businesses and marketing developers by integrating PBRs of two of its most popular apps— Instagram and Messenger[53]—into its core technical platform [‣ Ch. 2].

53 It is worth noting that unlike Instagram or WhatsApp—in fact, unlike most of Facebook's popular apps, which were all outcomes of M&As—Messenger was originally developed by Facebook itself (e.g., Nieborg and Helmond, 2019).

3.5. [ANALYSIS] The evolution of Facebook's business partner relationships

In the second line of enquiry, we examined how Facebook followed a 'multi-sided' market strategy with partnerships to leverage network effects and use its improved position in the marketplace to increase market share even further (cf. Rochet and Tirole, 2003; Gawer and Cusumano, 2014). Specifically, we chronicle how Facebook accrued business partnerships through (1) partner programmes and (2) their certification mechanisms (i.e., specialities and badges). This analysis set us up for a third step: tracing the changing composition of Facebook's marketing partner ecosystem. While APIs and reference documentation are primarily aimed at developers, these programmes and certifications are aimed at businesses (including business developers) and partners who build the integrations that not only connect, but also *integrate* Facebook's evolving suite of tools, products, and services in other markets and industries—an important distinction that I further conceptualise in Chapter 4 [‣ Ch. 4: §4.5]. We reconstructed the evolution of Facebook's partner programmes since 2007 and observed a shift in orientation from partnering with developers, and then marketing and advertising developers to media and content partners more broadly [‣ Figure 3.2].

3.5.1. *Partner programmes*

One of the earliest partner programmes, fbFund (2007–2009), awarded grants to developers to build 'their businesses on Facebook Platform' with 'innovative and engaging' apps (FD-2007). Additionally, the 'Application Verification Program' and 'Great Apps Program' (2008–2009) were launched to create a 'robust' and 'thriving' app ecosystem, pushing partners to build 'meaningful', 'trustworthy', and 'well-designed' apps. In return, verified app developers (i.e., verified by Facebook, after applying for the partner programme) would obtain deeper platform integrations, early access to new features, and support from Facebook's growing partner management team (FD-2008). The subsequent 'Preferred Developer Consultant' ['PDC'] programme (2009–2012) was aimed at connecting businesses with development partners who were experienced in using Facebook products and technologies and had 'a long track record of providing Facebook-centric services to large Fortune 500 businesses' (FD-2009).

The next set of Facebook's programmes focused on building and expanding its marketing and advertising partnerships. The 'Ads API Tools Vendors' programme (2009–2011), later renamed the 'Marketing API Program' (2011–2012), listed third-party tools that were built by selected partners 'on top' of the Ads API. The programme aimed at connecting partners with access to the Ads API to major companies and agencies to create and manage large Facebook advertising campaigns via these third-party partner tools (FD-2009). Later, these programmes merged with the Preferred Developer Consultant programme into the 'Preferred Marketing Developer' ['PMD'] programme (2012–2015), which was intended to find developers with the ability to build comprehensive 'solutions to Facebook marketing and business operations' (FNO-2011; FD-2012a) and to create a 'community of best-in-class developers focused on making social marketing easier and more effective' (FPMDC-2013). The successive 'Facebook Marketing Partners' ['FMP'] programme (since 2015), and related marketing programmes such as the 'Instagram Partners' programme (since 2015) and 'Atlas Partners' programme (2015–2017), further emphasised the development of marketing technology.

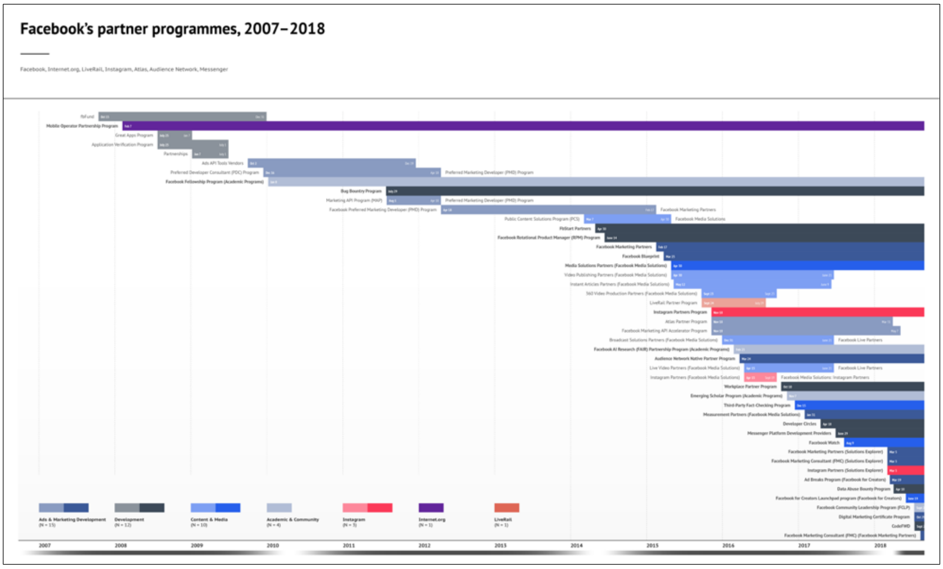

Figure 3.2. The evolution of Facebook's partner programmes, 2007–2018 [Gantt diagram]. Each horizontal bar represents a partner programme (e.g., 'Preferred Marketing Developer' ['PMD'] programme, 'Facebook Marketing Partners').

Bar length: by start and end date; groups and colour-coding: by platform type (e.g., 'Ads & Marketing Development', 'Content & Media', etc.). Data: Internet Archive. High-resolution figures are openly available in OSF at https://doi.org/10.17605/osf.io/47zyc.

The Facebook Marketing Partner programme promised businesses to help find partners who offer 'innovative technology' and 'custom-tailored solutions' to 'supercharge' their marketing efforts on and off Facebook (FMP-2015). The related 'Facebook Marketing API Accelerator Program' (2015) provided a 'path to serious API skills and support' to help marketing developers learn about the MAPI and Facebook marketing (FD-2015). Such accelerator programmes, including fbFund (2007–2009) and FbStart Partners (since 2014), provide developers with technical, educational, and financial support to stimulate and facilitate the development of Facebook-integrated business apps and marketing solutions, thereby contributing to the platform's expansion and embedding it further in the digital marketing ecosystem. The redesign of Facebook Marketing Partners' directory into 'Solutions Explorer' (2018) was accompanied by the introduction of the 'Facebook Marketing Consultants' ['FMC'] programme (FD-2018a). These consultants are not fully vetted partners but individuals who help smaller advertisers with their on-demand marketing and advertising needs that 'aren't always addressed by the traditional partner ecosystem' (FD-2018d). That is, these consultants and partners help make Facebook potentially more useful or valuable to a broader range of users, particularly unanticipated and custom uses that Facebook did not already offer [▸ Chs. 4 and 5].

The latest phase of Facebook's partner programmes shows an orientation towards media partners, including broadcasters, publishers, and content providers, with programmes such as 'Facebook Media Solutions' (since 2015) (Rein and Venturini, 2018). Additionally, there are general public-oriented partner programmes such as the 'Data Abuse Bounty Program' and 'Third-Party Fact-Checking Program', which emerged in response to recent critiques of Facebook concerning Cambridge Analytica and the spread of misinformation, together with a programme that foregrounds the company's renewed focus on community building with the 'Facebook Community Leadership Program' (since 2018). These public programmes signal another phase in the evolution of the platform and its relations and responsibilities to end-consumers and third-party stakeholders. The multiple types of partner programmes illustrate how Facebook interacts with various stakeholder groups and how the platform truly became a 'multi-sided' platform, connecting app developers, advertisers, marketers, content 'creators', media, and local communities.

3.5.2. *Marketing partners' specialities, badges, and certifications*

An important aspect of the marketing partner programmes' structure is the use of certifications. Here, we reconstructed how partners' specialities and official badges evolved to determine the role of partners in Facebook's expansion [▸ Figure 3.3]. Changes in specialities and badges indicate how and when Facebook shifted its orientation from platform-centric advertising services to business solutions that are familiar to a larger set of digital advertisers and marketers.

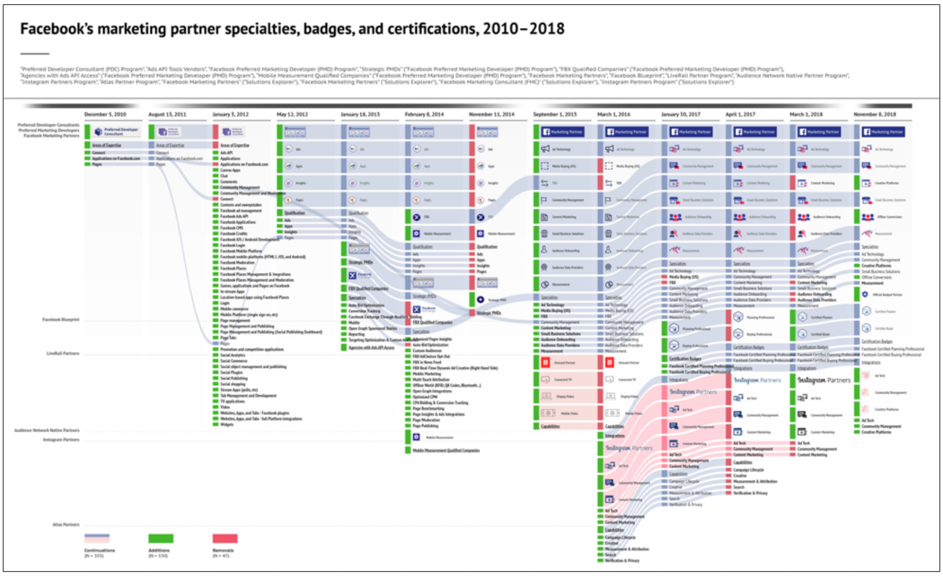

Figure 3.3. The evolution of Facebook's marketing partner specialities, official partner badges, and certifications, 2010–2018 [flow diagram]. Each vertical segment lists the available specialities, badges, and certifications at a specific moment in time.

Flows: continuations; segment size: scaled by life duration; colour-coding: by change type (i.e., continuations, additions, removals). Data: Internet Archive. High-resolution figures are openly available in OSF at https://doi.org/10.17605/osf.io/47zyc.

In 2010, Facebook offered a single Preferred Developer Consultant badge that partners could put on their websites to indicate a sanctioned relationship with the platform. Partners only had three 'Areas of Expertise' (i.e., 'Connect', 'Applications on Facebook.com', and 'Pages'), which were intended to build 'deeply integrated social experiences' within the confines of the platform or across its boundaries with 'Connect' (now 'Facebook Login'). In 2012, this list grew to an extensive list of unstructured, self-defined areas of expertise. Newly minted 'Preferred Marketing Developers' ['PMDs'] received a new badge displaying up to four main 'qualifications': 'Ads', 'Apps', 'Insights', and 'Pages.' In the words of Facebook, certified partners 'extend measurably beyond the functionality of Facebook's native tools' (FD-2012b). Later, the programme created a special badge for 'Strategic PMDs' for a select group of 'top marketing developers' who are 'driving outstanding results in the Facebook marketing developer ecosystem' and who, in return, receive the highest level of support (FS-2012).

In 2013–2014, several new 'qualifications' were added to the Preferred Marketing Developers programme for (1) 'FBX Qualified Companies', who successfully integrated with Facebook's programmatic advertising exchange, (2) 'Agencies with

Ads API Access', who qualified for API access but not for an official partner badge, and (3) 'Mobile Measurement Qualified Companies', who provided tools for mobile ad campaigns' performance measurements. These new specialities can be seen as part of Facebook's 'mobile career' (Goggin, 2014). One of the interviewees at a large mobile app tracking company states that 'being a Facebook Mobile Measurement partner helps us' and 'puts us on a good standing to work with a lot of advertisers' as they are one of a select few who are authorised to run and track campaigns on Facebook. Nevertheless, this partner also voiced concerns over how this authorisation can easily be retracted, stating that 'Facebook always holds a lot of power' over its partners (I-2015a). This type of power is further apparent in an interview with an early Mobile Measurement partner that measured app installs for Facebook, who was removed from the programme in 2014 for allegedly violating the platform's terms of services regarding data retention (I-2015b). According to the partner, Facebook 'built enough value around their product that people need it and because of that they set their own rules'. This partner concluded that platforms such as Facebook 'want to control the entire environment for app developers' (I-2015b). Thus, while partnerships are generally considered mutually beneficial, they are also inherently asymmetric.

In 2015, the Facebook Marketing Partners programme introduced a single 'Marketing Partner' badge to represent multiple 'Specialties', which no longer referred directly to platform-centric business products but instead employed common professional marketing terminology (e.g., 'Ad Technology', 'Content Marketing', 'Media Buying (US Only)', etc.). This updated terminology indicates how Facebook seeks to integrate the distinct tools, products, and services of its platforms into a single, unified marketing platform accessible to partners, using general marketing terminology. Moreover, Facebook dropped more than 15 partners related to its 'FBX' (Facebook Exchange) speciality. As one observer notes, downsizing the 'FBX' partner community was consistent with Facebook's longer-term focus on evolving its own real-time (programmatic) bidding capabilities through its own APIs and Custom Audiences, which lets advertisers find and target their own existing customers lists and audience segments across Facebook's advertising network (FB-2018a; Rodgers, 2015; cf. García Martínez, 2016). In this period, specialities such as 'Audience Onboarding' and 'Audience Data Providers' arose to enable marketers to find existing customers on Facebook using a marketer's own data and to create new audience profiles on Facebook with the help of third-party data partners. With the growth of its mobile app products, Instagram's marketing partner 'specialties' were aligned with Facebook's, by employing the same specialities and badges. Notably, in early 2018, as a response to the Facebook–Cambridge Analytica data scandal, the 'Audience Data Providers' speciality was removed.

Finally, official partner badges also signal certifications in knowledge and learning (cf. Halavais, 2012: 369), such as Facebook Blueprint's 'Certification Badges' (since 2015). Blueprint is an 'education program that trains agencies, partners and marketers on how to use Facebook' to create 'better campaigns' through online courses and exams (FB-2015). However, it is not merely a training programme because some Marketing Partner specialities require the completion of Blueprint courses (FB-2018c). Establishing such certification badges and programmes allows Facebook to both grow more rapidly with the help of strategic business partners, while also maintaining control over the *quality* of the tools, products, and services that are being built 'on top' of Facebook Platform—one of the key aspects of platform governance (e.g., Schreieck et al., 2018).

3.5.3. *Marketing partner ecosystem*

In addition to examining partner programmes and certification mechanisms, we also traced changes in the composition of Facebook's marketing partner ecosystem. The composition of this marketing partner ecosystem reveals much about Facebook's position in the marketplace, its dependence on external assets or specialities, and the larger evolutionary trajectory of the industries around Facebook, which are also its supply networks and revenue sources. We used archived partner materials to reconstruct the evolution and dynamics of partnerships in the partner ecosystem [‣ Figure 3.4(a) and (b)]. In total, we identified 3,129 partners over the period 2009–2018 (1,033 unique partners).[54] The number of partners increased most between 2009–2013, with the largest number of additions and removals between 2012–2013. Increases in partnerships correspond with major changes to the development platform and newly launched partner programmes, suggesting that they are used to attract developers, businesses, content producers, and publishers to adopt newly launched platform tools and products. Between 2014–2018, the total number of partners remained more constant, although in 2018 there are many new partners with the introduction of the Facebook Marketing Consultants programme as part of the Facebook Marketing Partners programme.

54 We found many instances of M&As, which are relatively common in these emerging sectors, including, or perhaps especially, in the selected time period. For all M&As, we used the name of the most recent parent company or organisations. For instance, the British Dentsu Aegis Network has done numerous M&As of previously independent partners, including Grip Limited, Gravity Media, and the M8 marketing agency. And data connectivity platform LiveRamp was acquired by the data marketing company Acxiom Corporation in 2014 for US$310 million, before Acxiom itself was acquired by the Interpublic Group [IPG] in 2018 for US$2.3 billion (Kaye, 2014; IPG, 2018). Grouping these M&As under their most recent parent company or organisation allows presenting the longer-term continuities we find across these partnerships, and which would otherwise remain hidden/invisible.

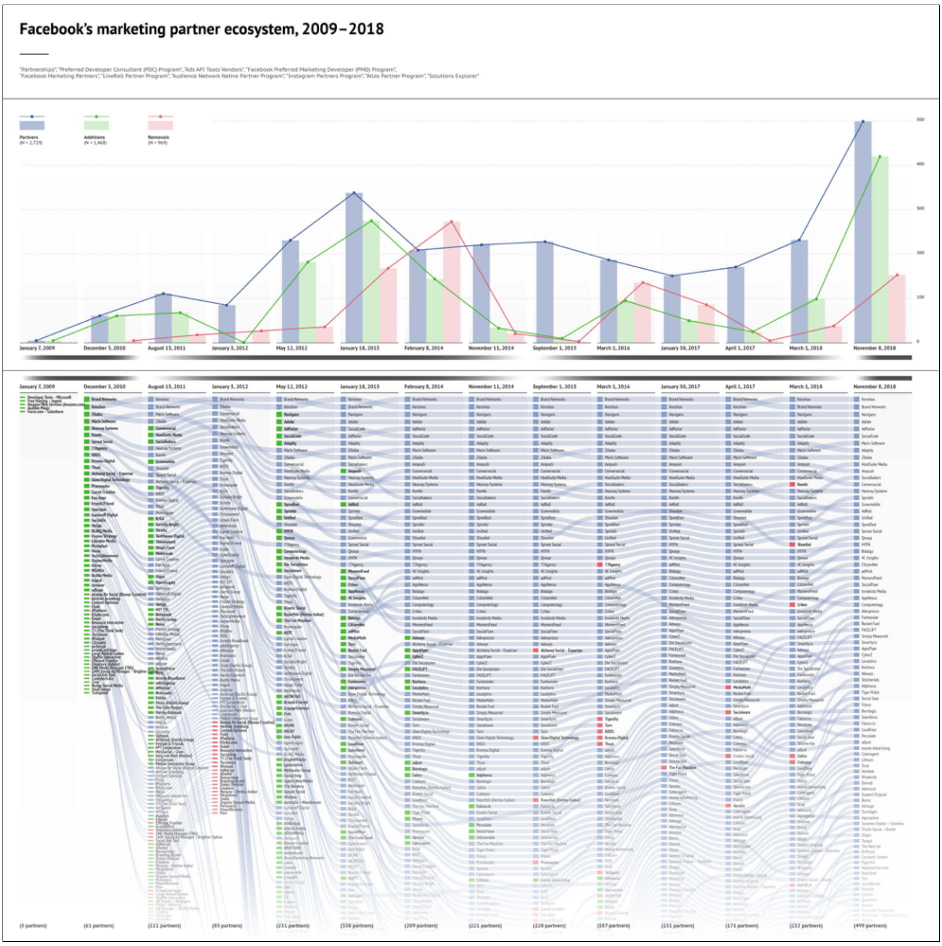

Figure 3.4(**a**) **and** (**b**). The evolution of Facebook's marketing partner ecosystem, 2009–2018 [combined bar chart and flow diagram]. Each vertical segment lists the enrolled partners at a specific moment in time. Please note that the overflow partnerships (at the bottom of the diagram) are hidden in this version of the diagram due to the lengths of the entire lists.

Flows: continuations; ranking and segment size: scaled by life duration; colour-coding: by change type (i.e., continuations, additions, removals). Data: Internet Archive. High-resolution figures are openly available in OSF at https://doi.org/10.17605/osf.io/47zyc.

While there are dozens of partnership additions and removals at every interval, as many as 42 of the partners appear more than 10 times across the 14 intervals (avg. length = 7.1 years). These longer-term partners are large digital marketing and advertising technology companies, such as Brand Networks, Kenshoo, Nanigans, Adobe, SocialCode, AdParlor, Adaptly, Marin Software, and Salesforce, all of which have integrated their own digital platforms—or specific tools, products, and services—with Facebook Platform by means of its APIs. These kinds of partnerships indicate how Facebook is entangled on a technical and organisational level with the global network of (mostly market-leading) marketing and advertising technology companies. One of the mobile advertising companies we interviewed has been a longer-term partner since 2011 and is technically integrated with over 130 distinct advertising networks and major traffic sources such as Facebook. It describes itself as helping advertisers to 'navigate through a really messy ecosystem' of interconnected platforms, each of which performs a specific task. For smaller companies such as these, of which there are many, a partnership with Facebook is not only strategic but also deemed essential (I-2016).

By tracing the changing composition of Facebook's partner ecosystem and describing partners' categories, we gained insights into Facebook's embedding in digital marketing and advertising technologies, other markets, industries, and countries. I matched the entire list of partners to the annual marketing technology dataset released on chiefmartec.com, a reputable market research blog since 2011 (Brinker, 2018).[55] This resource allowed identifying the specialities (categories) of the partners that we identified. Specifically, the 2018 dataset lists 6,829 distinct marketing technology solutions and their categories, which we employed to characterise Facebook's partnerships and understand their embedding in the marketing technology industry landscape [▸ Figure 3.5(a) and (b)].

55 Scott Brinker is renowned for his annual release of the Marketing Technology Landscape Supergraphic, which he updates and publishes annually on his blog (Chief Marketing Technologist). Each year, he summarises statistical trends in the evolving digital marketing industry based on his comprehensive directory of digital marketing companies and organisations and discusses the dynamics between 'new venture creation' and consolidation of companies. Despite the many M&As, the total number of companies (across all categories) included in the supergraphic evolved from roughly 150 companies in 2011 to more than 8,000 companies in 2020 and still continues to grow (Brinker, 2020).

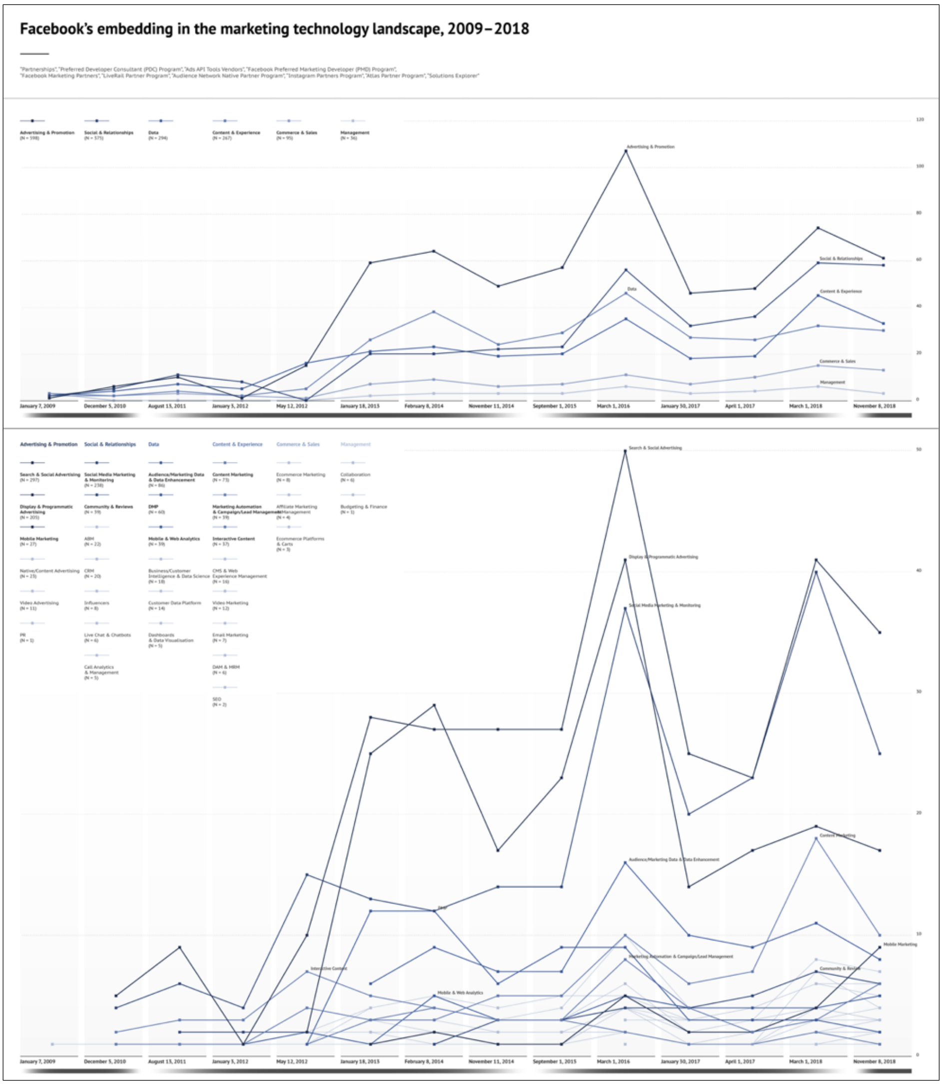

Figure 3.5(**a**) **and** (**b**). The evolution of Facebook's partnerships and its embedding in the digital marketing and advertising technology landscape, 2009–2018 [multiple line chart]. Each line represents the number of partners in a category or subcategory at a specific moment in time.

Colour-coding: by category (e.g., 'Advertising & Promotion', 'Data', etc.) and subcategory (e.g., 'Search & Social Advertising', 'Mobile Marketing', 'DMP', etc.). Categories: 2018 Marketing Technology Landscape Supergraphic (Brinker, 2018). Data: Internet Archive. High-resolution figures are openly available in OSF at https://doi.org/10.17605/osf.io/47zyc.

Partners were mostly specialised in the categories of 'Advertising & Promotion' (598), 'Social and Relationships' (375), 'Data' (294), and 'Content & Experience'

(267), while 'Commerce & Sales' (95) and 'Management' (36) did not have a significant presence. Notably, 'Advertising & Promotion' and 'Data' rose in prominence between 2012–2014, reflecting Facebook's orientation towards advertising technology and its growing prominence as a data platform within the industry. 'Content & Experience' has been steadily growing since 2009, pointing to Facebook's key role in the platformisation of cultural production (cf. Nieborg and Poell, 2018). And until 2016, it seems that Facebook prioritised partnerships in the areas of 'Advertising and Promotion', 'Social and Relationships', and 'Data' particularly. In this regard, the types of partnerships we find can be analysed in terms of the strategic and infrastructural ambitions of digital platforms going forward, such as how they attempt to enter and 'disrupt' other markets, industries, and sectors of society with the help of their business partners. We can observe that these partnership dynamics are subject to industry-wide trends: we see the rise of mobile marketing, influencer marketing, (live) video, live chat and chatbots, and other AI-driven apps.

On a sub-category level, we observed the rise of 'Search & Social Advertising' (297) and 'Display & Programmatic Advertising' (205), especially between 2012–2016. Display and programmatic partnerships declined since 2016 due to the shutdown of Facebook Exchange (2015), its advertising exchange platform. The growth of mobile-oriented partnerships (e.g., 'Mobile & Web Analytics' and 'Mobile Marketing') reflects Facebook's mobile orientation since the mid-2010s (Goggin, 2014), as well as a larger industry-level shift towards 'mobile-first'. First in 2012, then in 2015, there was an increase in partners engaging in 'Social Media Marketing & Monitoring' (238), reflecting the popularity of tools for online brand presence and community management on Facebook. Also, since 2012, Facebook has accrued many data-oriented partnerships in 'Audience/Marketing Data & Data Enhancement' (86) and 'DMP' (60)—or Data Management Platforms, which combine the collection, organisation, analysis, and activation of data for targeting and analytics purposes [▸ Ch. 4]. We further found a long tail of more widely-oriented partnerships across all categories.

3.6. [DISCUSSION] Facebook's evolutionary trajectory

3.6.1. *Four stages of platform evolution*

Surveying Facebook's decade-long deployment of PBRs provides the basis for a periodisation of its evolution. I discern four stages that together characterise key moments in Facebook's programmability and expansion of its boundaries. In the periodisation, particular development efforts introduced in earlier stages are built upon, extended, and integrated, or alternatively, discontinued and deprecated in subsequent stages. The purpose is not to discretise the historical developments as clear-cut periods but rather to characterise some longer-term developments in Facebook's evolution and thereby offer analytical handles for understanding the historical precedents of its transformation into a 'platform-as-infrastructure' (Plantin et al., 2018: 307).

Stage one in Facebook's evolution (2006–2010) concerns the expansion of its social network with the launch of the Facebook Development Platform. Facebook started attracting third-party app developers by offering PBRs and financial and technical support to accelerate 'good' app development (e.g., fbFund and Great Apps Program), thereby embedding itself into the developer community. The Preferred Developer Consultant programme helped brands and businesses to grow a Facebook presence, build apps, and accommodate the enrolment of high-profile partner organisations. Additionally, the Ads API and tools vendors programme were key initiatives to explore and extend the programmability of Facebook's platform towards a new stakeholder group of advertising developers. Despite being only available to a select few, these PBRs mark the early onset of Facebook's advertising development platform.

Stage two (2010–2014) surrounds Facebook's IPO in May 2012. Already, we can observe Facebook's infrastructural ambitions based on the maturation of its advertising development platform alongside its development platform for third-party app developers. In both cases, Facebook's embedding was achieved through the development of apps and integrations. During this period, the Ads API morphed into the MAPI, which signalled an ambition to grow the business side of the platform beyond advertising to include other marketing products and services such as programmatic advertising, analytics, and insights. The accompanying partner programme enrolled partners capable of implementing Facebook's marketing products into their own software platforms, thereby further expanding Facebook's platform boundaries, its capabilities, and the reach of its technical and business operations. Through engaging in business partnerships with large companies, Facebook legitimised itself not only as a viable advertising platform but also as a one-stop-shop marketing platform. This is also reflected in the merging of several partner programmes into a single Preferred Marketing Developer programme to accommodate and attract new marketing developers. Facebook's partners became vital in this effort by slotting themselves into Facebook-specific specialities conceived around its core platform-centric business products at the time (i.e., Ads, Apps, Pages, Insights). Furthermore, by adopting official partner badges, these partnerships legitimised Facebook's prominent position as a core player in digital marketing and advertising.

Stage three (2014–2018) revolves around the solidification and continued professionalisation of Facebook's marketing development platform and its integrations in other global markets and industries. Facebook's two main development platforms adopted a 'core and extended versioning model' with regular API releases and scheduled deprecation dates (FD-2018e). These communicative standards enable the growing developer and marketing developer communities to anticipate the maintenance work required to ensure their apps and integrations, upon which their businesses increasingly depend, will continue to work. Additionally, Facebook's M&As played an important role in the platform's different pivots—that is, somewhat unexpected changes in the platform's evolutionary trajectory—towards mobile (e.g., Instagram and WhatsApp in 2012–2014), (live) video and virtual reality (e.g., Oculus VR and LiveRail in 2014), and online advertising and analytics (e.g., Atlas and Onavo in 2013). Moreover, their acquired development platforms and PBRs were gradually streamlined into the Marketing API and Facebook Marketing Partners programme. The MAPI Accelerator Program provided developers with additional PBRs to work with Facebook's APIs to facilitate the platform's integration in other markets and industries, which enabled its technical and business operations to reach even further. Furthermore, Blueprint was launched to offer marketers and agencies training and certifications for Facebook's marketing tools and products. This coincided with another round of partner programmes by which Facebook addressed new stakeholder groups in media and publishing, content production, and local developer and business communities. As media and content partners gained visibility, Facebook further grew from a user-generated content 'site' into a 'platform' for professional content 'creators' and media publishers (Burgess, 2021).

Stage four (since 2018) marks Facebook's current efforts to address criticism about its market dominance and shortcomings with new programmes to combat data abuse and misinformation by offering new programmes and governance mechanisms for Facebook's PBRs (FD-2018b). This is accompanied by a major redesign and reconfiguration of Facebook's developer pages, business pages, and partner pages as part of Facebook's larger effort to 'reexamine our platform' for building end-consumer and developer trust (FD-2018c). These changes occurred with the v3.0 release of Facebook's platform APIs, which fully incorporates all Facebook products, including the Instagram Graph API. This is also reflected in the new unified Solutions Explorer with marketing partner programmes that cover Facebook's 'family of apps'—Facebook, Instagram, WhatsApp, and Messenger—and services. Finally, the new Facebook Marketing Consultants programme introduces individual consultants who can establish Facebook marketing technologies for smaller advertisers and businesses not addressed by the business partner ecosystem. Taken together, these stages thus reflect Faebook's ongoing transformation from a social networking 'site', into a platform (first 'for development, then 'for business'), into a platform-as-infrastructure that runs beneath the tools, products, and services of a growing group of users, stakeholders, and partners who build their business 'on top' of Facebook.

3.6.2. *Longer-term evolutionary dynamics*

These four consecutive and somewhat overlapping periods summarise Facebook's longer-term evolutionary trajectory as shaped by the complex interplay between its platform architecture and the dynamics of its technical and organisational environment. While stages one and two are characterised by a somewhat experimental attitude towards Facebook's programmability, especially towards third-party app developers and businesses, stages three and four are defined by the platform's ambitious infrastructural ventures; it is no coincidence that this incremental strategy towards infrastructuralization backfired as it attracted growing criticism from end-consumers, as well as authorities and regulators. For instance, between 2006–2010, Facebook focused on the development of 'in-Facebook' apps and widgets. To this end, it provided app development PBRs and developed (technical) standards and programming languages such as the 'Facebook Markup Language' ['FBML'] and the 'Facebook Query Language' ['FQL'], which were derived from open Web development standards. In this case, they were derived from HTML [Hypertext Markup Language] and SQL [Structured Query Language], a query language for managing data held in relational database management systems (e.g., van der Vlist, 2016).

By now, these standards and programming languages are streamlined and replaced with a suite of open (public) and semi-open (partner-oriented) APIs to enable more structured and programmatic forms of communication, interaction, and exchange between systems. As a *programmatic-oriented* platform, Facebook provides the tools, products, and services to facilitate large companies and organisations to run data-driven programmatic advertising campaigns at a (very) large scale, beyond Facebook's own properties—that is, across the Web, across many different 'media channels' and devices, and across countries or regions worldwide—typically on behalf of their networks of clients and customers. As such, Facebook provides the 'back-end' functionality, connectivity, and infrastructure required for such digital marketing and advertising campaigns—and they do so with the help of their business and marketing partners. Additionally, because infrastructuralisation requires standardisation, it is significant to note Facebook's continuous efforts to design, implement, and control the standards for others to use and exchange data or services.

We contend that tracing the evolution of Facebook's programmability and business partnerships is key to understanding these dynamics and the gradual accumulation of influence and power through the processes of platformisation and infrastructuralisation. On the one hand, the composability and malleability of Facebook's platform architecture enable partners to deploy Facebook's data and functionality with relative ease while simultaneously enabling Facebook to govern and control the conditions under which these can be reconfigured (cf. Tiwana et al., 2010). On the other hand, Facebook's business partnerships, particularly with market-leading, global companies, facilitate its rapid entry into new markets, thereby generating and solidifying asymmetrical platform growth and dependencies—including through processes of platform 'envelopment' or 'capture' (Eisenmann et al., 2011; Partin, 2020). Although such developments are often conceived in terms of innovation and disruption, they are in many ways better characterised as ongoing boundary-work with incremental, shorter-term effects that may (or may not) result in longer-term transformations.

With the empirical-historical approach, we can thus observe some of the smaller and larger evolutionary patterns that underpin today's social media platform and data services ecosystem. Similar to what Alaimo et al. found in the case of TripAdvisor (Alaimo et al., 2020), we find that Facebook evolved in cumulative, sometimes 'path-dependent' ways into a diversified, 'multi-sided' platform that accommodates increasingly diverse user groups around its data and functionality. Subsequent developments, whether concerning the platform's architecture, strategy, or ecosystem 'fit', seem to depend, at least in part, on prior technological or infrastructural investments, because these prior efforts represent a cumulative strategic advantage acquired by Facebook. That is, the integration of Facebook's platform with a wide range of external data sources and additional media channels, through development work on the technical level but also through business partnerships on the organisational level, provides an important competitive edge going forward. For instance, Facebook's ability to achieve greater computational efficiency, targeting effectiveness, and audience reach and scale for programmatic digital advertising campaigns. Additionally, by forging business partnerships, Facebook and other digital platform owners may leverage network effects on all 'sides' of the platform (end-consumers, businesses, content creators, investors) and use their improved position in the marketplace to increase market share even further (Gawer and Cusumano, 2014). Consequently, and as Gawer and others considered as well, digital platforms may benefit from economies of scale and economies of scope (Eisenmann et al., 2011; Gawer, 2014; Partin, 2020). In this regard, the integration of user-generated content, data-based services, and media channels is at the core of Facebook's position of power and a key driver behind the rapid growth of the larger ecosystem of social media [‣ Ch. 4].

3.7. Concluding remarks

This chapter asked [RQ2(a)] how governance and power are manifested in the developmental processes of Facebook's business ecosystem integrations since the launch of its Development Platform.

To address this question, it developed an empirical-evolutionary perspective on Facebook's integration with the larger business ecosystem, through its myriad partner programmes, which explains Facebook's development into a 'platform-as-infrastructure' for this larger ecosystem. I examined how Facebook, as an emblematic digital platform, evolved as a programmable architecture and, via integrations with business partners, as a business. By drawing from a unique set of primary historical sources, I offered an empirical-historical approach to chronicle these evolutionary trajectories. Facebook's archived PBRs enabled tracing the platform's shifting boundaries and the boundary-work that underpin its exponential growth and embedding in other markets and industries, especially marketing and advertising. Specifically, I traced the evolution of Facebook's platform boundaries through two complementary lines of enquiry. On the one hand, I reconstructed the evolution of its programmability as facilitated and governed by APIs, SDKs, and related PBRs [‣ Ch. 2]. On the other hand, I reconstructed the evolution of Facebook's business and marketing partnerships, which were especially important in developing the apps and integrations that connected and integrated Facebook with other markets and industries, especially related to digital marketing and advertising, thereby extending the platform's market power. Although many of Facebook's partnerships are publicly listed, previous revelations suggest that there are also non-public partnerships with organisations that have been 'whitelisted' for special API access—though it is unclear how Facebook decided which companies should be whitelisted or not (Collins, 2018; cf. Dance, Confessore, et al., 2018; Dance, LaForgia, et al., 2018). Further research could determine the implications of these non-public partnerships, such as by using additional secondary sources.

The study finds that Facebook and other social networks were not considered infrastructural at launch but rather gained infrastructural features over time by accumulating external dependencies through technical and organisational integrations of Facebook's increasingly complex, layered, and 'multi-sided' platform. First, in terms of evolving platform boundaries, Facebook has been steadily growing by accommodating various strategic stakeholder groups through its architectural design and programmability. Specifically, its programmability has facilitated multiple developer communities to embed Facebook's platform and operations in various other markets and industries, including software development, online digital marketing and advertising, data marketplaces, content production, and media publishing. Thus, I traced how the platform evolved from a social networking 'site' in its early days into a 'multi-sided', diversified platform for 'social' app development and programmatic-based digital marketing and advertising development—enabled by Facebook's infrastructure. This larger change occurred through internal boundary-work concerning the programmability of its multiple platform properties but also through collective boundary-work with a wide range of partner companies and organisations, mediated through domain-specific developer communities. In many regards, the role of these partners is to extend the reach and scale of Facebook's platform, such as by integrating distribution networks, data sources, or aggregating digital advertising inventory (commonly called 'demand'). Partners provide a wide range of specialised tools, products, and services built 'on top' of—or integrated with—Facebook's platform for different purposes, including advertising and promotion, social and relationship management, data, content creation, and commerce and sales. As such, business partnerships enable and accelerate Facebook's rapid growth from a technological and an economic perspective. As one journalist succinctly put it when TikTok (owned by ByteDance) launched a marketing partner programme in September 2020, following in the footsteps of 'its larger platform siblings', digital platforms introduce partner programmes to 'make it easier to spend' on their platforms (Schiff, 2020). That spending occurs by small local businesses but also, or especially, via large intermediary industry platform businesses integrated with Facebook, who may not be as widely known as Facebook itself but who are considered market leaders in their respective industries (e.g., Interpublic, Omnicom, Publicis, WPP, etc.). Chapter 4 focuses specifically on these partner companies and organisations and their connections to one another on the level of the entire social media platform ecosystem.

Second, as regards its evolving embedding, I discussed how Facebook has accumulated external dependencies by routing additional technical and business operations and stakeholder interactions through its platform. As an organisation, Facebook moved from a standalone technology company to a publicly-traded holding company with stakeholders and shareholders. Today, it operates a unified data infrastructure that gives way to a number of 'platform instances', such as Messenger and Instagram, each of which contributes to the platform's boundary-work (Nieborg and Helmond, 2019). Lastly, Facebook developed from a small online advertising business into a (market-leading) data-driven and programmatic digital marketing and advertising platform, as well as a content monetisation platform for creators and publishers (Nieborg and Poell, 2018). Partnerships and M&As seem to have served different strategic functions in this evolutionary trajectory of Facebook, with partnerships serving primarily to embed the platform in other markets, industries, and sectors of society, and with M&As serving to expand the company's core capabilities and strengths (e.g., around digital marketing and advertising across media channels and apps), address its weaknesses (e.g., around mobile in the early 2010s), and neutralise threats of competition in the same market (e.g., with Instagram and WhatsApp).

The interplay between the processes of platformisation and infrastructuralisation foregrounds different aspects of Facebook's economic growth and technological expansion. While platformisation speaks to Facebook's growing capabilities to mediate the interactions between multiple user and stakeholder groups and their diverging needs and interests, infrastructuralisation speaks to Facebook's growing ubiquity by embedding itself in other markets and industries to render technical and business operations more widely and immediately available. Indeed, infrastructure is not simply an analytical concept; *becoming infrastructural* is an effective platform strategy to 'survive in the long run' (de Reuver et al., 2018). Thus, digital platforms' power is as much economic, operationalised by access to finance capital (Elmer, 2017), as it is relational and strategic through Facebook's ability to mandate organisational alignment among its many different users, stakeholders, and partners (as further explored in Chapter 4). Therefore, both processes highlight different aspects of the boundary-work that Facebook and its partners perform, as well as the political-economic stakes and consequences of such work. This collective boundary-work embeds the platform in other markets, industries, and sectors of society, and removes barriers to entry, while at the same time avoids sectoral liability and responsibility (van Dijck et al., 2018). Specifically, I contribute a way to analyse how digital platforms' power is constituted through incremental and longer-term changes in a platform's architecture design, its platform's strategy and business side, and the larger environmental dynamics it is subjected to. Furthermore, since most large social media platforms have followed similar development trajectories—they also operate partner programmes, development platforms, and marketing and advertising platforms whose materials have been archived—there are ample opportunities for comparative historical platform research.

Finally, there is a critical need for additional historical digital platform and infrastructure research to denaturalise the present market dominance and reveal the contingencies of digital platforms such as Facebook. Because power and influence are relational concepts, critical platform histories should consider the platform not only as an ensemble of technical elements, but also as the relational intersection of multiple stakeholders that are embedded in multiple domains and countries or regions. Although social media platforms, at first glance, pose challenges for Internet historiography—the writing of Internet histories—due to their constant updates, archived (primary) Web sources afford new kinds of detailed, empirical histories. These materials can be used to trace the shorter-term, minor, and incremental changes that platforms undergo, thereby countering popular myths of ensuing radical innovation and platform revolution. ▾

4. Social media business partnerships and integrations

How partners mediate and shape platform power

THE PREVIOUS CHAPTERS WERE BOTH historical case studies of Facebook Platform, though each focused on different aspects: the first chapter traced Facebook's evolution as a 'platform' for different types of development; the second chapter linked this to the evolution of its business integrations with the larger digital marketing and advertising industry. However, the significance of these business partnerships and integrations extends beyond Facebook alone. Therefore, this second chapter in Part II [RQ2(b)] asks: *How are governance and power manifested in the developmental processes of the business ecosystem integrations of contemporary social media platforms generally?*

Building upon the empirical insights from the previous case study, the current chapter thus investigates the significance of business partnerships and integrations in the larger social media ecosystem, including but not limited to Facebook. As in my previous chapter, I especially consider the relationship between technological development and business partnership strategies. As I have argued, and will explain once more in this chapter, these technological and organisational dimensions of platform governance cannot be considered separate from one another. To the contrary, the technological and organisational dimensions are inextricably linked in the configurations and dynamics of platforms' governance and power.

4.1. Introduction to the case study

In 2020, Facebook (now Meta) and Twitter generated US$84.2 billion and US$3.2 billion in advertising revenue, respectively, representing 97.9% and 86.3% of their total revenue (Facebook Investor Relations, 2021; Twitter Investor Relations, 2021). As digital advertising has become the primary income source for social media platforms, their earnings rely on the development of both their end-consumer ('end-

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user') and business 'sides'. Digital advertising has developed into a highly complex and interconnected global ecosystem that involves most large digital platforms, including a wide range of technologies and practices driven by automated systems and applications of data and analytics. The larger contemporary global digital advertising market comprises thousands of interconnected platforms and is projected to be worth US$333 billion, in which 'programmatic advertising' accounts for the vast majority (84.5% or more) of total revenue (Cramer-Flood, 2020; Perrin, 2020). Despite its undeniable significance, not enough is known about the structure of the digital advertising market, how exactly it relates to social media, and the significance of business partnerships and partner integrations—particularly with players in the digital marketing and advertising industry. As I have argued in the chapters so far, these technological and market structures cannot be understood separately from the way that governance and power manifest themselves in the digital economy and society [‣ Chs. 1 to 3].

The Observatory on the Online Platform Economy summarises that 'the online advertising market relies on a complex ecosystem of industry players, where advertisers and publishers trade ads via a range of intermediaries including advertising networks and exchanges, demand-side platforms ['DSPs'], and supply-side platforms ['SSPs'], and can resort to additional services such as data management platforms or data analytics' (Lechardoy et al., 2020: 68). Critical scholars and policymakers have studied this complex and interconnected ecosystem, including some of its key players and privacy implications (e.g., Braun, 2013; Crain, 2019; Crain, 2021; Christl and Spiekermann, 2016; Fourberg et al., 2021; Turow, 2013). Business partnerships and alliances have become endemic to the advertising market because of its inherent fragmentation, 'walled gardens', and data 'silos': each industry player has a particular role in the digital supply chain while only a handful of players have multiple roles. This is especially the case for the growing ecosystem of 'programmatic advertising', where ads and audience commodities are automatically traded and served across media distribution channels and geographic regions in mere milliseconds through real-time bidding auctions of 'dizzying computational and organizational complexity' (Alaimo and Kallinikos, 2018: 110). This form of advertising involves specific computational technologies and infrastructures, as well as many different types of companies and organisations that each do only some things (and not all things), as explored in this chapter. 'Big Tech' and large social media platforms are uniquely positioned within this complex ecosystem because they play a significant role both on the consumer 'side' of the market (e.g., with access to billions of consumers worldwide, across many websites and apps) and the publisher 'side' of the market where online digital advertising capabilities and inventory are offered to those with advertising needs (i.e., advertisers or 'buyers'), including website or app developers, individual advertisers, or larger agencies who manage advertising campaigns for multiple client companies and organisations. These are traditionally separate market 'sides' (i.e., relating to supply and demand), with distinct players and networks. Moreover, they typically collect and store a wealth of information on both these market 'sides' (i.e., about audiences, advertising campaigns, prices, etc.), providing competitive and strategic advantages.

As I also mentioned in Chapter 3, Facebook and Google are known as the online digital advertising 'duopoly' because they dominate the end-consumer 'side' (e.g., with their popular social networks, search engines, online marketplaces, 'cloud' services, and apps) as well as the publisher (business) 'side' of the digital advertising market (e.g., with their popular self-service advertising tools, 'lightning-fast' ad auctions and ad-serving technologies, tracking technologies such as Facebook Login and Google Analytics, and immense social graphs), raising important concerns about monopoly power and antitrust (CMA, 2020; USA House Judiciary Committee, 2020). At the same time, platform power concerns more than market or monopoly power alone, and questions remain as to where power is located precisely and how it is exercised. The UK Competition and Markets Authority [CMA] highlights the importance of Facebook and Google's large interconnected platform ecosystems, which have been key in growing 'the range of their infrastructures, technologies, products, and services' (2020: Appendix E1–E2). Similarly, van Dijck et al. call for 'nuanced analyses of power in the integrated platform ecosystem' to examine 'how platforms are behaving in relation to each other, across markets, and across societal sectors' (2019). In short, the challenge is to situate and contextualise digital platforms and the sources and forms of their power as part of an integrated platform ecosystem, acknowledging their interrelational and dynamic structure. Technological and organisational analyses of platform ecosystems reveal distinct relationship structures and provide different insights into 'platform power' (e.g., van Dijck et al., 2019; [‣ Ch. 1]).

As explained in the previous chapters, developer tools are vital to platforms' unique positions of power, particularly the infrastructural aspects of that power [‣ Chs. 2 and 3]. Business software developer tools like application programming interfaces [APIs] and software development kits [SDKs], commonly supplied to help implement APIs) are not only central to Facebook Platform but are at the heart of the larger (programmatic) advertising ecosystem. They facilitate the software development and integration work that is necessary to make programmatic advertising 'work' at a large scale. As I found in Chapter 3, access to these business software tools is typically governed through partner programmes. Social media platforms engage partners and form (strategic) business partnerships through partner programmes, which attract advertisers, business partners, media publishers, and content creators. Industry players require these partnerships with social media to gain privileged (sometimes exclusive) programmatic access to social media advertising tools, products, and services—and their massive datafied audiences—via these business-facing software tools. Many of these business partners are themselves large companies (e.g., Interpublic, Omnicom, Publicis, WPP, etc.), primarily active in the digital marketing and advertising industry (i.e., advertisers, publishers, and many different intermediaries engaged in the distribution and targeting of ads using data (EP, 2021: 21)), that operate in various markets and industries worldwide and have software tools, products, services, and partner networks of their own. In fact, Facebook considered its integrated partners 'extensions of itself' (Dance et al., 2018a); they helped the platform to grow rapidly and integrate Facebook data and functionality into other software-based systems, markets, industries, and sectors of society, whereby the platform's reach and scope are expanded. Ultimately, these partnerships and business software tools supported the diversified 'data-based service ecosystems' that have helped social media become so profitable (Alaimo et al., 2020).

Building upon the empirical(-historical) analyses of Chapters 2 and 3, this chapter considers the role and significance of business partnerships in the entire larger ecosystem of social media platforms (i.e., beyond Facebook) to understand the business (partner) ecosystem integrations of social media generally, and how business partners help mediate and shape platform power. It is the outcome of a comprehensive, large-scale empirical study of the (technical and business) integrations and dependencies between the most popular (i.e., most-used) social media and the larger business (partner) ecosystems around them. I explain how business partners contribute to the ongoing process of 'platformisation'—'the penetration of the infrastructures, economic processes, and governmental frameworks of platforms in different economic sectors and spheres of life' (Poell et al., 2019; [‣ Ch. 3])—through their collective development of business-to-business [B2B] platform infrastructures that extend the larger ecosystem of social media platforms (and not just Facebook's individual business (partner) ecosystem [‣ Ch. 3]). Many partners are powerful industry players with 'their own interests, business models, and bottom lines', but have remained relatively invisible to consumers (Braun, 2013: 127) and underexplored in the literature on platformisation and platform power. This ecosystem of social media and industry players is exceptionally difficult to understand, not least because of the substantial amount of specialised terminology and its constantly changing structure. Moreover, the complexity of this ecosystem poses challenges to regulators and lawmakers, who mostly focus on consumer markets (van Dijck et al., 2019). Nonetheless, this chapter identifies a significant number of the public business partnerships and partner integrations that comprise this complex global ecosystem. This is crucial to situate and contextualise the power and business models of digital platforms generally, beyond Facebook alone.

I present an empirical method for tracing business partnerships and partner integrations and visualising the partner relationship networks of the 20 most-used social media. I use this method to detect and analyse which relationships are involved, which are exclusive or shared, and identify key sources and locations, or 'nodes', of power in this ecosystem (Broughton Micova and Jacques, 2020). I also discuss the two types of infrastructures that these partners have built, based on the empirical analysis: infrastructures for data sourcing and for media distribution. Industry players, through partnerships and the software integrations they build, integrate social media platforms with what I call the *audience economy*—a complex global and interconnected marketplace of business intermediaries involved in the creation, commodification, analysis, and circulation of datafied audiences for purposes including but not limited to online digital marketing and advertising. I will call those business intermediaries that create software tools, products, and services for shaping the creation, buying, modelling, measurement, and targeting of datafied audiences *audience intermediaries* (cf. Beer, 2018; Braun, 2013; Braun and Eklund, 2019; Napoli, 2003; Turow, 2005). They include some of the partners identified in Chapter 3, as well as many additional companies and organisations. This valuation process is often described in terms of 'commodification' (e.g., Nieborg, 2016) or, more recently, 'assetization' (e.g., Birch et al., 2021; Mellet and Beauvisage, 2020). Audience intermediaries tend to be the central players in this industry, where 'audiences' (or 'segments') are purposefully constructed, modelled, linked, and ultimately put to use or shared—a process involving many different players, infrastructures, and forms of 'data-work' that are vital in the audience economy (e.g., Alaimo and Kallinikos, 2021; Alaimo and Kallinikos, 2018: 110). Additionally, audience intermediaries uniquely tend to span (and thus bridge) a multitude of distinct corporate platform ecosystems (e.g., Facebook, Google, and Twitter's own ecosystems), thus mediating and shaping platform power in the larger ecosystem.

The empirical approach enables consideration of how platform power and governance are dispersed and mediated by partners, the different markets and industries they partake in, and the infrastructure that runs *between* their industry platforms. As such, I make an empirical contribution to the literature on platform and infrastructure research (Blanke and Pybus, 2020; Helmond, 2015a; Plantin et al., 2018; Poell et al., 2019; [▸ Ch. 3]). Additionally, such empirical research is vital to adapt existing regulatory frameworks and practices regarding the users and uses (including the provenance and permissibility) of data. Furthermore, the analysis integrates various primary sources and trade publications to contextualise the empirical findings. Using this combination of materials facilitates a growing understanding of this complex, layered, and globally interconnected ecosystem of social media and the global digital advertising market and how partnerships are endemic and essential to the business of digital platforms.

In the next sections, I first situate the contribution within the literature on platformisation and power in platform ecosystems. Second, I detail the empirical materials and methods used to identify and visualise business partnerships and partner integrations.[56] Third, I present the empirical partnership analysis of the 20 most-used social media and, subsequently, of the audience intermediaries connected to social media, which are powerful players in the audience economy. Finally, I discuss the significance of partnerships and partner integrations in relation to platformisation and the mediation of platform power.

4.2. [BACKGROUND AND POSITIONING] Platformisation and power in platform ecosystems

The technological and economic growth of digital platforms is driven not only by user growth but also by (third-party) app development (Blanke and Pybus, 2020; Helmond, 2015a; [‣ Ch. 2]), (strategic) business partnerships (Alaimo et al., 2020; [‣ Ch. 3]), and mergers and acquisitions (M&As) (Smith, 2019). In this process, a platform's 'complementors' are those individuals or organisations who create and provide complementary tools, products, or services for a specific platform (Gawer and Cusumano, 2014), including app developers, businesses and partners, advertisers and marketers, content creators, and media publishers. These complementors contribute significantly to platforms' unique positions of power, particularly the infrastructural and strategic aspects of that power in the larger ecosystem. Additionally, social media are especially powerful—and central to this study—because they uniquely govern and control access to massive datafied audiences (i.e., billions of end-consumers, millions of developers, and businesses all around the globe). However, this study finds that they are also part of a larger ecosystem of audience intermediaries, who similarly hold or mediate access to massive amounts of data for modelling and targeting purposes. Because of the partnerships they have with social media, these audience intermediaries are uniquely positioned to offer tools, products, and services built around (access to) data from many different sources, providing access to audiences across multiple social networks and thousands of websites and apps all at once. The larger level of analysis applied in this study uniquely enables insights into these relationships between social media and industry players in the larger ecosystem (i.e., partners).

56 The data that support the findings of this study are openly available in the Open Science Framework [OSF] at https://doi.org/10.17605/osf.io/ekum8. Data collection was conducted between January–March 2018. Please note that any names of companies and organisations, particularly their parents, may have changed since then (e.g., due to M&As).

Business partners play an important role in the entrenchment of platform power. Business partners, as a privileged complementor type, develop complementary apps and services, and *integrate* their own software-based systems or platforms with social media, giving rise to a *global interconnected platform infrastructure* that runs between social media platforms and the platforms of those partners. Braun examined the growing importance of software providers and how 'software infrastructures' for online video distribution, as both technological artefacts and 'social, commercial and legal strata' facilitate and constrain the distribution process (2013: 125). Building upon initial insights about partnerships from Chapter 3, I conceive of platform infrastructure as the technological, API-based relationship networks operating between nodes within a platform's ecosystem and beyond, as built and maintained by industry players (e.g., business partners) in particular. This dual focus is critical because an analysis of platforms' power concerns not only the technology developed by large digital platforms themselves (e.g., proposed technical standards and protocols), but also the actors who build and uphold those infrastructures, and what is in it for them. This condition of mutuality suggests that power is not solely held by the largest of digital platforms, which enables a nuanced perspective on the deterministic analysis of power dynamics as part of larger ecosystems (e.g., Hurni et al., 2022; [▸ Ch. 1: §1.3.2]).

As I suggest in this chapter, an ecosystem perspective on digital platforms has direct implications for understanding platforms' power (van Dijck et al., 2019). The power of digital platforms is often conceived in terms of market or monopoly power (e.g., Blanke and Pybus, 2020). However, there are also infrastructural and strategic types and sources of power that can provide 'a potential source of dominance' for platforms (Broughton Micova and Jacques, 2020). Power is dispersed and exercised through infrastructure, wherein the gateway function of APIs is an important source for this 'infrastructural power' held by platforms (Blanke and Pybus, 2020; Busch, 2021; van Dijck et al., 2019; [▸ Ch. 2]). Therefore, an analysis of platforms' power should consider how APIs are deployed, used, and by whom they are governed and controlled. Similarly, Braun highlighted the role of infrastructure in the exercise of 'structural power', influencing 'who sees what content' (2013: 126). Furthermore, platforms can accrue 'strategic power' through what Broughton Micova and Jacques (2020) call 'relationship advantages' (i.e., having direct close relationships with other actors in the network, e.g., through partnerships) and 'opacity bias' (i.e., a lack of transparency as to how programmatic advertising 'works'). I draw on these notions of platform power to discuss the significance of partnerships that are driving the process of platformisation in the audience economy and to better understand how partners mediate and shape platform power through infrastructure development. Unlike Chapters 2 and 3, the current study thus does not concern (the role of these partnerships in) Facebook's platform evolution, but the larger ecosystem—the audience economy—around Facebook and all other popular social media.

4.2.1. *Platform infrastructure development*

The technological extensibility of platform infrastructure is, in general terms, facilitated by the 'programmability' of digital platforms—here conceived as 'the extensible codebase of a software-based system' (de Reuver et al., 2018: 126; [▸ Ch. 1]). As discussed in Chapters 2 and 3, platform owners stimulate and govern such development by offering 'platform boundary resources' [PBRS], which comprise all the software tools and information needed to build apps and services 'on top' of digital platforms (Eaton et al., 2015), and whereby ecosystems of connected software apps and services may evolve. 'Technical' PBRS, including APIS and SDKS, facilitate app development by exposing the platform architecture (Dal Bianco et al., 2014). APIS provide programmatic access to platform data and functionality (or services) and enable communication between platforms (Helmond, 2015a). Importantly, APIS are not necessarily data export tools but give programmatic access to another platform's data-based services (e.g., for audience targeting, campaign optimisation, etc.). Complementary 'social' PBRS coordinate and govern the interactions between platforms and complementors, including app developer guidelines and policies (Dal Bianco et al., 2014). Taken together, these PBRS govern the platforms' external relationships with complementors (e.g., app developers, businesses, advertisers, publishers, partners, etc.) while concurrently, they ensure that their owners maintain 'infrastructural control' over that development work (Eaton et al., 2015).

Prior research on app development and platform ecosystems remains implicit about the role of complementors in the process of platformisation. Technical and market-based perspectives have emphasised the multiple 'sides' of digital platforms and the role of complementors in 'co-creating' complementary tools, products, and services—contributing value to the platform ecosystem—facilitated by the generativity and innovation capabilities of platform ecosystems (Gawer and Cusumano, 2014; [▸ Ch. 1]). Critical scholars have highlighted how app developers negotiate platforms' technological affordances and constraints when building complements [▸ Ch. 5] or how apps distribute data generation and valuation in platform ecosystems (Gerlitz and Rieder, 2018). Additionally, some studies have highlighted the role of complementors in platform infrastructure development by focusing on webmasters and app developers (Gerlitz and Helmond, 2013; Helmond, 2015a; [▸ Ch. 5]) or on (B2B) 'transparent intermediaries' (Braun, 2013), business developers, and partners [▸ Ch. 3]. All these complementor types, especially the business partners of social media platforms, have been driving platform infrastructure development in the ecosystem of social media platforms and beyond through the integration of platforms' software tools, products, and services into partners' own software-based systems to extend capabilities into specific markets and industries worldwide.

4.2.2. *Business partnerships*

From the organisational perspective, platformisation is driven by the accrual of ('strategic', 'preferred', and other) business partnerships, which serve several purposes. In the software industry, partnerships serve to form strategic alliances, encourage complementary innovation, expand customers and market reach, gain access to external, exclusive, and specialised data and resources, prompt network effects, and manage business (partner) ecosystems and developer networks (van Angeren et al., 2016; Ceccagnoli et al., 2012). Software platforms such as Google, IBM, Microsoft, and SAP have thrived in the software industry due to their partnership models. In the social media industry, partnerships similarly serve to drive growth and facilitate access to (exclusive) data and functionality, markets, and industries [‣ Ch. 3].

Additionally, in the online digital marketing and advertising industry, wherein social media plays a pivotal role, it is common practice to source (or obtain access to) data through partnership agreements and to use data for purposes other than originally intended (Jarvenpaa and Markus, 2020; Marshall, 2019). Such data partnerships are formed because data is a strategic asset for many companies, supporting advertising-based business models, data-driven business operations, and AI-based tools, products, and services, which all depend on (access to) large volumes of data. Given this context, Jarvenpaa and Markus (2020) expressly call upon digital platform and infrastructure researchers to focus on 'data sourcing' (or acquisition) and partnerships, as they are important for understanding how the relationship networks of the ecosystem of social media platforms form around such data assets (cf. Alaimo et al., 2020).

Within the audience economy, *data intermediaries* such as 'data marketplaces', 'data providers' (e.g., data brokers, suppliers, vendors), and data analytics and advertising technology ('adtech') companies have become central players in the B2B audience economy because of the strategic importance of data (Spiekermann, 2019). Intermediaries thus connect different markets and industries, including search engines and social media for the purpose of digital marketing and advertising 'at scale'. These industry players—companies that are also organised on a platform logic—act as data intermediaries because they shape 'the circulation and integration of new forms of data' and actively build infrastructure for data marketplaces and transactions as well as for mediating interactions and exchanges between data providers, third-party service providers, and data buyers worldwide (Beer, 2018: 12; Spiekermann, 2019). Further, data intermediaries play a central role in contemporary 'people-based marketing' (Smith, 2019), where unique customer identifiers (e.g., email addresses, phone numbers, social media logins, etc.)

are used to 'map' digital traces onto individuals, extending the process of platform capitalisation across media properties and driving new forms of data resolutions through 'identity resolution' solutions and strategic M&As—particularly with and by the larger, more powerful businesses in the industry, including not only the Big Five ('GAFAM') tech companies but also Adobe, Salesforce, Oracle, The Trade Desk, LiveRamp, and many others [‣ Ch. 3].

It is standard practice, if not essential, for social media and industry platforms to form partnerships with these intermediaries and with each other to make programmatic advertising 'work'. There are many intermediary types serving different purposes in this vast 'digital market infrastructure', where thousands of new industry platforms have emerged and consolidated around the acquisition, trading, and use of diverse data forms (Christl and Spiekermann, 2016; Crain, 2018; Crain, 2021; Mellet and Beauvisage, 2020; Smith, 2019). Ultimately, these market infrastructures 'affect the distribution of economic power and wealth' and 'are subject to strong network effects' (Poell et al., 2019), despite centring on what are essentially just small pieces of data (e.g., Web cookies, device identifiers).

Next, I detail the materials and methods for tracing these important business (including data) partnerships in the case of social media to better understand the nature and structure of the global partner ecosystem.

4.3. [MATERIALS AND METHODS] Tracing business partner relationship networks

Platform ecosystems are complex and interconnected relational structures that are difficult to study and understand. Some previous approaches for 'mapping' platform ecosystems have used ProgrammableWeb's API directory to characterise technological, API-based ecosystems (Evans and Basole, 2016). Other approaches have used financial transaction databases, company databases, company blogs, public filings, annual reports, and news articles to find partnerships and 'map' organisational ecosystems (van Angeren et al., 2016). Many primary sources are available in relation to the different user groups of social media platforms, including app developers, businesses, and partners, that offer unique research opportunities (Helmond and van der Vlist, 2019). My co-author and I used these primary sources to trace the partner relationship networks that have emerged around social media.

We focused on PBRs offered by the 20 most-used social media worldwide (Statista, 2020) to locate relevant resources for business partners and about partnerships. These types of resources provide additional marketing and advertising-related resources for business developers and partners, including product and training pages, partner programmes, and special APIs and SDKs (e.g., Facebook

Marketing API, Facebook Business SDK, Twitter Ads API, etc.). Contrary to what is the case with most app developer resources, these business resources are exclusively accessible to approved or certified business partners and are thus governed through partnership agreements. While Chapters 2 and 3 were focused on the historical evolution of Facebook in particular (i.e., through diachronic analysis), the current chapter thus examines the larger technological and structural configurations and market embeddings that exist around social media today (at a specific moment, i.e., through synchronic analysis). Such a complementary analysis is necessary for situating and contextualising social media in the larger audience economy (comprising a variety of Internet-related markets and industries, as we find in this study). This additionally enables a nuanced perspective on the deterministic analysis of power, which, as we find, is not only located in Big Tech companies, but also mediated and shared by key ecosystem partners [‣ §4.4].

As introduced in Chapter 3, social media launch partner programmes to attract partners and to solicit contributions that extend a platform's value, reach, and influence (van Angeren et al., 2016; [‣ Ch. 3]). These are business partner programmes for digital marketing and advertising, media publishers, journalists, as well as 'accelerator' and consultancy programmes linked to platforms' business-facing (marketing or ads) APIs. They claim that partners are 'vetted for excellence' in specific technology, advertising, and marketing-related areas and 'periodically reviewed' across '80+ points of criteria' as part of the approval or certification process.[57] Consequently, business partners comprise mostly large (market-leading) companies in their own specific markets or industries, including specialised marketing or advertising technology (e.g., data management, ad networks and exchanges, tag management, etc.) or specific data forms that are not widely available (e.g., niche demographics, credit ratings and scores, location data, etc.). For instance, Twitter's invitation-only partner programme includes partners selected for their value-adding skills and capacities to combine 'their own enterprise tools and expertise' with Twitter's Ads API to 'create and manage high-quality ads with advanced features and capabilities' and Twitter's data partners have 'unlimited access to every data product without restriction'. Similarly, Facebook's selected partners are expected to add 'measurable value' and 'build beyond' the already existing tools, products, and services provided by the core platform (Chen, 2017). While there are different partnership types, 80% of social media operate one or more marketing partner programmes, representing global communities of leading technology, service, and data providers in marketing and advertising-related areas.

57 Non-certified businesses and individuals can use the self-service advertising tools and solutions, including https://www.facebook.com/business/ads and https://business.twitter.com/en/advertising.html.

Partner directories provide detailed information about those enrolled in partner programmes, including their specialities, pricing models, and the markets or industries they partake in, signalling their capabilities to potential business customers (Ceccagnoli et al., 2012). These directories are publicly accessible to anyone and are available on the platforms' business pages. They serve to showcase platforms' many types of ('strategic', 'preferred', and other) business partners (e.g., marketing partners, technology integration partners, creative partners, data partners, etc.), use cases, and provide contact details, like yellow pages or other types of business directories. Further, these directories are frequently updated because they serve an important role in attracting business customers who would like to advertise on social media. To facilitate this process, the traces and information about these partnerships are publicly available, even if the legal or contractual norms and details of each individual partnership relation may not be equally available.

We used these public partner directories to trace partnerships. Among the 20 social media platforms examined, we found 36 different partner directories, listing 1,549 partnerships in total [‣ Appendix D: Table D 4.1]. We extracted the names and details for each partner using custom-built Web scrapers to derive a structured dataset using information concerning these partners' names, descriptions, logos, URLs, specialities, industries, countries, languages, service types, goals, and pricing models. Next, we focused specifically on those partners who were categorised as data intermediaries. From 67 categorised audience intermediaries, we found and scraped another 50 partner directories on their websites, listing 9,941 additional partnerships and integrations [‣ Appendix D: Table D 4.2], and extracted all names and relevant details. By combining both datasets, we were able to gain a comprehensive view of the overall audience economy as it relates to social media through organisational partnerships and through technological (API-based) partner integrations. Additionally, we matched the dataset to expert lists of identified data intermediaries to locate these in the network,[58] as well as to Ghostery's curated library of over 4,500 tracker scripts from over 2,200 companies to compare the partner and tracking technology ecosystems.[59] Companies use these embedded tracking technologies to source data from external websites and apps. We further integrate many primary sources and trade publications into the data to contextualise the empirical analysis.

58 We used various reputable industry sources, including the 2018 Marketing Technology Landscape Supergraphic (Brinker, 2018) available from the Chief Marketing Technologist Blog [Ch.3: Figure 3.5(a) and (b)], as well as Forrester Research, G2, and Crunchbase.

59 https://ghostery.zendesk.com/hc/en-us/sections/115000206793-Tracker-Library (accessed 21 June 2018)

The next section identifies how social media are embedded in the audience economy through different partnership types. The first part of the analysis describes the structure of the partner ecosystem, highlighting key partnership types and products and service types commonly offered—using the partners' own specialised terminology (i.e., 'industry speak') where necessary. The most significant partnership and service types are discussed thoroughly in the second part of the analysis.

4.4. [ANALYSIS] Situating and contextualising social media in the audience economy

4.4.1. *Social media partnership networks*

Figure 4.1 presents the social media partner ecosystem, which comprises the most-used social media and their partner relationship networks. The nodes represent partner companies and organisations, while the links signify partnership relations, where each partnership represents multiple (data-based) tools, products, and services exchanged, integrated, or shared between social media and their partners. Interconnections arise when companies form partnerships with multiple social media platforms. In short, these partner relationship networks represent not only organisational arrangements of companies, but also the platform infrastructure that runs *between them*.

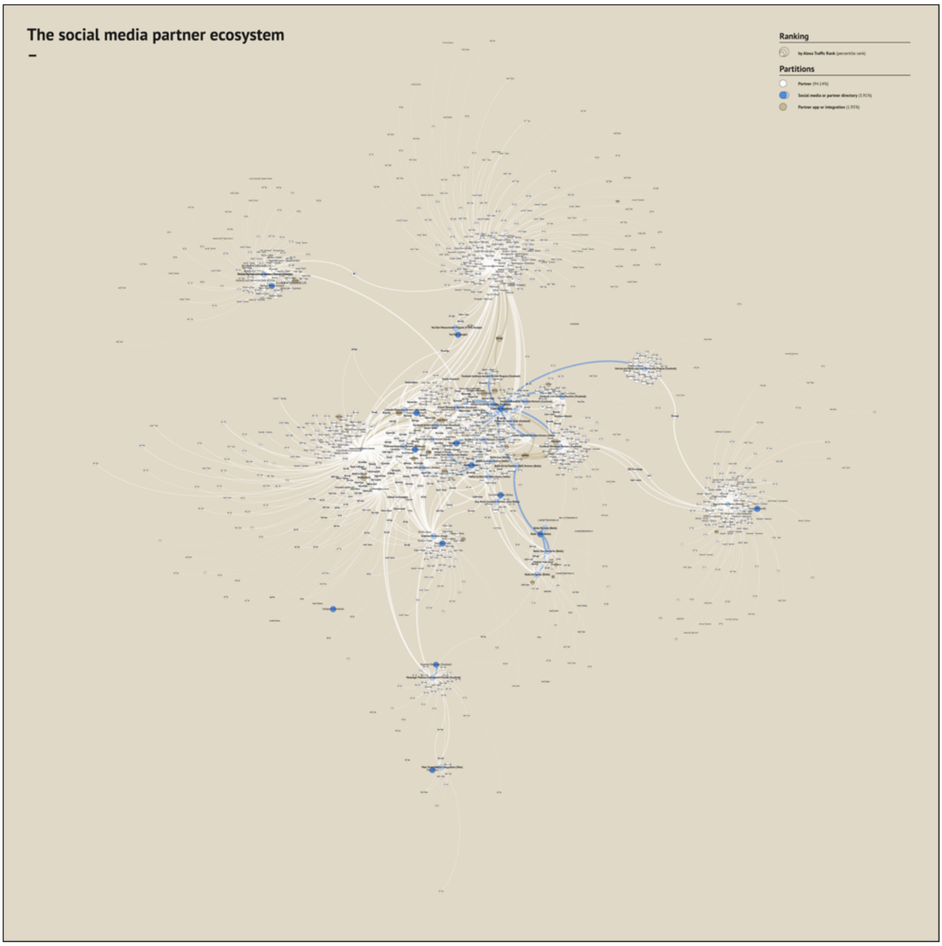

Figure 4.1. The entire social media partner ecosystem [network diagram].

*Directed graph: nodes are social media partner directories (*N = *32) and referenced partners (*N = *1,177); links are partnership relations (*N = *1,523). Layout:* ForceAtlas 2*; filters: giant component, node degree range ≥2 (19.46% labels visible); ranking: by Alexa Traffic Rank;*[60] *colour-coding: by type (i.e., partners, social media, partner apps or integrations). High-resolution figures are openly available in OSF at https://doi.org/10.17605/osf.io/ekum8.*

Most prominently, partnerships converge around programmatic marketing and advertising (e.g., supply and demand aggregation) and data sourcing (e.g., audience data acquisition, data management). Most partners list specialties related to marketing and advertising technologies and solutions. Facebook and Twitter's

60 Alexa Traffic Rank is based on global Web traffic analytics. We use it to rank nodes by how each partner's website traffic compares to other partners' websites. See: https://www.alexa.com/siteinfo.

partner specialties also reveal their 'mobile-first' (marketing and advertising) strategies. YouTube, Pinterest, and Snapchat focus on content partnerships, while Facebook Messenger, WeChat, and Viber focus on automated messaging, chatbots, and payment integrations.

Most partners (79.4%) are mentioned once and deal with platform-specific features and content formats. This does not make them any less important; rather, it is a matter of what is needed for social media business models. The remaining 242 partners (20.6%) are referenced in multiple partner directories, indicating that their services span several platforms. It is worth listing the most important partners at this stage, before delving into them in the next sections of this analysis. The most connected partners (node degree count ≥6) are large advertising agencies (e.g., Dentsu and WPP), digital marketing and advertising clouds (e.g., Adobe Marketing Cloud, Oracle Marketing Cloud, and Salesforce Marketing Cloud), audience data aggregators such as data management and customer data platforms (respectively called 'DMPs' and 'CDPs' (e.g., eXelate, LiveRamp (owned by Acxiom), Oracle DMP (formerly BlueKai), and Salesforce DMP (formerly Krux)), and data analytics and measurement companies (e.g., 4C Insights, Nielsen, and SocialCode). Additionally, they offer 'multichannel' (or 'omnichannel') marketing and advertising solutions that cover many different media types (e.g., Adobe, AdParlor, Brand Networks, Oracle, Percolate, Salesforce, Spredfast, and Sprinklr) and 'customer relation management' ['CRM'] solutions (e.g., Adobe, Salesforce, Spredfast, and Sprinklr). These partners are centrally positioned either because their core business relies on partnerships and integrations with popular social media and publishers, or because they aggregate ('unify') different sources of data. They offer tools for the automation, management, scaling, and optimisation of their customers' advertising campaigns across several social media, the management of customer and brand relations, and the integration of external data sources to find and reach audiences elsewhere. Therefore, partners each add distinct value to social media by developing complementary tools, products, and services that rely on data or functionality from social media (and thus make this data or functionality valuable and useful in new ways to the benefit of both).

Social media also form partnerships with (independent) third-party 'audience measurement', 'attribution', and 'verification' partners (e.g., AppsFlyer, Comscore, and Nielsen) who validate the (self-reported) metrics of one or multiple platforms. In this role, so-called 'measurement' partners are important for advertisers to help develop trust in a platform's reported metrics of engagement and advertising campaign performance (e.g., Web traffic, bounce rates, sales revenue, engagement, conversion rates, cost per conversion, etc.), because these metrics may also become 'a source of concern or even mistrust' (Broughton Micova and Jacques, 2020), as prior controversies around advertising fraud (e.g., fraudulent representations of engagement or viewership metrics) have demonstrated (Vranica and Marshall, 2016; cf. Hwang, 2020). It is because of the distributed nature of this industry that it is so difficult to ensure that ads are, in fact, rendered on users' screens at all, or to accurately attribute 'events' and measure them in terms of views, clicks, or conversions. This is the reason why independent third-party measurement partners are important.[61] In the past, their privileged access led to privacy and security issues when Twitter and Facebook shared users' device data with their measurement partners—a practice that was terminated due to potential data leakage and abuse (Fisher, 2019; Sloane, 2020).

Furthermore, social media commonly forge partnerships with 'audience data providers' (e.g., Acxiom, Datalogix, Epsilon, and Experian) to provide special audience targeting options (targeting 'categories', 'segments', or 'audiences') directly integrated into the platforms' self-serve advertising tools. For example, Snapchat, Pinterest, and LinkedIn offer third-party audiences in their advertising tools from their respective data partners Oracle and Nielsen, Oracle, and LiveRamp (owned by Acxiom), enabling advertisers to 'tap into an expansive data marketplace'.[62] This thus enables advertisers to use data from these partners to find and reach (larger or very specific) audiences on social media. Facebook and Twitter terminated this functionality after the Facebook–Cambridge Analytica data scandal and amid growing privacy concerns (Bruell, 2019). While they removed the partner targeting categories from their self-serve advertising tools, they did not end their partnerships with these audience intermediaries. Instead, they now require companies to create or purchase their own 'custom audiences',[63] which they can subsequently upload or automatically import into social media's targeting tools using partner integrations. In other words, although this functionality is no longer openly available to everyone, it is still available to partners and to those who work with any of Facebook's partners.

61 Hwang warned of a looming 'subprime attention crisis' (2020), in reference to the 2007–2010 United States of America [USA] subprime mortgage crisis that contributed to the global financial crisis. His critical perspective differs from many others that take issue with behavioural manipulation and exploitation (e.g., Zuboff, 2019).

62 https://forbusiness.snapchat.com/advertising/targeting

63 This option lets marketers and advertisers match their own audience data (e.g., customer lists, website or app traffic, newsletter subscribers, etc.) to Facebook's social graph to 'find [their] existing audiences among people who are on Facebook'. This option is also used to expand existing audiences with 'lookalike audiences' (i.e., with people who are similar according to Facebook). See: https://www.facebook.com/business/help/744354708981227 and https://www.facebook.com/business/help/164749007013531

For instance, key ecosystem partner LiveRamp has access to the Facebook Marketing API, which offers a 'unique integration with Facebook Custom Audiences',[64] to automatically upload custom audiences built from over 40 third-party data providers, including LiveRamp partners Mastercard and Equifax (transactions and credit data). Oracle offers similar API integrations with Facebook and Twitter to send third-party audiences from its own data partners to social media's targeting systems (in the USA). Consequently, the industry practice of using partner targeting categories has not really changed, while accountability under the EU General Data Protection Regulation [GDPR] 'for the provenance and permissibility of the data they are injecting' (Bruell, 2019) has shifted to partners. This, again, is crucial to adapt existing regulatory frameworks and practices regarding the users and uses of data by audience intermediaries in this larger audience economy.

Partnerships thus signal exclusive access to proprietary data and functionality from the 'walled gardens' or 'data silos' of popular social media. Most other competitors do not have such privileged access and thus need to work with at least one of these partner companies (who thus become 'gatekeepers' as well). For instance, Salesforce, a key ecosystem partner, has a 'Data Studio' (part of its 'Marketing Cloud'), and the company boasts that it is 'the only platform trusted by large retailers and other walled gardens for direct data deals'.[65] Additionally, 4C Insights (then Scope, now owned by Mediaocean), with its 'Closed Ecosystem Platform', promises that customers will move 'seamlessly across closed ecosystems'.[66] Access to these closed platform ecosystems is governed through partnerships and API access privileges, where long-standing API arrangements may be used to signal access, expertise, and experience. AdParlor, 'one of Facebook's very first API partners', boasts that it 'understands Facebook advertising better than anyone in the industry' due to its strategic API advantage.[67]

Accordingly, business-facing APIs are key elements of platform infrastructure that facilitate partner integrations, which they require to run 'multichannel' programmatic advertising campaigns across the ecosystem on behalf of their customers. With these integrations, partners assist their customers in finding, creating, expanding, and targeting audiences on social media and beyond. In this way, APIs enable the remote use ('activation') of social media data by partners without needing to leave the platform. For platform owners, APIs are an important mechanism of

64 https://liveramp.com/blog/facebook-integration/ and https://liveramp.com/our-platform/data-network/

65 https://www.salesforce.com/products/marketing-cloud/data-sharing/

66 https://www.4cinsights.com/scope/ (now https://www.mediaocean.com/closed-ecosystems-scope-4c)

67 https://adparlor.com/platform/facebook/

infrastructural control. Therefore, partners' positions in the ecosystem are of strategic importance because they provide and signal privileged access to exclusive social media data or functionality, as governed through partnerships and technical PBRs. More generally, partnerships and integrations are what facilitate the programmable and programmatic substrates of the audience economy. They create interoperability—or indeed, a form of 'intraoperability' between selected software-based systems only (Bechmann, 2013; Sutor, 2011; [▸ Ch. 3: §3.2.1])—and reduce friction between the software-based systems of social media and their partners (cf. Bates, 2018). These relationship networks thus serve as a proxy for dataflow networks, wherein audience data moves (or is 'activated') between different software-based systems through partner integrations.

4.4.2. *Audience intermediary partnership networks*

To better understand these partnerships as a feature of platform power, consideration is needed of how exactly these partners—especially the data intermediaries among them—have integrated social media in the larger global audience economy. Audience intermediaries occupy central positions in digital marketing and advertising processes due to the strategic importance of data, its sourcing from third-party vendors (Jarvenpaa and Markus, 2020), and the need for data resolution in 'people-based marketing' (Smith, 2019). Data is collected, analysed, modelled, and segmented for various purposes (e.g., analytics, targeting, and credit scoring), thus serving as an important basis for partnership relations and integrations between different types of digital platforms. To begin understanding these relationship networks, we chart ('map') which players are involved and which partnerships are exclusive or shared.

Figure 4.2(a) to (c) present the partner ecosystem of audience intermediaries as it relates to social media. It displays the relationships between the source set of the 20 most-used social media and the 67 data intermediaries connected to them, resulting in an ecosystem of 6,750 unique partners and integrations. Altogether, 495 (41.3%) of the identified data intermediaries appeared in this partner ecosystem. AppsFlyer (2,607), Kochava (1,644), Zapier (1,349), Oracle (881), Microsoft (853), Acxiom (532), LiveRamp (423), Marketo (376), Segment (320), DataXu (272), Salesforce (219), SAP (198), mParticle (146), and Experian (102) were the intermediaries with the highest connectivity in this ecosystem. The included intermediaries had, on average, 243 relationships, and we traced a total of 10,357 relationships. We found a complex relationship network where each player provided part of the service needed for online digital marketing and advertising, making it nearly impossible to trace and understand where data originates, what happens to it, and where it moves over time—that is, to account for the 'lineages' and 'provenance' of (audience) data.

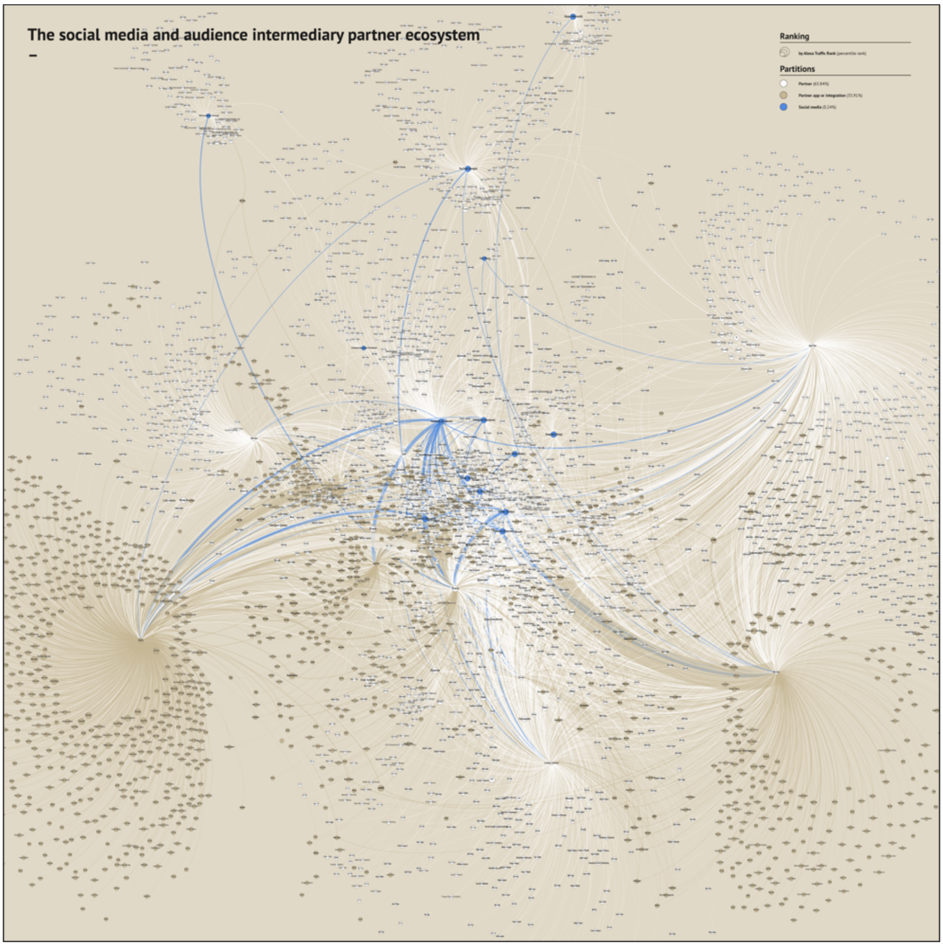

Figure 4.2(a). The entire combined social media and audience intermediary partner ecosystems [network diagram].

*Directed graph: nodes are referenced partners (81.1%) and apps or integrations (18.9%) (*N *= 6,782); links are partnership relations (*N *= 9,184). Layout:* ForceAtlas 2*; filters: giant component, node degree range ≥2 (19.28% labels visible); ranking: by Alexa Traffic Rank; colour-coding: by type (i.e., partners, social media, and partner apps or integrations). High-resolution figures are openly available in OSF at https://doi.org/10.17605/osf.io/ekum8.*

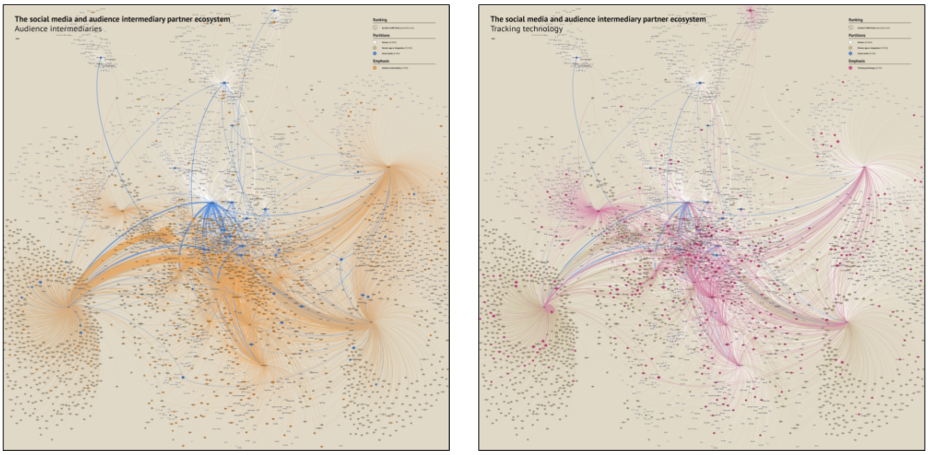

Figure 4.2(**b**) **and** (**c**). The entire combined social media and audience intermediary partner ecosystems [network diagram]: (b) as it intersects with audience intermediaries (orange) and (c) as it intersects with tracking technology (purple).

Categories (audience intermediaries): various industry sources (i.e., Chief Marketing Technologist Blog, Forrester Research, G2, and Crunchbase); Categories (tracking technology): Ghostery tracker library. High-resolution figures are openly available in OSF at https://doi.org/10.17605/osf.io/ekum8.

We further identified large advertising agencies representing large brands,[68] digital publishers,[69] supply-side advertising platforms ['SSPs'] that aggregate publishers' advertising inventory,[70] demand-side advertising platforms ['DSPs'] used by advertisers to buy and manage advertising inventory,[71] and advertising networks and exchanges that mediate the sale and purchase of ads.[72] Among the publishers, we identified the largest social media, search engines, dating apps, and music streaming, messaging, cloud, and blog services.

All the intermediaries mediated more than half (54.1%) of the relations in the partner ecosystem and comprised the core of the global digital advertising market, particularly the (growing) market of data-centric and programmatic solutions. In this context, this figure indicates that the supply networks of these markets have

68 E.g., IPG, Omnicom, Publicis, and WPP.

69 E.g., Brightcove, Business Insider, Forbes, Roku, Wallstreet Journal, and Washington Post.

70 E.g., AdMob (owned by Google), AppNexus, Amobee, BounceX, and MoPub (owned by Twitter).

71 E.g., Adform, Adobe, AppNexus, BrightRoll, Criteo, DataXu, MediaMath, Sizmek, Quantcast, and The Trade Desk.

72 E.g., MoPub (owned by Twitter), One (owned by AOL), PubMatic, and RhythmOne.

evolved so that the tools, products, and services from one platform are commonly supplemented with data or functionality components from another, leading to a complex and highly interconnected ecosystem. Even the advertising duopoly of Facebook and Google, with their own self-serve advertising tools and detailed targeting capabilities, benefit from partnerships and integrations as they allow the companies to increase their revenue. Data is not inherently valuable but *made useful and valuable* for specific purposes (cf. Birch et al., 2021; Mellet and Beauvisage, 2020), most notably through partnerships and the entire ecosystem of tools, products, and services built around that data, and not just by a single platform (however powerful it may be). This applies to anything from advertising campaign management to data analytics to 'community management' and messaging solution types.[73] Consequently, the most connective nodes at the centre of the ecosystem profit from their positions of strategic power.

Figure 4.2(c) highlights the intersections of the combined social media and audience intermediary partner ecosystems with the tracking technology ecosystem. We found that nearly 600 companies in the dataset are known to operate trackers to source data from websites and apps, including advertising (366), site analytics (108), and customer interaction (49). Among these are BlueKai (owned by Oracle) pixel tags and Web cookies, tracking 1.2% of all Web traffic.[74] While its platform is barely known outside the digital marketing and advertising industry, it holds one of the largest audience databases with billions of records—data that was recently exposed online (Whittaker, 2020). Social media platforms such as Facebook and Twitter also have their own trackers (pixels, plugins, social logins, etc.). In the case of mobile apps, this process works through software libraries (or SDKs) embedded in apps' code by mobile app developers, which ultimately 'led to a much deeper technical integration of these ecosystems', and which Blanke and Pybus contend has been 'overlooked and underresearched' (2020: 3). Moreover, anyone using a Facebook partner can connect their partner account to Facebook and configure advertising or create audiences based on its Pixel, App Events, or conversions APIs.[75] Thus, we were able to locate how and where the tracking technology and partner ecosystems intersect and how data consolidation contributes to the formation of platform monopolies (cf. Blanke and Pybus, 2020).

73 E.g., https://developers.facebook.com/ads/blog/post/2018/03/05/solutions-explorer-directory/

74 https://whotracks.me/trackers/bluekai.html

75 https://www.facebook.com/business/help/1179210765468894?id=1205376682832142

Prior research has exposed trackers embedded in websites and apps and considered the implications of these data flows (e.g., Gerlitz and Helmond, 2013). However, this aspect is only part of the story because these tracking technology companies partake in the larger ecosystem of audience intermediaries, digital advertising, and marketing technology companies. Trackers, thus, represent only one of the many data sources used for audience creation, modelling, and targeting. Therefore, to understand more effectively the movement of data and how audience intermediary partnerships mediate and shape platform power, these relationships need to be examined as more than just one part of platform-specific economies; instead, they need to be investigated as part of an ecosystem-wide audience economy, comprising countless industry platforms interconnected through partnerships. The audience economy is an infinitely more complex ecosystem composed of thousands of data intermediaries, providing hundreds of thousands of buyable audience attributes between them (Marshall, 2019).

4.4.3. *Data aggregation and 'identity resolution'*

We found that data management platforms ['DMPs'] and customer data platforms ['CDPs'], as they are called by companies in this industry, are central audience data aggregators—and central 'nodes' of power—in the audience economy. In contrast to DMPs, CDPs typically organise and centre their data tools, products, and services *around specific individuals* (i.e., customers). Specifically, DMPs unify the collection, organisation, circulation, and use of aggregate data from any source (e.g., Web cookies, device identifiers, IP [Internet Protocol] addresses, etc.) and have, therefore, become indispensable to those offering programmatic advertising solutions.[76] CDPs have a similar role but typically aggregate identifiable 'raw' first-party data (e.g., customer names, email addresses, phone numbers, etc.). They offer 'audience onboarding', 'audience monetisation', and 'audience management' solutions to any business with a customer record.[77] Both types of audience intermediaries assemble and aggregate audiences through data provider partnerships (with data brokers, data marketplaces, or directly with businesses). These 'identity resolution' solutions are used to build rich audience profiles and identify (e.g., 'find', 'reach', 'target', 'retarget', etc.) current, past, or potential customers—linking personal information and other kinds of information from many different online and offline

76 E.g., DataXu (now Roku OneView), Google Audience Center, Lotame, LiveRamp (owned by Acxiom), MediaMath TerminalOne, Oracle DMP (formerly BlueKai), and Salesforce DMP (formerly Krux).

77 E.g., ActionIQ, Blueshift, Microsoft Dynamics 365 Customer Insights, Lytics, mParticle, Salesforce Interaction Studio (formerly Evergage), Segment, Tealium AudienceStream CDP, and Zeta.

sources in productive ways (e.g., around user identifiers, device identifiers, interests, locations, proclivities, etc.). This form of data aggregation is very valuable in the industry and has enabled many different audience data intermediaries to thrive and specialise in recent years (Smith, 2019).

This was especially the case since the GDPR went into force in May 2018, which yielded additional power to audience intermediaries like LiveRamp and Salesforce who formed *direct relationships* with consumers (in contrast to the indirect, intermediated relationships of many competitors).[78] Moreover, each of these data providers creates an average of 760 buyable 'audience attributes' (or data points, e.g., interests, demographics, behaviours, etc.), which DMPs and CDPs aggregate (Marshall, 2019). For instance, Oracle Data Cloud enables audience creation from multiple sources (i.e., AddThis, BlueKai, and Datalogix, all three now acquired by Adobe), each offering distinct audiences for targeting. BlueKai is one of the largest third-party data marketplaces worldwide and provides access to data from over 1,500 partners and 45,000 modelled audiences, as well as integrations with over 250 media and technology partners (e.g., digital publishers, advertising networks and exchanges, etc.). In short, DMPs and CDPs facilitate the creation, modelling, and use of audiences, making them core infrastructure providers that power the audience economy [▸ Figure 4.2(b) and (c)].

DMPs and CDPs are central because of their roles as data aggregators as well as their extensive partner integration networks, enabling them to 'activate' audiences as far as their integration networks extend. Consequently, they function as 'gatekeepers' to a universe of audiences, devices, and media distribution channels only programmatically accessible through them. For example, AppsFlyer is a mobile app analytics platform whose Universal SDK 'connect[s] advertisers to the entire mobile ecosystem' through its integration with over 5,000 partners.[79] Given the strategic importance of data aggregation and partner integration networks in the audience economy, many large companies have acquired leading audience intermediaries of their own (Smith, 2019: 6).[80] These M&As are not only significant because of the

78 For example, the GDPR has shifted the business models of data intermediaries based around 'third-party' data (i.e., collected by companies with no direct relation to the respective customers) to 'first-party' (and sometimes 'second-party') data (i.e., collected by companies and organisations with a direct relation to customers, thus presumably derived with users' permission).

79 https://www.appsflyer.com/mobile-ecosystem/productad-networks/productad-network/

80 E.g., LiveRamp by Acxiom (2014, US$310 million), BlueKai and Marketo by Oracle (2014, US$1.2 billion and 2018, US$4.75 billion, respectively), eXelate by Nielsen (2015, US$200 million), Krux by Salesforce (2016, US$700 million),

consolidation of data assets but also because of the consolidation of infrastructure and other assets (e.g., partnerships, integration networks, reputation, customer records, etc.), transferring their infrastructural and strategic power to their new owners.

Comparable to social media platforms, audience intermediaries differentiate their partners and integrations with speciality labels. These include distinctions based on data source types, whereby the quality and value of data depends on a firm's relation to, or distance from, the data source (e.g., so-called 'first-party', 'second-party', and 'third-party' data).[81] Not all data is equally useful or valuable, and these differences contribute to the structuring of the partner relationship networks we traced and the digital advertising market more generally. Thus, data source distance provides important relationship benefits (i.e., strategic power). To activate audiences and run 'people-based marketing' campaigns across multiple devices and channels, it is necessary for advertisers to identify and 'unify' individuals across channels and devices. While Facebook and Google, through their login services, have access to reliable first-party data about their billions of users across devices and can offer 'people-based' targeting capabilities to advertisers, most of their competitors do not have access to such data. Instead, they can go to any audience intermediary (DMPs, CDPs, data brokers, data marketplaces, etc.) to obtain access to second- and third-party data sources. These data sources are typically less valuable because data may be sourced from external and unknown sources, where it is unclear how such data was gathered (e.g., 'declared', 'inferred', 'modelled', etc.). Moreover, data may have been processed, segmented, repackaged, or sold previously, thus limiting the quality and reliability of the data.

Many audience intermediaries offer so-called 'identity resolution' solutions for matching (or linking) multiple identifiers associated with the same individuals to create and target customer profiles across multiple social networks, websites, and apps (where those individuals are active users). Many of the leading players are

Segment by Twilio (US$3.2 billion), SessionM by Mastercard (2019), and Sizmek, Rocket Fuel, and IgnitionOne by Zeta (2019).

81 As used by many companies and organisations in this industry, 'first-party' data is the information that companies and organisations obtain directly from consumers or customers (i.e., compliant with the EU GDPR, and therefore considered the most valuable type of audience data). 'Second-party' data is the same data, but obtained indirectly from a business partner (i.e., shared under a partnership agreement). 'Third-party' data is considered the least valuable because it is obtained indirectly via data marketplaces that are operated by other companies (who may have transformed and repackaged the original collected data). These terms are thus used to communicate the status of the data for a given company or organisation, not the contents of the data.

now subsumed as part of larger holding companies in this industry (e.g., Adobe, Acxiom, Oracle, Salesforce, etc.), after a significant M&A 'wave'. These third-party 'identity graphs' are used to resolve identities across different devices and sites, and to facilitate personalised marketing and advertising campaigns across these devices and sites (so-called 'people-based marketing').[82] They facilitate the use of audiences across partner integration networks for digital marketing and advertising campaigns. As such, identity resolution providers create the 'connective tissue' between the different platform types found in the ecosystem, including data intermediaries, digital publishers, and advertising networks and exchanges. In short, identity resolution platforms hold strategic and infrastructural power in the audience economy because they *(inter)mediate* the relationships between many different digital platforms and the larger digital marketing and advertising industry.

Facebook and Google are undeniably the most powerful players in this market due to their vast amounts of first-party data. However, there are also initiatives launched to counter the dominance of Facebook and Google's 'walled gardens'. For example, key ecosystem partners Adobe, AppNexus (now Xandr, owned by Microsoft, and formerly owned by AT&T), LiveRamp, Rubicon, DataXu, Quantcast, and MediaMath formed industry alliances to create alternative open identity solutions in response to Facebook and Google's closed solutions. The Advertising ID Consortium based its solution on LiveRamp's IdentityLink technology,[83] while the DigiTrust consortium aimed to develop a 'neutral' identity solution with a common identifier based on cookies.[84] While both consortia failed, partner The Trade Desk, is still actively working on an open-source identity framework 'for the open [W]eb' with industry partners such as LiveRamp, Criteo, and Nielsen (Blustein, 2020). In this market environment, Smith argues, LiveRamp has become an 'essential monopoly', appealing to 'the value of data partnerships to unify consumer identities across markets' and boasting 'the largest deterministic [identity] graph on the open internet […] on par with the largest deterministic closed internet ecosystems' such as Facebook and Google (Smith, 2019: 7).[85] These identity resolution providers have thus become central and powerful players in the audience economy, next to Facebook and Google. Finally, it is worth noting Salesforce's recent acquisition of

82 E.g., Cartographer (owned by Lotame), Shopper Graph (owned by Criteo), PeopleCloud (owned by Epsilon), Identity Graph (owned by LiveRamp), Oracle ID Graph (owned by Oracle), and Experience Platform Identity Service (owned by Adobe).

83 https://www.adidentity.org/

84 https://www.digitru.st/

85 https://liveramp.com/our-platform/identity-graph/

Slack (2021, US$27.7 billion) and TikTok's (owned by ByteDance) partnership-acquisition deal with Oracle as its 'trusted technology partner' in the USA (2020), both reflecting the further integration of social media and the audience economy.

Business partners thus play many different roles in the audience economy, which all contribute to the development of what became a highly complex and interconnected global ecosystem of digital platforms and intermediaries. Because of the immense scale and complexity of this ecosystem, additional research will be necessary to further improve our grasp of specific partnership relations (each of which will be custom and distinct). Nevertheless, this analysis provides an empirical view of the technological and structural features of this complex market environment, which could serve as a basis for such further investigations.

4.5. [DISCUSSION] The significance of business partnerships and partner integrations

Partnerships in the audience economy materialise in both organisational and technological relationships between social media and industry platforms, which makes them powerful and significant. Based on the analysis of these partnership relations, we suggest several ways in which partners and the platform infrastructure they build mediate and shape platformisation and the implications for platform power.

First, partners develop data-sourcing and media distribution infrastructures. They build and extend infrastructures for *data-sourcing* by integrating (collecting, aggregating, linking, and matching) audiences from a large variety of disparate online and offline data sources, enabling the sourcing of data, the creation and modelling of audiences, and the development of analytics services across the ecosystem. They develop infrastructures for *media distribution* (cf. Braun, 2013) by integrating (linking) a large variety of online and offline media distribution channels, enabling the programmatic buying, selling, and delivery of targeted ads and content, the 'activation' of audiences, and the measurement and attribution across the ecosystem. While the first type leads to the aggregation and consolidation of data sources (e.g., interests, purchases, searches, likes, etc.), the second type leads to the aggregation and consolidation of media distribution channels (e.g., social media, search engines, email lists, websites, apps, TV, radio, outdoor advertising, etc.). In short, partners assist in the horizontal and vertical integration—or 'infrastructuralisation'—of many different types of digital platforms and intermediaries, shifting the boundaries 'between infrastructures and sectors, private and public platforms' (van Dijck, 2021b: 2808; cf. Plantin et al., 2018).

These infrastructures are built differently on the Web and mobile media, where SDKs are commonly used (cf. Blanke and Pybus, 2020). However, strategically-placed audience intermediaries such as LiveRamp unify those infrastructures through their identity resolution solutions. As such, the role of partners has become even more important with Google's decision to end Chrome support for third-party Web cookies (imposing its Privacy Sandbox as the alternative) and with Apple giving end-consumers a choice to block its Identifier for Advertisers [IDFA] at the app-level. These changes will have serious implications for the current structure of the partner ecosystem, the strategic positions of partners (especially those in the third-party data marketplace), and the distribution of power within the digital advertising market. Regulators warn that these changes will likely further consolidate Facebook and Google's dominance in the first-party data and digital advertising markets because they can leverage their unique position of power in the ecosystem (e.g., CMA, 2020).

Power is not evenly distributed across the ecosystem and is, in part, the outcome of partnership governance. Ultimately, it is in the interest of players such as Facebook and Google to attain a strategic position within the industry, most effectively through strategic business partnership programmes and integrations with partners' platforms, enabling them to acquire, leverage, and benefit from their strategic and infrastructural power. Only a small number of companies can build both types of infrastructure due to exclusivity as governed through partnerships. This gives such companies positions of strategic power within the ecosystem where both social media and their partners benefit from relationship advantages and the lack of transparency in their platform (Broughton Micova and Jacques, 2020). Without such partners or the infrastructure they have built, there would not be the vast 'digital market infrastructure' (Mellet and Beauvisage, 2020) that gives the largest platforms ecosystem-wide advantages.

Second, any partner creates value not just for one platform but for the entire larger ecosystem and all its members by connecting and integrating the different ends of the audience economy. Many players benefit from these integrations, albeit in different or potentially uneven ways. Social media have a central role in complex 'innovation ecosystems', wherein new value is not only generated by their own (internal) developers but also through innovation by external complementors such as partners (Gawer and Cusumano, 2014). Each partner contributes distinct value and often enhances platform growth in specific markets and industries not otherwise accessible to them, consolidating their infrastructural power (van Dijck et al., 2019; [▸ Ch. 3]). For instance, we found that partners mediate trust and provide specialised digital marketing and advertising technology, data sources, advertising inventory, segments, and the means to target audiences. Audience data providers, in turn, also engage their own partners to further extend the reach and targeting capabilities of social media. In these ways, partners overcome existing barriers and frictions in the accessibility of social media data and functionality, making it easier to spend both on and off their platforms and drive advertising revenue growth. They also translate the (indeterminate) value of social media data and functionality to additional domains and tailor them to their own customers' needs. In short, it is apparent that platforms address and gain a foothold in specific B2B marketplaces and industries in addition to their global consumer reach, which drives revenue growth and the consolidation of strategic and infrastructural power.

More generally, social media's large scale and scope should not be taken for granted, as its status is the outcome of user growth as well as (strategic) business partnerships and partner integrations with selected industry platforms. While platform scale is typically expressed by the total number of active users, we suggest that it is also constituted in the countless technological integrations built between platforms and partners, integrating the many platform ecosystems that comprise the audience economy. Similarly, platform scope involves not only a collection of consumer-facing products and services (CMA, 2020) but also includes the diversified ecosystem of business-facing tools, products, and services complemented by partners or other companies in the ecosystem.

Finally, platform infrastructures for data-sourcing and media distribution developed by partners are typically programmable and programmatic. They are *programmatic* because they define and formalise the interactions and exchanges between a large variety of industry platforms, including audience intermediaries, DSPs, SSPs, and advertising networks and exchanges. As such, they represent the technological middleware between these platforms, enabling the large-scale automation of marketing and advertising-related solutions. These large-scale marketing automations with little oversight have facilitated the 'weaponization' of platform infrastructures by political and anti-democratic actors (Nadler et al., 2018). They are also *programmable* to the extent that any business developer can build 'on top' of any partner's programmable interfaces (APIs, SDKs, or other), extending the reach, scope, and infrastructural power of core digital platforms. Technological relations such as these are necessarily subject to the logic of infrastructural control—PBRs facilitate app development and simultaneously enable platform providers to maintain a firm grip on that development work (Eaton et al., 2015). This logic applies to social media app development platforms as well as to their business platforms. Therefore, API-based platform ecosystems always reflect the underlying networks of infrastructural control and extend the sphere of corporate influence and power (Christl and Spiekermann, 2016) on the business 'side' of digital platforms.

The affordances of programmatic and programmable infrastructure are controlled through distinct governance strategies for app development (through PBRs) and for business and marketing development (additionally governed through partnerships). These differences are tied to social media data and advertising-based business models. App developers can *interface with* social media using their public (open) APIs to access specific data and functionality. By contrast, partners can access social media marketing data and functionality using exclusive business-facing

APIs. This possibility allows those partners to *integrate* their own enterprise software platforms and business solutions with those of social media, facilitating programmatic tools, products, and services while establishing dependencies (cf. Braun, 2013; Blanke and Pybus, 2020). Indeed, the modular architecture of digital platforms, characterised by APIs and SDKs, facilitates the decomposition and recomposition of digital supply chains in the audience economy, largely around a handful of powerful 'nodes'. This study finds that they include not only Facebook and Google, but also other powerful audience intermediaries involved in data aggregation and identity resolution, owned and operated by Big Tech companies. This is also necessary because of the inherent fragmentation of the audience economy with its closed ecosystems, 'walled gardens', and marketing technology and data 'silos' (e.g., Byrne, 2019), which only few can afford to operate to begin with. Unlike third-party app developers and self-serve advertisers, only partners can automate the creation, management, and measurement of ads and targeting of data-based audiences through CRM software integrations. Additionally, only partners can analyse advertising campaign performance across media distribution channels using custom dashboards. Given this environment, we suggest that these partner integrations serve as a key driver of platformisation in the audience economy—one that is governed through PBRs and partnership strategies, and which consolidates the power of large social media and industry platforms. Consequently, it is also a key driver not only for the 'generative entrenchment' of specific digital platforms (Rodón Mòdol and Eaton, 2021; [‣ Ch. 3]) but also for the audience economy as a whole, including its many different participant digital platforms and audience data intermediaries and the ways in which they are (and are not) connected.

4.6. Concluding remarks

This second chapter of Part II asked [RQ2(b)] how governance and power are manifested in the developmental processes of the business ecosystem integrations of contemporary social media platforms generally—that is, beyond just Facebook's integrations with the business ecosystem.

To address this question, it examined the significance of partnerships and partner integrations in the process of platformisation for the 20 most-used social media platforms and explored how their partners mediate and shape power. Specifically, it focused on how the organisational arrangements between social media and other industry players based on partnerships, and the API-based software integrations that underlie these partnership relations, provide insights into platformisation and different features of platform power. I found that partnerships are significant in mediating the effects of social media in different markets and industries worldwide, particularly through key players in marketing and advertising-related areas.

Within this process, I noted that platform power concerns more than market or monopoly power alone.

Partnerships are *endemic* and essential to the advertising business of digital platforms—and to the dominant data and advertising-based business models on the Web and on mobile media. Partners expand the collection, use, and integration of audience data in other industry platforms, markets, industries, and sectors of society. Consequently, platform power is not just held by a single platform but is in part mediated by partners and dispersed within the platform ecosystem, where governance and control are exercised through infrastructure and partnership agreements. Business partnerships establish and govern the preferred pathways (e.g., digital supply chains) and 'nodes' of connectivity in this ecosystem, which delivers strategic and infrastructural power to a handful of social media and industry platforms. Within this process, business-facing APIs have an important gateway function and serve as a source of infrastructural control for platform owners. These partners represent diverse types of audience intermediaries with distinct business models predicated on privileged access to social media's audience data and marketing and advertising services. The advertising duopoly of Facebook and Google depends to a certain extent on their strategic position within the partner ecosystem, while strategic business partners such as Acxiom, Oracle, and Experian benefit from partnerships with Facebook and Google through being among the few with privileged API access to their 'walled gardens'. Additionally, the prevalence of partnerships between audience intermediaries means that it is exceptionally difficult, if not impossible, to trace the origins and flow of audience data throughout the ecosystem.

I further found that the mediation of platform power takes many different forms, ranging from co-operation with digital platforms (e.g., partnerships, integrations, revenue-sharing deals, etc.) to forms of resistance (e.g., industry partnership alliances, open standards, advertising boycotts, etc.). Partnerships simultaneously make data widely accessible and exclusive, that is, they remove barriers and frictions in the exchange of social media data and functionality for businesses and customers, while also making it more difficult for new competitors to participate because of the consolidation of strategic and infrastructural power. Furthermore, companies acquire and leverage these forms of power through M&As in which they extend control over existing partnerships and partner integrations.

Platform power and governance are entangled with partnerships and platform infrastructure in significant ways. Therefore, governing platforms' power necessarily involves studying how this entanglement manifests itself in practice (i.e., through empirical research). Additionally, to clearly understand where digital platforms (social media, audience intermediaries, etc.) obtain their power, and where audience data derives its value, it is necessary to understand the observable B2B relationship networks that exist between different platform types, which create a universe of middlemen and middleware (i.e., intermediaries). That is, API-based partner integration networks serve as conduits for infrastructural and strategic power. Consequently, it is insufficient to focus only on regulating individual technology companies; instead, it is necessary to focus on the artefactual (e.g., technological or API-based) and contractual (e.g., organisational or partnership-based) aspects of connectivity and power (cf. Kenney et al., 2021) that shape the larger ecosystem as a whole. The empirical research identified key (high-level) topological and structural features of the audience economy and identified how the audience economy relates to, or gravitates towards, core social media platforms—whether directly or indirectly through audience intermediaries. Ultimately, this critical orientation allowed situating and contextualising digital platforms, and the sources and limits of their power, as part of an integrated platform ecosystem (Caplan et al., 2020; van Dijck et al., 2019) as opposed to using a single-platform focus. Consequently, this is not only about 'platform power' in a narrow sense but also the configurations and dynamics of power that manifest themselves in the ongoing processes of platformisation and infrastructuralisation (cf. van Dijck, 2021b; van Dijck et al., 2021).

Several areas provide opportunities for further research. First, the audience economy is larger and involves more than what was specifically addressed in this study. The approach and dataset provide useful starting points to undertake additional empirical research to further improve understanding of the structure of the overall platform ecosystem and the (relative positions of) industry players within it. Second, the audience economy has changed rapidly due to evolving industry needs and challenges, legal and regulatory frameworks, and the many M&As within this ecosystem. These constant changes pose methodological challenges but also offer opportunities for tracing platform consolidation and applying evolutionary perspectives to understand individual partnerships and the overall ecosystem better (Helmond and van der Vlist, 2019; [▸ Ch. 3]). Third, this global partner ecosystem has geographical and geo-political characteristics and implications necessitating further research that would provide an informed basis from which to compare USA–European and Chinese platform ecosystems, determine how partnerships cause data to move across (international and intercontinental) borders, and (more generally) identify where data originates, is stored, and moves—a requirement under the GDPR. Local partnerships mediate between Chinese advertisers and major American social media platforms, with an unknown number of audience intermediary partnerships running between them, raising important questions about the geopolitics of data flows (Wodinsky, 2020). Moreover, a network of local Chinese partners allegedly offer Oracle's technology and services to Chinese police and defence entities (Hvistendahl, 2021). Comparative studies of partnerships may reveal different features of platform power and identify other points of intervention for activists, policymakers, and regulators. ▾

III. Mobile ecosystems

5. Governing platform programmability

Exploring the ecosystem of social media-related mobile apps

PARTS I AND II OF THIS DISSERTATION have examined the intricate relationship between the technological and organisational dimensions of platform governance, including from an evolutionary (historical) perspective. Specifically, the chapters in Part II investigated the relationship between (API-based) development 'on top' of platforms and business partnership strategies. This has not only provided empirical insights regarding the integration of social media platforms with larger business ecosystems, but also revealed the significance of business partners in the development of platforms' larger ecosystems.

The last two chapters in Part III both examine the 'technicity' of platform governance in the developmental processes that constitute *mobile application ('app') ecosystems*. Most people today do not use 'desktop' computers to access social media anymore; instead, they use smartphones or other mobile (device) platforms. The apps made for those devices are created by individual developers, business developers, or other types of third-party developers who use APIs to access platforms' data or services. They distribute and monetise their apps through Google Play or Apple's App Store, where users can find and download all Android or iOS apps. Therefore, the chapters in Part III [RQ3(a) and (b)] ask: *How are governance and power manifested in the developmental processes of:* (a) *social media-related mobile app ecosystems for Android (Google Play) and iOS (App Store)* [▸ Ch. 5]; and (b) *the COVID-19-related mobile app ecosystems emerging in the initial stages of the global pandemic crisis (also for Android and iOS)* [▸ Ch. 6]*?*

The current chapter investigates the complex interactions and contested boundary dynamics that manifest around the 'programmability' of platforms—that is, around platforms' capability to change or adapt in response to app developers'

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needs. Because of Google and Apple's unique position as 'gatekeepers' of the mobile ecosystem, these interactions and dynamics do not only manifest between platform owners and third-party app developers, but also with their app stores. Because mobile app ecosystems are constituted by different developmental processes and stakeholders, surfacing the relations and material conditions of platform governance and power involves different empirical approaches than in the previous chapters.

5.1. Introduction to the case study

In May 2018, Instagram announced a new function for end-consumers to share other people's posts to their own Instagram Stories (Instagram Info Center, 2018). This practice of 'resharing', as Instagram called it, had already been introduced over six years prior in a third-party app entitled *Regram*.[86] This popular app with over 500,000 downloads, addressed the platform's lack of support for reposting images on Instagram—a practice referred to as 'regramming' (e.g., [Port:9], 2012). As a workaround, the *Regram* app would load a user's feed and add a 'Regram' button underneath each post to instantly reshare and credit other people's posts. Since 2012, many additional apps have been developed for reposting Instagram content before Instagram finally introduced the then-already popular practice to its own app, albeit in a limited form (Constine, 2019).[87]

Similarly for Twitter, there have been many alternative client apps that people download and use instead of, or in addition to, the official Twitter client app since 2006 (Stone, 2006; cf. Gerlitz and Rieder, 2018). End-consumers may need functionality that is not supported by the official client app, such as mute options, or prefer a different user experience, as offered by minimalist or lightweight client apps. Similar to Instagram, some of these functionalities (such as retweeting and muting) were eventually re-appropriated and implemented on the Twitter website or in the official app (Perez, 2018a). But, as soon as this happens, the original third-party app usually no longer stands a chance at survival. The performance quality of third-party apps often cannot match that of the original app. And even when it does, Instagram and Twitter are still far ahead in other ways: they have already established and consolidated their market and power and can discourage, discredit,

86 Khader, *Regram (Repost Photo & Video for Instagram)*, https://play.google.com/store/apps/details?id=regram.instagram.download

87 As of January 2019, Instagram started rolling out a new 'self regram' function, allowing end-consumers to cross-syndicate their own content to multiple Instagram accounts.

and disallow third-party apps ways, including through infrastructural power (e.g., Blanke and Pybus, 2020; [▸ Ch. 2]).

Digital platforms deploy various governance mechanisms to control third-party app development and cultivate platform ecosystems. On the one hand, they design policies and terms and conditions to communicate to app developers and other user groups about what is and is not allowed on the platform. These policies and regulations also regularly change to cover emerging usage contexts (e.g., Helmond, van der Vlist, et al., 2019). On the other hand, I have argued that they design technical 'platform boundary resources' [PBRs], especially application programming interfaces [APIs] and software development kits [SDKs], to control what can and cannot be built 'on top' of the platform architecture in the first place [▸ Chs. 2 and 3]. PBRs mediate the conflicting goals of third-party app development by transferring design capabilities to third-party app developers whilst enabling digital platforms to maintain control (Ghazawneh and Henfridsson, 2013). In other words, there are inevitable tensions between digital platforms and third-party app developers, whose conflicting interests are continuously negotiated through app development work on both 'sides'.

This chapter is the outcome of another empirical study that surfaces some of the complex relationships and interactions (or relationship dynamics) between digital platform owners and third-party app developers. It argues how the 'programmability' of digital platforms (e.g., Bucher, 2013; Helmond, 2015a; Mackenzie, 2019) turns into a key 'site' of politics (or contestation) where governance and power dynamics manifest themselves. Consequently, it highlights the role of PBR design in cultivating and 'orchestrating' platform ecosystems (Rodón Mòdol and Eaton, 2021; Tiwana, 2014; [▸ Ch. 2]), particularly regarding third-party app development. Additionally, it challenges the concept of 'ecosystem innovation' with empirical insights into the configurations and dynamics of governance and power involved in 'innovation' (e.g., Granstrand and Holgersson, 2020; cf. Cusumano et al., 2019; Gawer and Cusumano, 2014).

These configurations and dynamics are difficult to study empirically because the apps related to social media are not listed in a single place. Instead, it is up to the researcher to locate and demarcate an app ecosystem, which may be done in any number of ways. A common approach is to demarcate platform-based app ecosystems through 'API-based' connections (e.g., Evans and Basole, 2016). For this research, however, I devise an alternative approach that is based on a large sample of social media-related Android and iOS apps derived and demarcated through Google Play and Apple's App Store. This 'app-centric' approach, as I call it, uniquely enables considering *how or when* third-party apps are connected (or otherwise related) to 'core' technical platforms in the first place. As such, I consider the complex relationships and interactions (including infrastructural) that emerge in the appropriation of social media *as platforms*. This inevitably evokes tensions between third-party app developer communities and the respective platform owners, which, as I detail, may be surfaced through critical empirical investigation [‣ Ch. 2].

Specifically, I investigate the Android and iOS apps related to Facebook, Instagram, Snapchat, and Twitter, which are four of the most popular social media worldwide at the time of data collection (Statista, 2019a).[88] While Facebook and Twitter both originally started as social networking sites on the open Web and only later pivoted to mobile, Instagram and Snapchat both originally launched as mobile apps for Android and iOS only and were only later available on the Web. This is a relevant consideration regarding the differences and similarities of their app ecosystems, as I discuss in the analysis [‣ §5.4]. Finally, as I discuss, there are platform architecture design differences between Android Platform and the iOS operating system, which affords and constraints (limits) the development of certain kinds of third-party apps related to each of these social media platforms. Consequently, it is necessary to consider the implications of medium specificity throughout this analysis.

Many third-party app developers use the official PBRs provided by social media platforms, but some also probe the limits of what they are allowed (or encouraged) to build. That is, many apps built for social media comply with the platform's terms and policies, but some also find creative and critical technical workarounds for the technical limitations imposed by the official PBRs. In some cases, digital platform owners respond to these workarounds, such as by revoking the API access credentials of apps, removing their app store listings, or deprecating certain functionality components, as discussed in Chapter 2. Platform owners may also adopt (or integrate) specific functionality components as part of their own tools, products, and services—a process called 'coring' (e.g., Bender, 2021; Rodón Mòdol and Eaton, 2021), which also serves strategic and anti-competitive ends. These types of *boundary dynamics*—that is, the ongoing battle over what is (and is not) part of a platform's 'core' or its larger ecosystem, as I further theorise and analyse in this chapter—are particularly articulated around the most popular social media platforms because they represent commercial opportunities for app and business developers. Their high-quality (and generally well-documented) PBRs offer third-party app developers free, easy, and immediate access to potentially billions of people worldwide. Consequently, there are many third-party apps, developers, and businesses associated with these social media platforms. The examples of apps related to Instagram and Twitter thus represent only some of the many third-party

88 The data that support the findings of this study are openly available in the Open Science Framework [OSF] at https://doi.org/10.17605/osf.io/n3mpj. Data collection was conducted in mid-July 2018.

apps that are in fact built 'on top' of and 'for' popular social media platforms, and which are made available in the leading app stores as well as in some lesser-known app catalogues and directories.[89]

In the next section, I first introduce the contemporary academic literature on Platform Studies and App Studies to position the contribution in-between these research areas. Specifically, I look at the configurations and dynamics of platform governance and power from the perspective of third-party app developers. Second, I detail the empirical approach to identify, demarcate, and derive information about social media platforms' app ecosystems. Third, I present and discuss the outcomes of the empirical analysis in two parts. The first part focuses on the use practices supported by the apps and the medium-specific functions (often called 'features') that underpin them, as well as how these apps are connected to social media platforms in the first place (e.g., technically integrated or otherwise related). The second part distinguishes different ways of *regramming*—that is, how app developers work with (and work around) the distinct affordances, action grammars, and constraints imposed by digital platforms for using their data and functionality. As such, regramming surfaces the politics of a platform's programmability, which, in turn, is crucial to the platform's ecosystem and involves API design, platform governance, and infrastructural control, as well as highly distributed and heterogeneous use practices. Finally, I discuss some of the implications for ecosystem governance, which manifests itself as a complex layered and interconnected configuration of technical specifications and terms and policies that are highly distributed (including the apps themselves, the Android and iOS mobile platforms, their associated app stores, and the social media platforms upon and 'for' which were built).

5.2. [BACKGROUND AND POSITIONING] Platforms and mobile app ecosystems

Research on digital platforms and infrastructure, apps, and their relations largely originates from two different research areas: from critical Communication and Media Studies [C&MS] and from Business and Management Studies, Economics, and Information Systems [IS] research [▸ Ch. 1].

There has been a growing interest in the materiality and technical underpinnings of social media as software-based platforms that (inter)mediate and structure the interactions among multiple user and stakeholder groups with diverging interests and that enable third parties to use their data and functionality to build

89 For example, as of August 2018, IFTTT lists 163 Instagram 'Applets' while Google Play returns 250 app search query results for [Instagram].

new apps and services (Montfort and Bogost, 2009; Gillespie, 2010; Langlois and Elmer, 2013; van Dijck, 2013). (Socio-)technical approaches aim to develop material accounts of software for understanding contemporary computational culture (Fuller, 2014). The relationships between digital platforms and apps have been studied regarding platforms' capacities to govern and control the conditions for app development, for instance by focusing on controlled interactions and exchanges of data and services through standardised interfaces, including APIs and social plugins (Bodle, 2011; Gerlitz and Helmond, 2013; Gillespie, 2010; Puschmann and Burgess, 2013; Werning, 2017).

Additionally, there is an increased dialogue between Platform Studies and Infrastructure Studies, which observes how 'platform-based services acquire characteristics of infrastructure, while both new and existing infrastructures are built or reorganized on the logic of platforms' (Plantin et al., 2018: 1). Meanwhile, apps are also considered to operate as platforms for app developers to build upon, as demonstrated by Facebook's popular Messenger app and development platform (Nieborg and Helmond, 2019). APIs are central to these infrastructural perspectives as common interfaces and 'sociotechnical gateways' (Plantin et al., 2018: 7) for app developers and for the apps they build. For platform owners, API connections render the process of building 'on top' of platforms traceable and controllable, as they enable monitoring and regulating who makes connections and which data, functionality and practices are being built upon or altered [▸ Ch. 2]. More fundamentally, Andreessen suggested that APIs enable the programmability of platforms and their adaptability to custom needs, which may lead to new and unforeseen platform interpretations (and benefit the 'evolutionary trajectories' of these digital platforms, as discussed in Chapters 2 and 3):

> A 'platform' is a system that can be programmed and therefore customized by outside developers—users—and in that way, adapted to countless needs and niches that the platform's original developers could not have possibly contemplated, much less had time to accommodate. (Andreessen, 2007)

In their developer documentation, Facebook and Instagram invite third-party app developers to use their platform resources to 'Add something unique to the community' (Facebook for Developers, n.d.) while ruling out the replication of their core functionality. Twitter similarly demands that app developers 'Avoid Replicating the Core Twitter Experience' (Twitter Developer, n.d.), and Snapchat only recently opened a limited set of public (open) APIs (Snap Business, 2018). While APIs impose de facto infrastructural standards through the data forms and functionality components they make available, they also allow for certain degrees of openness of interpretation. This previously-called 'interpretative flexibility'

(Oudshoorn and Pinch, 2003; Pinch and Bijker, 2012; [▸ Ch. 1: §1.4.3]) concerns perceptions of what digital platforms, social media data, and functions can be used for, and raises the question how third-party apps enable alternative interpretations of social media data and functionality and how platform owners respond to them (Gerlitz et al., 2016; Paßmann and Gerlitz, 2014).

From market-based and innovation perspectives, the interest in platforms concerns the socio-technical relations among core—or 'keystone'—platforms, connected apps, third-party app developers, and businesses, which are underpinned by technological infrastructures (Constantinides et al., 2018; de Reuver et al., 2018; Tiwana, 2014; [▸ Ch. 1: §1.2.2]). Like C&MS scholars, IS researchers generally follow 'platform-centric' approaches with empirical contributions to the understanding of digital platforms—including 'industry platforms', social media, app development platforms, and app stores—and their platform-based 'innovation ecosystems', which consist of heterogeneous app developers, businesses, and apps connected to platforms through APIs (Baldwin and Woodard, 2009; Granstrand and Holgersson, 2020). These apps are often built 'on top' of other platforms as external contributions but may also be embedded within them. Here, platforms are understood as extensible codebases that foster 'generativity' by stimulating external contributions and innovation through hosting open architectures and platform resources that document how to develop apps for them (de Reuver et al., 2018). Most platforms offer various technical PBRs, such as APIs and SDKs, as well as non-technical PBRs, such as developer documentation and platform policies, to enable third-party app development while simultaneously constituting their means of control (Eaton et al., 2015; Ghazawneh and Henfridsson, 2013). An app, in this specific context, is an 'add-on software subsystem or software service that connects to a platform to extend its functionality', and it figures as a complementary good or service presumed to add value to that platform or its 'ecosystem' (Tiwana, 2014: 5–6). However, not all apps contribute equally to the platform, and some may not even align with its objectives, raising the question of how exactly those apps relate to or complement platforms.

The two approaches share a 'platform-centric' perspective that provide insights into the role of the core technical platform in facilitating and governing the relations between digital platforms—which serve as the underpinning technological infrastructure—and their ecosystems of third-party apps. I examine these relations between digital platforms and app ecosystems from what I will call an 'app-centric' perspective instead of a 'platform-centric' perspective. This is increasingly relevant because large numbers of apps are not created as standalone software applications but are built 'on top' of and for social media platforms, which raises critical questions around the configurations and dynamics of power between them (Dieter et al., 2019). Many apps establish connections with remote hosts or servers to request content, serve ads, and connect to social media platforms' APIs to retrieve structured social data or embed social plugins. An 'app-centric' perspective thus enables an exploratory empirical approach to the study of digital infrastructure and the *infrastructural relations* that emerge between digital platforms and their app ecosystems. In short, I shift the perspective from 'innovation' by digital platform owners themselves to the distributed value creation by third-party app developers, and the subsequent centralised value capture by the platform owner (e.g., Barns, 2019: 5; Gawer, 2021a; Gerlitz and Helmond, 2013; Kapoor, 2018). Arguably, this is a key feature of platforms' architectures and a key source of their influence and power in the larger ecosystem.

Typically, the relationships between digital platforms and third-party apps are studied in a narrow sense as technical 'API-based' connections because APIs (and SDKs) provide the official means for the programmability of platforms. This approach includes using publicly-accessible app directories such as ProgrammableWeb and IFTTT to locate and examine apps built 'on top' of social media platforms' APIs (Evans and Basole, 2016; Werning, 2017).[90] This presumes, however, that the relations between platforms and apps are always 'API-based', which is not always the case. As such, the approach does not consider the possibility of alternative and less structured kinds of relations, including relations that are not inherently centralised or hierarchical in the interests of the platform owners. Instead, I am interested in scoping the broader set of relations that exist between apps and social media. Consequently, I explore a corpus of apps related to social media by using app stores for Android and iOS mobile apps. These apps may be built 'on top' of social media platforms' APIs, or they may be built 'for' (or 'complement') social media without a technical integration with the social media platform, such as a third-party app that merely complements the user experience.

The analytical approach relies on a relational concept of infrastructure. According to Star and Ruhleder, infrastructure is not just a layering of technical standards but 'shapes and is shaped by the conventions of a community of practice' (Star and Ruhleder, 1996: 113). That is, they ask '*when*—not *what*—is an infrastructure' (1996: 113; cf. Gerlitz, Helmond, Nieborg, et al., 2019), which means that an infrastructure should be understood and studied in relation to the specific behaviours, practices, and systems that it supports in practice (i.e., empirically). Indeed, this relationality between infrastructure and communities of practice is central to the empirical study of the relations between apps and social media. I suggest that social media usage is highly standardised through 'grammars of action' (or action grammars)—the set of specific 'unitary actions' (and interactions) that are supported

90 ProgrammableWeb, 'API Directory', https://www.programmableweb.com/apis/directory; IFTTT, 'Services', https://ifttt.com/services.

and 'captured' by the system (Agre, 1994: 107–109); that is, articulated and 'tracked', analysed, and ultimately monetised in different ways (e.g., Gerlitz, 2016; Gerlitz and Rieder, 2018; Kornberger et al., 2017; van der Vlist, 2016). Posting, sharing, liking, and following represent such action grammars for end-consumers as well as data objects used to establish 'orders of worth' (Gerlitz, 2016; Kornberger et al., 2017). Here, APIs are the gateways that enable the exchange of this information between software-based systems and subsystems. The *Regram* app for Instagram accommodates image-reposting practices on Instagram but also raises the question of how (or how much) third-party app developers (are allowed to) appropriate social media's proprietary action grammars before running into trouble with the platform owner (seeking to secure and control the uses of those action grammars).

5.3. [MATERIALS AND METHODS] Investigating platform-based mobile app ecosystems

5.3.1. *App store data collection*

App stores are key (perhaps 'native') environments for the distribution and monetisation of mobile apps to identify apps related to the specific social networks of Facebook, Instagram, Snapchat, and Twitter. Serving both as markets and indices of apps, app stores can be used to scope collections of apps in various ways (Dieter et al., 2019). My co-authors and I focused on Google Play and Apple's App Store as the two most popular app stores serving nearly the entire mobile app market (Statista, 2020), and queried them for apps associated with Facebook, Instagram, Snapchat, and Twitter. Facebook and Twitter have both been around for over a decade and have consolidated their platforms and APIs for app developers and businesses, while Instagram and Snapchat originally launched as mobile apps, before launching their platforms and APIs for app developers, businesses, and digital marketers and advertisers (Statista, 2019a; [‣ Chs. 2 and 3]). Additionally, Instagram and Snapchat reach different, mostly younger audiences as compared to Facebook and Twitter, which leads to different motivations and uses of these social media (e.g., Alhabash and Ma, 2017).

Although this study covers two different app stores and four different social media, it is not the aim to develop a comparative analysis based on these stores and social media. Yet, the multiple app ecosystems that we study give a broader view of the relationships between digital platforms, mobile platforms, app stores, and app ecosystems. Specifically, we 'repurpose' the extensive directories of app stores and their built-in search and clustering capabilities for demarcating our source sets of apps (Dieter et al., 2019; cf. Rogers, 2013b). In this regard, it is relevant to consider the commonalities and differences between both stores. Google Play and the App Store may look like one another on the 'front-end', but methodologically there are relevant differences that manage the visibility of individual apps as well as how app data may be collected. Both app stores follow their own logic and mechanisms for reviewing, listing, organising, sorting, ranking, relating, and recommending apps. These aspects influence which apps are shown for a query and which apps are considered related to other apps. And even before apps become visible in the app store, there are policies, regulations, and app review guidelines that may prevent developers from listing their apps.

Due to these and other differences, both app stores demand custom methods of data collection. Studying mobile apps comes with many challenges and limitations, not least because it is impossible to 'scrape' information from mobile apps or devices, a technique commonly used for collecting data on the Web (Dieter et al., 2019). However, we found that both Google Play and the App Store maintain a Web-based presence in addition to their 'native' Android and iOS apps that we used for data collection.

5.3.2. *'Repurposing' the analytical techniques of app stores*

In this research, we 'repurpose' some of the analytical techniques of app stores and use them for digital research instead. As app 'marketplaces', app stores hold valuable and detailed information about individual apps for their investigation. Additionally, app stores organise and structure that information in certain ways and use it to drive techniques for sorting, ranking, clustering, and relating apps to one another such that end-consumers can more easily find and compare apps. In the tradition of 'digital methods' research, we explore these affordances and design methods and tools for repurposing online devices and platforms, such as app stores in this case, for social and cultural research (Rogers, 2013b; Weltevrede, 2016; Dieter et al., 2019). Here, we are particularly interested in employing the capabilities of app stores for characterising the relations between social media and the connected ecosystems of third-party Android and iOS apps (and, of course, the app developers who built them), and the governance and power dynamics that manifest themselves in these relations. This is also a user-centric perspective on the study of apps because most people—developers and end-consumers alike—find and use apps through the app stores.

First, we queried Google Play and the App Store for [Facebook], [Instagram], [Snapchat], and [Twitter].[91] To prevent personalisation and localisation in the results returned, we used Internet proxies to default the locale to the United States and to English language settings. This type of customisation poses challenges for empirical research but may also provide opportunities for research that purposefully *employs* these methods of the medium (Dieter et al., 2019). In total, Google Play yielded 998 apps across all four search queries, and the App Store yielded 531

91 Square brackets are commonly used to represent search engine queries, following conventions employed at Google (Rogers, 2013b: 213).

apps [▸ Table 5.1]. For each app listing, app stores provide several details, including app titles, descriptions, and various technological specifications. Most of these details are written by app developers themselves, and there are app store guidelines that stress the importance of accurate and focused titles and descriptions to cover what the app is about (Apple Developer, n.d.; Google Play Console Help, n.d.; Google Play Console Help, n.d.). This is important information for the analysis because we use these titles and descriptions for identifying the key practices, functions, and platform connections of apps. Second, to enlarge these source sets with additional relevant apps that were not returned by the initial search queries, we subsequently followed each app's recommendations. Notably, app stores employ different kinds of algorithmic and personalised recommendations to recommend related or similar apps to end-consumers (Dieter et al., 2019). Google Play shows 'Similar' apps based on topics derived from words and phrases in the titles and descriptions of apps—creating relations based on topical clusters. The App Store, however, lists related apps under 'You May Also Like' (specified in the URL as 'customers-also-bought'), which are based on other apps purchased, downloaded, or installed by end-consumers—creating relations based on use practices. App store listings, clusterings, and rankings all tie into how large app stores function as powerful 'gatekeepers', shaping (if not determining) the success and failure of individual apps (e.g., Dieter et al., 2019; Helmond et al., 2018; Morris and Morris, 2019; cf. Walz, 2015). Taking all related apps listed for the initial search results, the Google Play source set led to a source set of 12,772 unique apps and the App Store to 5,180 in total [▸ Table 5.1]. We collected the names and details of all these apps (e.g., bundle identifiers, app store categories, app developer names, descriptions, ratings, reviews, prices, software versions) using custom programmatic data retrieval tools and Web 'scrapers'.[92] We 'scraped' the Web pages of the Android and iOS apps to collect their details and related apps, which conflicts with the terms and policies of both stores.

92 The tools were designed by the authors and implemented in collaboration with Emile den Tex (Digital Methods Initiative, University of Amsterdam). Digital Methods Initiative, *Google Play 'Similar' Apps*, https://tools.digitalmethods.net/beta/googlePlaySimilar/; Digital Methods Initiative, *iTunes Store*, https://tools.digitalmethods.net/beta/itunesStore/. See also: App Studies Initiative, *ASI Tools*, http://appstudies.org/tools/. Please note that both tools were updated in 2020 for the purpose of the research presented in Chapter 6 and are now available at different URLs.

Table 5.1. Number of unique Android and iOS apps per social media-related source set.

Search query	Google Play		iTunes (App) Store	
	Search	'Similar'	Search	'You May Also Like'
[Facebook]	250	2,419	161	1,736
[Instagram]	250	2,906	106	772
[Snapchat]	250	3,673	130	1,369
[Twitter]	248	3,774	134	1,303

To analyse how apps and their app developers make use of platforms' action grammars, we developed a methodology with qualitative and quantitative (computational) components. The methodology involves a close reading of app titles and descriptions followed by an emergent, collaborative app coding process. The outcome is a hierarchical model of classification based on many advanced search queries to enable a computational analysis and categorisation process for the entire corpus of social media-related apps. Like the computational topic classifier models used for identifying Google Play topic clusters, we identified prominent words and phrases describing the apps and subsequently determined broader topics to cluster and interpret them. For this study, these broader topics are of three different kinds: social media-related use practices (e.g., monitoring and growth, content creation), common functions shared by all four social media (e.g., growth, effects, and filters), and functions linked to medium-specific features (e.g., friends, followers, Snaps, tweets). This dual focus on practices and functions allows determining the forms of functionality present in apps, and how they relate to the specific action grammars of each social media platform.

To detect the resonance of each identified use practice and function in the entire source set, we created search patterns with extended regular expressions that enabled doing advanced pattern-based searches across all four source sets.[93] In a second step, we also ran 'nested' searches to further contextualise each positive match when it co-occurred with one of the social media platform names (i.e., Facebook, Instagram, Snapchat, Twitter), which helped determine the relevance of all matches. The outcome is a frequency count for each classified use practice and

93 Most apps in the corpus had English descriptions (95.71%), followed by a relatively small number in Arabic (1.14%), and Spanish (0.91%), which led us to include some search patterns in these languages. All searches were processed computationally with *grep*, a UNIX-based command-line utility for searching textual data. Each use practice and function is searched for with multiple search patterns (although we counted positive matches only once per app).

function (per store, per source set), which enables further qualifying the relations between apps and associated platforms.[94]

5.4. [ANALYSIS] Social media-related mobile app ecosystems

In the first part of the empirical analysis, we show how third-party mobile apps are related to social media platforms, which we captured in several figures. Figures 5.1(a) to (d) provide overviews of the functions and practices that social media-related apps support and how they compare across source sets. This enables analysing and comparing the results for each social media platform, which helps to better understand the unique relations between those platforms and their ecosystems of apps and app developers. Each figure combines two hierarchical 'sunburst' diagrams in one image, displaying the range of functions and practices associated with each social media platform. The inner 'sunbursts' show the results for the smaller source sets only—that is, of the initial and most relevant search query results only (i.e., app results for the search queries [Facebook], [Instagram], [Snapchat] and [Twitter]). The outer 'sunbursts', by contrast, show the results for the larger source sets of all the algorithmically-curated—and inevitably less relevant—app results (i.e., app results listed as 'Similar' and 'You May Also Like').

The inner and outer 'sunbursts' themselves display the range of practices supported by third-party apps (in the innermost rings) as well as the affordances or functions that enable these practices in the first place (in the outer rings). The more each use practice or function resonates with the source set of apps, the larger its relative size. Finally, the thinnest rings on the edge of each 'sunburst' show the number of apps that co-occur with the initial search query for that source set. That is, it shows the number of apps in each category that explicitly acknowledge their connections to social media platforms, which usually indicates stronger relationships (e.g., a technical, API-based integration) between platforms and apps.

Overall, we found that apps sourced directly from the initial search queries have much higher relevance, whereas algorithmically-related 'Similar' apps or apps 'You May Also Like' score lower due to topic drift. Apps in the latter category are often complementary and may be used alongside the official social media app but are usually not explicitly built for or 'on top' of that platform. They are complementary

94 We designed and used the *Lexicon-Based Categorization and Analysis Tool [LE-CAT]* to automate the analysis and categorisation of apps based on app titles and descriptions. The tool was implemented in collaboration with James Tripp (Centre for Interdisciplinary Methodologies, University of Warwick). See: App Studies Initiative, ASI Tools, http://appstudies.org/tools/.

to social media, rather than integrated with social media. Among the four social media that we examined, apps for Instagram scored the highest on relevance, with nearly 9 out of 10 apps making explicit references to the core platform in the apps' title or description (avg. = 87.86%; [▸ Figure 5.1(b)]).

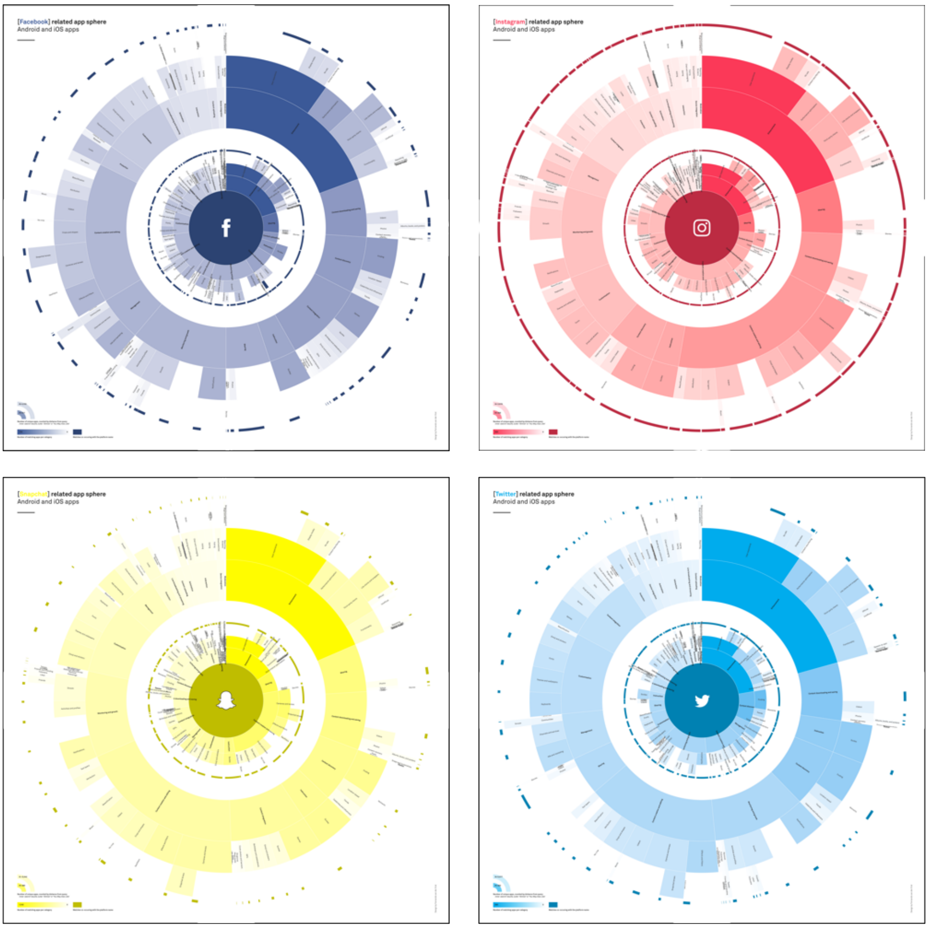


Figure 5.1(a) to (d). Android and iOS apps related to [Facebook] (N = 4,566), [Instagram] (N = 4,034), [Snapchat] (N = 5,422), and [Twitter] (N = 5,459) ['sunburst' diagram, small multiples]. Each diagram contains two 'sunbursts': inner 'sunburst' rings present the categorised search results for the initial search query results only (N = ca. 1,000 apps each); the outer 'sunburst' rings present the categorised (algorithmically-)related apps (N = ca. 3,500 apps each).

Hierarchy: use practices (first ring), first-order functions ('features) common to all four social media (second ring), and second-order functions specific to each social media (third ring); segment size and colour-coding: scaled by frequency count of matching apps (linear scale). Data: Google Play and App Store. High-resolution figures are openly available in OSF at https://doi.org/10.17605/osf.io/n3mpj.

5.4.1. *Social media-related use practices and functions*

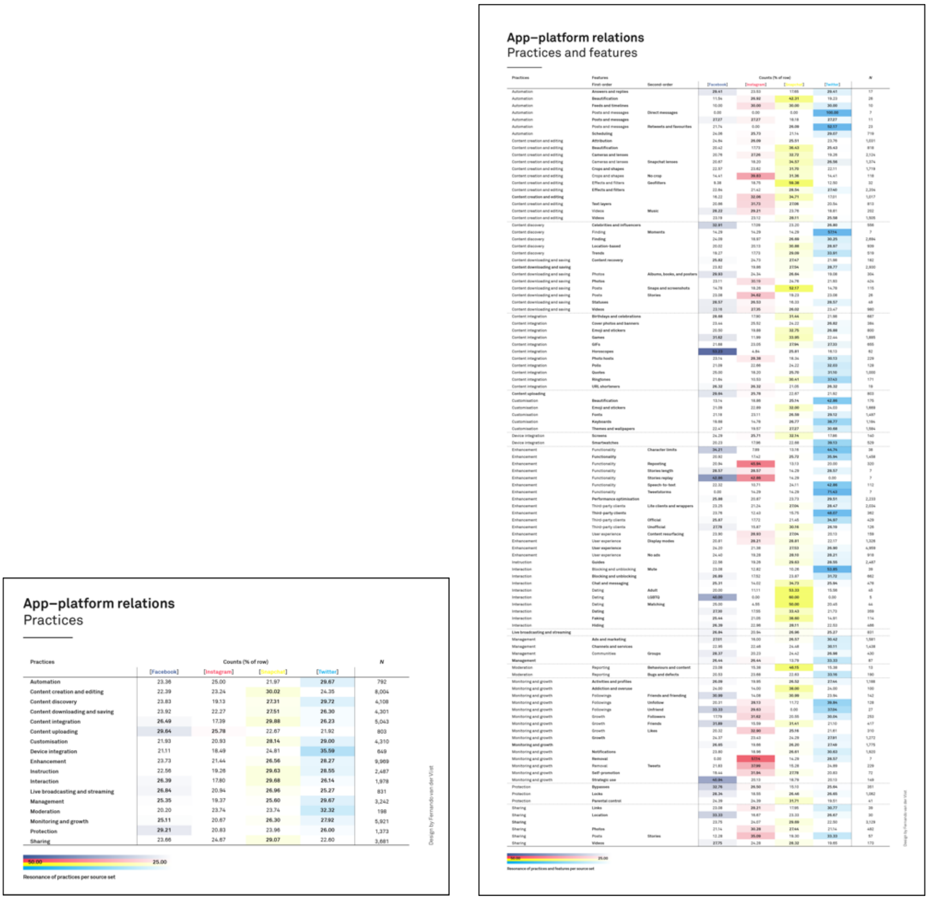
By combining quantitative and qualitative methods of analysis, we gain detailed insights into the individual apps related to each social media platform, as well as an overview of all the kinds of apps that are available [▸ Figure 5.2(a) and (b)]. As such, this analysis differs from those of individual apps and their varied graphical user interfaces [GUIs], affordances, features, use practices, and user communities (e.g., MacLeod and McArthur, 2018; Duguay, 2017; cf. Dieter et al., 2019; Gerlitz, Helmond, Nieborg, et al., 2019).

The analysed apps relate to the social media action grammars in several ways.[95] Most prominently, most apps related to social media do not alter but enhance the existing functionality components or user experience. They also complement the existing practices of content creation for all four of the social media platforms. Many apps offer analytics-related functionality, which may enable the end-consumers of these apps to do 'social monitoring' and to grow or manage their followings on the platform. In these cases, apps are supporting practices that are ultimately in line with the aims and objectives of the social media platform itself. By contrast, a smaller number of apps enhance the existing functionality related to 'content discovery' or finding new appropriate content and to sharing, uploading, (live) streaming, downloading, and saving content from a particular social media platform such as to the user's mobile device. And finally, we also counted many apps that inform new end-consumers with instructions and 'how to' guides, to protect the privacy of end-consumers, and screen locks to regulate immediate access to a user's account or mobile device. These examples were found across all four social media platforms and do not seem to be platform-specific but may be specific to social media in general.

In addition to use practices shared by multiple social media platforms, Figure 5.2(a) shows that there are also social media-specific use practices and functions. For example, there are apps for integrating connected devices in Twitter-related apps, unique camera content creation and editing apps for Snapchat, and content discovery and integration-related apps for Snapchat and Twitter, and content uploading and protection and screen lock apps for Facebook. Although the app category can be shared across multiple social media platforms, the specific implementation is often unique due to the distinct architecture design of each social media platform. Compared to Facebook, Snapchat, and Twitter, Instagram-related apps seem to be the least distinctive regarding the associated use practices. Overall, it makes sense that Instagram and Snapchat-related apps focus much more on the creation and editing of original content while Twitter and Facebook-

95 Specific examples of apps are discussed in further detail in the next section.

related apps contain much more alternative client apps, speaking to their longer existence and higher number of GUI redesigns.



Practices	Counts (% of row) [Facebook]	[Instagram]	[Snapchat]	[Twitter]	N
Automation	23.36	25.00	21.97	29.67	792
Content creation and editing	22.39	23.24	30.02	24.35	8,004
Content discovery	23.83	19.13	27.31	29.72	4,108
Content downloading and saving	23.92	22.27	27.51	26.30	4,301
Content integration	26.49	17.39	29.88	26.23	5,043
Content uploading	29.64	25.78	22.67	21.92	803
Customisation	21.93	20.93	28.14	29.00	4,310
Device integration	21.11	18.49	24.81	35.59	649
Enhancement	23.73	21.44	26.56	28.27	9,969
Instruction	22.56	19.26	29.63	28.55	2,487
Interaction	26.39	17.80	29.68	26.14	1,978
Live broadcasting and streaming	26.84	20.94	26.96	25.27	831
Management	25.35	19.37	25.60	29.67	3,242
Moderation	20.20	23.74	23.74	32.32	198
Monitoring and growth	25.11	20.67	26.30	27.92	5,921
Protection	29.21	20.83	23.96	26.00	1,373
Sharing	23.66	24.67	29.07	22.60	3,681

Figure 5.2(**a**) **and** (**b**). Categorised relations from social media-related Android and iOS mobile apps to 'core' technical platforms (i.e., 'app–platform relations'), grouped by use practices [heat map matrix diagram]. Each row presents a percentage corresponding to the count of matching apps per source set. Cells with values higher than 25.00% are indicative of relative *medium specificity*: the higher the percentage value, the more specific the corresponding use practice or function ('feature') is to the respective social media-related source set, as compared to the other source sets.

Cell colour-coding: by frequency count of matching apps (linear scale). Data: Google Play and App Store. High-resolution figures are openly available in OSF at https://doi.org/10.17605/osf.io/n3mpj.

Looking at the function level, however, the distinctions between these four social media platforms are more strongly articulated. In contrast to use practices, functions are related specifically to the functionality components and technological architectures of digital platforms, which makes those platforms unique and different from one another. Even if functions look similar on the 'front-end', they are usually implemented differently at the 'back-end', and their accessibility for third-party app development purposes may be governed differently. As Figure 5.2(b) shows, there are clear differences between social media platforms on the function level due to their different use contexts: Instagram and Snapchat are primarily image and video-based, while Twitter is still mostly text-based. Snapchat-related apps include many 'cameras' and 'lenses', effects, and filters, while Instagram-related 'no crop' and square image apps may let end-consumers post full size images without cropping or let end-consumers superimpose text layers such as for quotations over their photos. When introduced, the 'no crop' apps addressed a limitation unique to Instagram, namely, that the official app automatically square-cropped images before the platform would allow portrait and landscape formats.[96] By contrast, for Facebook we found birthday calendars and other event-related celebration apps, horoscopes, and games. And for Twitter, we found apps related to photo hosting, polling, quotations, and ringtones.

Some use practices are common to all four social media but are implemented differently due to different platform architecture design specifications, including constraints, functions, metrics, and numbers. Apps for content discovery, for instance, are common in all source sets but are articulated differently for each social media platform. For Twitter, we found apps related to Twitter Moments, Trends, location-based discovery of content or end-consumers, and for Facebook, we found apps for discovering celebrities or influencers on the platform. Additionally, we found many apps that enhance certain functionality components—especially for Facebook, Instagram, and Twitter. For Facebook and Instagram, these apps enable end-consumers to replay Stories, share video Stories with a duration longer than the set limit of fifteen seconds, or add music and sounds to Stories. For Twitter, there are enhancement apps for letting end-consumers write tweet posts beyond the character limit (originally 140 characters, now 280 characters), post so-called 'tweetstorms', where end-consumers post a series of related tweets successively, or post tweets through voice dictation instead of keyboard input. None of these alternative use practices were originally supported in the official apps. They were eventually subjected to 'coring', whereby functionality provided by third-party apps is integrated into a software platform's 'core' (Bender, 2021; Rodón Mòdol and Eaton, 2021), thus potentially posing an (anti-)competitive threat for

96 This is after the company discovered that 'nearly one in five photos or videos people post aren't in the square format', which suggests that these photos or videos are created with third-party apps before they are posted on Instagram (Instagram Info Center, 2015).

third-party app developers. For example, Twitter updated its 140-character limit in 2017, 'giving you more characters to express yourself' (Rosen and Ihara, 2017).

We also found apps that seek to enhance the user experience generally, not just specific functions. Apps for blocking ads and 'resurfacing' past content occurred more frequently for Snapchat, while for Facebook and Twitter, we found many apps for optimising mobile device performance and reducing network traffic loads of 'heavy' apps like Facebook and Twitter. These apps, importantly, let end-consumers in remote and unconnected areas participate on social media despite the physical network infrastructure constraints that exist for them and increase the battery life of their phones.

Social monitoring and follower growth-related apps are prominent in all source sets. We found Twitter-related apps for unfollowing, content removal, and follower growth; Instagram-related apps for content removal, self-promotion, follower and like-growth, and self-monitoring to limit use (and overuse) and smartphone addiction; Snapchat-related apps for monitoring one's following and also for tracking use (and overuse); and Facebook-related apps for monitoring (or lurking) friend activity, profiles, unfriending, and apps for strategic use practices such as for scheduling and timing posts. Instagram notably features the most anti-addiction apps, which are apps for monitoring and controlling one's time spent on Instagram, for instance. And here too, Facebook and Instagram launched their own 'wellbeing dashboards' for combatting app addiction (Facebook Newsroom, 2018), providing another example of platform coring.

For Facebook and Twitter, we noticed many apps developed to address the needs of businesses, including digital marketers and advertisers, with apps for operating multiple social media accounts from a single interface and for cross-posting content or marketing across multiple channels. And although sharing is a core aspect of social media in general (e.g., Bodle, 2011; John, 2016; van Dijck, 2013), we find differences regarding the object of sharing. For Twitter, sharing-related apps focus on links, locations, and posts, and for Facebook and Instagram they focus on Stories, videos, photos, and links. Similarly, apps for downloading or saving social media content onto the user's mobile device target different media forms, relevant to each social media platform. While Facebook and Instagram-related apps were mostly content 'downloaders' and 'savers' for photos, videos, Stories, and status updates, apps for Snapchat allegedly provide functionality for recovering deleted posts, saving Snaps, and downloading videos.

Like the apps for Facebook and Twitter, some apps explicitly target the existing use restrictions of Snapchat, a platform characterised by its 'ephemeral content'—content that lasts only for a limited period (e.g., Stories posted automatically disappear after 24 hours). Clearly, not all third-party mobile apps straightforwardly 'complement' social media; some of them (temporarily) destabilise or alter the existing user experience of end-consumers, despite the existence of platform terms and policies. Consequently, the question is whether social media platforms take notice of such violations, and if they do, how they respond to them. This concerns the reach and limits of platforms' governance and control mechanisms, which depend on their PBRs (e.g., access controls implemented in APIs and SDKs, rate limits, app review processes, etc.), associated reference documentation, and platforms' terms and policies (Ghazawneh and Henfridsson, 2013; Poell et al., 2021; [▸ Chs. 2 and 3]).

5.4.2. *The relations between apps and social media*

The analysis of app titles and descriptions revealed many ways for apps to relate to social media platforms by enhancing or changing existing functions and use practices or by adding new ones. In the next step of the analysis, we consider if and how those relations are implemented on the technical level, or from an app developer's perspective. That is, we explore whether these apps connect to social media platforms using any of the official technical PBRs, such as the platforms' own APIs, as the preferred and official means for app development. In the section that follows this, we then discuss a variety of apps that each seem to violate platforms' terms and policies [▸ §5.5].

It is relevant to distinguish several kinds of relations between these Android apps and social media [▸ Table 5.2]. Looking merely for mentions of the names of social media platforms, or terms and phrases unique to them, such as 'tweet' for Twitter, signals that there is at least some explicit relation between the app and social media platform. When we then look for co-occurrences with terms such as 'disclaimer', we find that a considerable number of app developers include legal disclaimers in their app descriptions. This way, app developers aim to distance themselves or their creations explicitly from a certain social media platform. It can be difficult for end-consumers to distinguish official and third-party apps merely based on app titles, so this practice communicates about the status of these apps. Additionally, app developers may believe that a disclaimer protects them in case their apps are found to be in violation with the platform's terms and policies.

Some app developers use the description field to explain how their app is built or integrated with the social media platform by mentioning the APIs used, to ensure potential users about its proper functioning. Not all the functions and use practices promised by these third-party apps are technically feasible, given the possibilities and limitations of each social media platform. Certain functionality components are supported on the technical level, which enables developers to programmatically access particular action grammars through the official provided APIs and SDKs. But not all the social media platforms in this study provide such programmatic access to third-party app developers, and even if they do, their possibilities are limited. Since their early days, Facebook and Twitter have had open development platforms with public APIs and SDKs for third-party app developers and business developers. Instagram, by contrast, shut down its legacy Platform APIs for third-party app development in 2018. While Instagram launched a new and rebranded Graph API, which is now integrated with Facebook Platform [‣ Chs. 2 and 3], this is not a public API and only available for business developers (Facebook for Developers, n.d.). Snapchat never had a public API for third-party developers but offered technical PBRS, such as its Marketing APIs and Lens Studio, to its business partners (Snap Business, n.d.). This indicates that the relationship between third-party app developers, social media platforms, and mobile platforms (including associated app stores) is volatile and subject to continuous change, with potentially severe implications for app developers.

To explore if and how apps actually connect to social media platforms on the technical level, we further conducted a 'static analysis' of Android Package [APK] files to examine the contents of Android app files in the four source sets of social media-related apps, using their decompiled source code (Dieter et al., 2019). With this form of technical inspection, we can detect the use of APIs and SDKs by app developers as actually implemented in specific apps as well as the addresses for remote network requests made to platforms, which are necessary for connecting to social media APIs and which are subsequently used by apps to load, embed, and wrap social media content or functionality components within apps. In other words, we can look for elements of digital infrastructure and traces of network connections between apps and social media. When we detect such elements or traces in the decompiled source code of an app, we know that the app is *in fact* built 'on top' of a particular social media platform and has embedded its official technical PBRS to support (part of) the app's functionality. If we locate the presence of an official API or SDK in the app's source code, it means that the app complies with the platforms' preferred and official means of app development, whilst enabling the platform to control and govern its programmability. And conversely, if we cannot detect any such elements or traces in an app's source code, it is most likely not built with any of the official technical PBRS provided by the social media platform. That is, app developers may claim to have implemented certain functionality for their end-consumers (including to mislead users), but that usually necessitates an official API-based integration with the platform in one way or another. However, as we found, app developers sometimes discover workarounds that involve the use of unofficial technical PBRS. Thus, locating the presence or absence of official PBRS provides important means to characterise how a platform's programmability is used and governed in practice.

Table 5.2 provides an overview of the number of detected relations between apps and social media platforms, sorted by relation type. This analysis only includes the Android apps from the initial source sets of Google Play search query results, and not the apps 'Similar' to those apps. We did not include iOS apps in this part of the analysis because they are protected by Apple's digital rights management [DRM] system, which makes it more difficult to decompile their source code for the purpose of this analysis. Apple's approach thus also limits the possibilities for critical investigation.

Table 5.2. Number of relations between apps and social media per source set.

Type	[Facebook]	[Instagram]	[Snapchat]	[Twitter]
Brand (mentions)	1,449 (34.96%)	2,945 (80.03%)	614 (12.17%)	1,107 (21.80%)
Legal (mentions)	302 (7.29%)	318 (8.65%)	268 (5.31%)	305 (6.01%)
Technical (mentions)	61 (1.47%)	62 (1.68%)	70 (1.39%)	114 (2.24%)
Technical (libraries, SDKs)*	83 (33.20%)	0 (0%)	0 (0%)	40 (16.13%)
Technical (HTTP requests)*	156 (62.40%)	89 (35.60%)	12 (4.80%)	102 (41.13%)

* *Only for the subset of Google Play search results (N = 998).*

Based on the technical inspection, we found that a third (33.20%) of all the Android apps for Facebook in the source set contain the Facebook Android SDK (Facebook for Developers, n.d.), and that a sixth (16.13%) of the apps for Twitter use the Twitter Kit (Twitter Developer, n.d.), which are the official software libraries for integrating Facebook and Twitter content or functionality in third-party apps. Instagram and Snapchat both did not provide open SDKs, so we could not identify any official software libraries in the apps for these two social media platforms. But when we look at the HTTP [Hypertext Transfer Protocol] requests made by these Android apps to the servers of Facebook, Instagram, Snapchat, and Twitter, we get a different perspective. HTTP requests are used to structure the network traffic for communication between 'clients' and servers, such as between apps for Facebook and a Facebook server. We noticed that apps make network requests to access social media platform's public (open) APIs but also their private (internal) APIs, their mobile sites, and request content from their content delivery networks [CDNs]. Nearly two-thirds (62.40%) of the apps for Facebook make requests to facebook.com (e.g., graph.facebook.com, m.facebook.com), to sign in and authenticate with Facebook, and to retrieve data from Facebook's mobile site, on which the majority of 'lite' or lightweight clients in our source set are built. Over 41% of apps for Twitter make requests to Twitter's APIs and mobile site (e.g., api.twitter.com, mobile.twitter.com), and over 35% of the apps for Instagram connect to Instagram's open (legacy) or internal APIs (e.g., api.instagram.com, i.instagram.com). Only 4.8% of the apps for Snapchat make network requests to the platform. Snapchat had no public API and actively blocked third-party apps from accessing its internal API (Team Snapchat, 2014). These numbers reveal the significant differences in terms of how these app ecosystems are related to each of the social media platforms, and, in some sense, the strength of the platform owner's grip on that app ecosystem.

Direct connections between apps and social media platforms that manifest on the technical level are particularly relevant because they are indicative of data-sharing or of exchanging content or functionality. While many of these direct connections are established via the official social media APIs and SDKs, we found that app developers also use other, unofficial APIs and SDKs to build their apps and to connect to social media platforms. For example, api.instagram.com is the subdomain for Instagram's publicly accessible and well documented official (legacy) API. However, we found that many apps made requests to the i.instagram.com subdomain instead. This subdomain is an internal API which is not intended for public use and hence not publicly documented by Instagram. When we detect links pointing to such unofficial domains and subdomains, it indicates that app developers came up with improvised workarounds to overcome, bypass, or minimise the limitations and restrictions posed by the official technical PBRs. In this way, developers can bypass the inability to access certain data fields or the 'rate limiting' of an API, which controls the amount of incoming and outgoing network traffic to or from the API. Workarounds and other improvisations are particularly interesting in relation to adaptations and planned changes in systems and can serve as a basis for understanding compliance and noncompliance with platform policies and behavioural guidance (Alter, 2014). Like Instagram, we also noticed that apps for Twitter commonly contain Twitter SDKs other than the official Twitter software libraries (i.e., the Twitter Kit SDK), which indicates that these improvised development workarounds are not unique to Instagram-related apps. However, even apps with no direct connections can provide relevant functionality that is complementary to social media, such as apps for content creation and editing, some of which are merely used alongside Instagram or Snapchat. In other words, not all apps necessarily require a direct technical connection to function, though most do. The next sections consider some of the implications for the relationships between third-party app developers, social media platforms, and mobile platforms and app stores.

There are differences between how each social media platform governs and controls its app ecosystem, and how it treats the proliferation of alternative APIs and SKDs, for instance. Of the four social media platforms we examined, apps for Facebook are most likely to make use of the official APIs and SDKs. At the same time, Facebook prominently lists popular unofficial SDKs 'built by amazing communities of active developers' on their developer pages (Facebook for Developers, n.d.). By contrast, Snapchat explicitly forbids unauthorised access to any of its services (Team Snapchat, 2014). More generally, though, the analysis has revealed that the ecosystems of apps and app developers around the largest social media platforms are more than just the apps registered and built 'on top' of the official APIs, which is how their ecosystems' are normally studied (e.g., Evans and Basole, 2016). In other words, the programmability of social media and of digital platforms in general is not a given and extends beyond the use of the official APIs. Moreover, this larger context of official and unofficial uses or implementations of platforms' APIs reflects the ongoing battle between platforms and third parties over the legitimate use or appropriation of 'core' platforms' data or functionality, and over the *boundaries* of those platforms in relation to their larger ecosystems (including if, when, and how they are enforced) [▸ Chs. 2 and 3]. An infrastructural perspective on apps can reveal the alternative software libraries and other resources used by app developers. It further enables a characterisation of the different types of infrastructural relations between platforms and third-party apps, including official and unofficial APIs, SDKs, and CDNs, which each enable different forms of programmability that are governed distinctly. Looking at the larger ecosystems of social media-related Android and iOS apps, we can also observe the contingent relations and interactions between third-party app developers on the one hand and digital platform governance on the other hand.

5.5. [ANALYSIS]

Regramming social media platforms

In the second part of the analysis, we derive some different ways of *regramming* social media platforms by third-party app developers. I develop this notion to conceptualise how app developers work with (and work around) the distinct affordances, action grammars, and constraints imposed by digital platforms for using their data and functionality (i.e., their unique programmability). With this concept, I draw from the work of Agre on 'grammars of action' in information systems (Agre, 1994), which both enable and constrain the action (and interaction) possibilities for users and developers. As such, the term regramming is a way to describe the (contested) *boundary dynamics* that manifest themselves between third-party digital platforms, app developers, and communities of users. The identified ways of regramming by app developers lead to: (1) an intensification of existing social media use practices; (2) a reduction of existing social media functionality; (3) a revival of former (or legacy) functionality; and (4) an extension or transformation of existing functionality, occasionally leading to new functionality or use practices. Each of these reveals the complex relationships and mutual interactions between social media platforms and third-party app developers. Additionally, they involve Google and Apple's mobile platforms and app stores, and social media user communities (who download and use the apps).

App developers' interests and objectives are not necessarily aligned with those of social media platforms, which means that all ways of regramming reveal the delicate balancing act 'between maintaining platform control and, at the same time, stimulating third-party app developers to build apps' (Ghazawneh and Henfridsson, 2013: 174; cf. Eaton et al., 2015). As we have seen, third-party mobile apps support social media user communities in a broad variety of use practices, and developers of apps look for ways to meet end-consumers' needs and sometimes discover workarounds. Most of the ecosystem innovations are welcomed by digital platform owners, as they provide additional value, and some are eventually adopted as part of their platforms ('coring'), whilst others may pose a risk, leading to their removal. APIs, SDKs, and other technical PBRs are key to provide access to functionality on the one hand and monitor and control ecosystem innovations on the other hand. In response to the Facebook–Cambridge Analytica [FB–CA] 'data scandal', for instance, Instagram limited how much data developers could retrieve from its legacy APIs by reducing the 'rate limit' for Instagram's Platform API (i.e., the number of times a developer can use the API to ping Instagram for updated information) from 5,000 calls per hour to just 200 calls per hour and even cut off some app developers altogether (Wagner, 2018). Two days later, Instagram abruptly shut down its legacy API amidst the scandal. These are interventions by the platform owner, which attests to the power it holds over—and through—these API-based action grammars.

5.5.1. *Intensifying existing use practices*

A first group of apps provide or extend functionality that aligns with the interests and objectives of the platforms for which they are built, with the consequence that social media usage further intensifies. They represent minor adjustments or appropriations of the existing functionality, which results in an intensification of already-existing use practices and logic of data capture. That is, the app's functionality is distinct from the platform's existing functionality but is nonetheless structured and captured according to the logic and action grammars of the platform, thus further intensifying its specific use practices and its data capture about those use practices. If we indeed consider social media as being designed as 'empty frames' that await user-generated content, as Gehl argued (Gehl, 2014: 81), then it is to be expected that many apps in this group provide content creation and editing functionality.

Most of the intensifying apps concern visual content creation and editing. Featuring prominently in all source sets, content creation and editing apps such as

Beautify[97] and *Snapseed*[98] enable end-consumers to create, edit, and 'beautify' (i.e., optimise) visual content before posting on their channels or feeds. For Instagram and Snapchat, such apps include photo or video content editors, cameras and lenses, filters, face masks, image cropping, and image collages. They provide a means for end-consumers to create content in a particular aesthetic format or style. Consequently, creative expression is inevitably structured and channelled through visual action grammars that can suddenly recur across social media, such as popular camera or image filters, animal faces, thematic masks, and 'face swaps' that let end-consumers change faces. The standardisation of aesthetic styles and formats is particularly apparent in the many apps for face-changing functionality, skin smoothening, hairstyle alterations, and applying thematic make-up. Apps providing these functionalities usually offer pre-sets for quick editing of photos, videos, and selfies, right before that content is posted on social media using any of the built-in posting methods.

A smaller share of the intensifying apps targets textual content. For Facebook and Twitter, where textual content figures centrally, we find apps for discovering inspirational quotations, assistance for selecting effective hashtags for audience growth purposes, and customised emoji and stickers usually implemented via operating system [OS]-level keyboards. Additionally, we found apps for automatically generating posts, answers, and replies. These apps intensify existing action grammars by increasing the volume of content created, shared, and engaged with while standardising content formats. They are not necessarily concerned with content quality at all, although for Snapchat we found several 'auto-beautification' apps. Twitter leads in terms of the number of such automation apps, many of which are professional social media management apps, such as *Hootsuite - Social Media Tools*[99] and *Everypost for Social Media*.[100] While Twitter initially used to be an 'automation-friendly' platform, it has become increasingly restrictive, as reflected in its current 'Automation Rules' (Twitter Developer, n.d.; Twitter Help Center, 2017). Since these apps operate against Twitter's interests and objectives, the platform is increasingly monitoring the uses and abuses of its APIs to detect violations of its policy. For instance, this led to the suspension of API access for apps enabling bulk

97 Neelkanth, *Beautify - Skin Tone Filters*, https://itunes.apple.com/us/app/beautify-skin-tone-filters/id1136143080.

98 Google, *Snapseed*, https://itunes.apple.com/us/app/snapseed/id439438619.

99 Hootsuite Media, *Hootsuite - Social Media Tools*, https://itunes.apple.com/us/app/hootsuite-social-media-tools/id341249709.

100 Everypost, *Everypost for Social Media*, https://itunes.apple.com/us/app/everypost-for-social-media/id572530903.

user following and unfollowing actions on Twitter, such as *Statusbrew*[101] and *Crowdfire*[102], which are featured in both the Android and iOS source sets (Constine, 2019).

Finally, some of the intensifying apps target the reputation mechanisms and the performance measures and metrics designed to optimise for end-consumers' engagement and audience reach. For Twitter and Snapchat, we find many apps for monitoring, managing, and growing audiences. These apps are used by 'influencers' and social media-savvy businesses to 'understand and manage their audience', to 'develop their content strategy' in Instagram's case (Instagram, n.d.), and to 'publish and analyze Tweets, optimise ads, and create unique customer experiences' in Twitter's case (Twitter Developer, n.d.). We found business-oriented apps for all four social media. Apps for Facebook, Instagram, and Twitter have a focus on monitoring end-consumers who are not currently following the user or have previously unfriended or unfollowed the user. That information is not provided by these platforms via their APIs, yet the information is valuable to end-consumers seeking larger audiences, so these kinds of apps can be popular but must rely on workarounds. We finally find apps that combine several social media channels in a single app, especially for Facebook, Twitter, and Snapchat. Such apps make it possible to connect and use multiple social media accounts or channels at once or make it easier to manage ad campaigns, engage teams in organisations, and to do 'community management'. Instagram claims that it removes 'inauthentic likes, follows and comments from accounts that use third-party apps to boost their popularity' when such apps violate community guidelines, policies, or terms of service (Instagram Info Center, 2018).

5.5.2. *Reducing existing functionality*

A second group of apps reduce or minimise existing functionality to customise or improve certain use practices. They also make use of the existing functionality components provided by social media platforms but in reduced or minimal form, which usually improves the app's performance.

Most of these apps fall in the category of alternative (third-party) 'clients'. Particularly for Facebook and Twitter, there are many apps that offer a 'lite' or lightweight alternative to the official clients provided by Facebook and Twitter themselves. These lightweight apps may free up device storage space, limit memory and data usage, and increase battery life so that end-consumers'

101 Statusbrew, *Statusbrew: Social Media Tools*, https://itunes.apple.com/us/app/statusbrew-social-media-tools/id1079388184.

102 Codigami Technologies, *Crowdfire*, https://itunes.apple.com/us/app/crowdfire/id528626975.

smartphones last longer. As such, alternative clients represent the appropriation by end-consumers regarding their mobile devices and use contexts, which inevitably depends on network infrastructure conditions and the availability of electricity. Particularly in 'low bandwidth' regions and countries, usage suffers from limited network performance, and bandwidth issues are typically exacerbated by attempts to process larger amounts of data over an extended period, such as when streaming Facebook videos and Stories. Moreover, there are people who choose to buy low-end smartphones and low-bandwidth mobile phone plans, not only in low-income developing countries (Statista, 2019b). Lightweight clients ensure better app and device performance and reduce the costs of mobile data plans. For Facebook, for instance, we found that many of the apps are so-called 'wrappers', which refers to a common software packaging technique used to make the development process more convenient. Content and functionality components of Facebook can be loaded from Facebook's mobile site, Facebook Zero, or its Free Basics sites (i.e., m.facebook.com, mobile.facebook.com, 0.facebook.com, mbasic.facebook.com). 'Lite' apps only need to repackage the existing, already reduced, and optimised content and functionality from these sites, signalling how developers work around the official APIs. Compared to Facebook, there are many fewer apps for Twitter focused on reducing or minimising content and functionality. Apparently, many end-consumers find the official Facebook app too heavy. Alternative clients for Twitter tend to call upon the official APIs (i.e., api.twitter.com), rather than to its mobile site (i.e., m.twitter.com). While there are lightweight clients too, some apps add additional functionality, such as options to use colour-coded labels or to mark tweets as read (e.g., *Tweecha Lite*[103]).

Both kinds of unofficial clients provide an alternative user experience of the social media platform regarding its treatment of content and functionality. But again, this seems to violate platform policy. As Facebook's platform policy reads: 'Respect the way Facebook looks and functions. Don't offer experiences that change it' (Facebook for Developers, n.d.). And Twitter's developer policy asks developers and end-consumers to 'Maintain the Integrity of Twitter's Products' (Twitter Developer, n.d.). Despite the tensions, these unofficial clients are quite popular and

103 sinProject, *Tweecha Lite for Twitter: Presented in Papers*, https://play.google.com/store/apps/details?id=net.sinproject.android.tweecha.lite.

both Facebook and Twitter eventually started to provide their own 'lite' clients: *Facebook Lite*,[104] *Messenger Lite*,[105] and *Twitter Lite*,[106] thus 'coring' lightweight functionality into their own official apps. And in their descriptions, all three apps explicitly reference developing countries and their emerging economies, just as many third-party apps do. Interestingly, though, we find these apps for Android but not for iOS, which seems related to the focus of these apps on developing countries and their emerging economies: people in developing regions and countries typically own lower-end Android mobile devices instead of the more expensive (and more restrictive) iPhones (Facebook Code, 2016). Beyond smartphones, we only find some apps that explore the integration of social media with smartwatches, other wearables, and smart TVs.[107]

In short, the apps in this second group are appropriating functionality given the limitations and restrictions of certain use contexts, which makes these social media accessible to communities of practices facing such things as limited electrical power supply, slower mobile device replacement cycles, and lower network bandwidth.

5.5.3. *Reviving former functionality*

A third group of apps revive former (or legacy) functionality formerly available and supported but now discontinued. They are reproducing user experiences that used to be available but are no longer part of social media due to changes in platform design, for instance.

Especially for Twitter, we find apps that revive former use practices, such as *Twitterific*,[108] which claims to bring back Twitter's reverse-chronological timeline after it was (controversially) replaced with an algorithmically-sorted timeline in 2016 to increase user engagement (Bucher and Helmond, 2017). *Twitterific* considers its app an acknowledgement of use practices for end-consumers who want to view all tweets 'in the way you expect' and for end-consumers who want to return to a less commercialised version of Twitter by promising a 'clutter free' experience

104 Facebook, *Facebook Lite*, https://play.google.com/store/apps/details?id=com.facebook.lite.

105 Facebook, *Messenger Lite*, https://play.google.com/store/apps/details?id=com.facebook.mlite.

106 Twitter, *Twitter Lite*, https://play.google.com/store/apps/details?id=com.twitter.android.lite.

107 Kumagai, *Looking for Twitter*, https://play.google.com/store/apps/details?id=com.droibit.looking.

108 The Iconfactory, *Twitterrific 5 for Twitter*, https://itunes.apple.com/us/app/twitterrific-5-for-twitter/id580311103.

of the reverse-chronological timeline, free of promoted tweets and ads.[109] To implement a reverse-chronological order for tweets, the app relied on functionality available through now-deprecated Twitter's APIs (Perez, 2018a). Another Twitter client, *Tweecha Prime*[110] revives a former retweeting practice, where end-consumers put 'RT' at the start of their tweets to signal when tweets are retweets (Paßmann, 2019). And *Speed Social for Twitter*[111] reversed Twitter's 'front-end' design decision to replace 'Favorites' with 'Hearts' (i.e., likes) in 2015 (Kumar, 2015). The app claims to accommodate end-consumers who want their 'stars back' and enables them to 'Use favourite (★) instead of like (❤)'. It is worth noting that such apps cannot change the button itself; instead, they merely alter the 'front-end' appearance of 'Hearts' back to 'Favorites' without changing the data structure in the 'back-end' at all. In other words, the intervention merely modifies the perceived affordances and user experience, which may nonetheless influence the use of that functionality. What Twitter captures and stores in the 'back-end' as a 'Heart' associated with a tweet may, instead, represent someone's bookmark.

Additionally, some app developers are reuniting divided families of apps. These apps were broken up into groups of separate related apps by the same developers and thus distribute functionality across several apps (Wilson, 2014). For example, *Floating Lite for Facebook*[112] and *Messenger for Facebook - Security Lock*[113] both allow end-consumers to reunite Facebook and Messenger into one app, after Facebook separated them (Facebook Notes, 2011; cf. Nieborg and Helmond, 2019). Facebook's modular approach is in contrast to so-called 'super apps', mostly in East Asia, such as China's WeChat, South Korea's KakaoTalk, or Japan's LINE (e.g., Steinberg, 2020), which represents an entire suite of functionality inside a single app (instead of outside, or related to it). In the case of Facebook, however, the app stores help end-consumers to navigate these divided families of apps, including by

109 The Iconfactory, *Twitterrific 5 for Twitter*, https://itunes.apple.com/us/app/twitterrific-5-for-twitter/id580311103.

110 sinProject, *Tweecha Prime for Twitter: Presented in papers*, https://play.google.com/store/apps/details?id=net.sinproject.android.tweecha.prime.

111 Shikh Apps, *Speed Social for Twitter*, https://play.google.com/store/apps/details?id=net.alshikh.speedtwi.

112 sarvopari infotech, *Floating Lite for Facebook*, https://play.google.com/store/apps/details?id=com.sarvopari.lite.floatingfb.

113 Rain Studio, *Messenger for Facebook - Security Lock*, https://play.google.com/store/apps/details?id=com.a2z.liteforfacebook.

listing 'More by Facebook'.[114] When the apps are built by different developers, they are included in the lists of 'Similar' apps on Google Play or the apps 'You May Also Like' on the App Store. In this way, both app stores support the modular approach to the development and distribution of mobile apps.

5.5.4. *Extending or transforming existing functionality*

A fourth group of apps either extend or transform existing functionality or use practices. They aim to stretch or circumvent the limits of existing action grammars, such as by introducing new functionality and supporting new use practices. Of the different ways of regramming that we identify, the apps in this group interfere most directly with social media's action grammars. We find apps for replaying Stories on Snapchat, saving ephemeral content such as Snaps onto end-consumers' mobile devices, posting 'tweetstorms' on Twitter, muting tweets from other end-consumers, monitoring how other users have visited or engaged with users' profiles, hiding their public statuses, and downloading images and videos from social media.

Many apps 'chain' (or link) several existing action grammars together as a way of creating workarounds to introduce new action grammars. For instance, *Regrann*[115] and *Regram*[116] both introduce new reposting functionality not already available for Instagram at the time, which their app developers have implemented as such a chain of action grammars. To make the reposting function work, these apps are used alongside the official Instagram client, rather than taking its place as an alternative client. The apps are linked to the official client and both are necessary to achieve said functionality: end-consumers first copy a publicly-accessible link (i.e., URL) to a certain image from within the Instagram app; the third-party app then downloads the input photo onto the end-consumers' mobile device, prepares the repost with photo overlays such as watermarks or photo credits to the original creators, and then also posts the newly edited photo back to Instagram using the official app.[117] Since it is not possible either to post the content directly to Instagram,

114 Android apps by Facebook on Google Play, https://play.google.com/store/apps/developer?id=Facebook

115 JaredCo, *Repost for Instagram - Regrann*, https://play.google.com/store/apps/details?id=com.jaredco.regrann.

116 Khader, *Regram (Repost Photo & Video for Instagram)*, https://play.google.com/store/apps/details?id=regram.instagram.download
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117 While such techniques could in principle be used by inauthentic accounts (e.g., bots and 'bad actors') for the distribution of 'fake news', they likely involve too many manual actions that hinder low-cost and large-scale coordinated inauthentic activity.

these apps commonly use the 'share to' functionality, which subsequently foregrounds Instagram again. In other words, end-consumers switch back and forth between both apps as a workaround, using both apps and even Android's built-in share functionality to make the use practice possible.

Other reposting apps, such as *InRepost*[118] use Instagram's internal APIs (i.e., i.instagram.com) instead: it loads the entire Instagram Feed in the app and inserts an additional reposting button right underneath the post. Similarly, *Twitterific*[119] introduces new functionality for editing tweets posted previously, also by chaining several action grammars together. Here, the workaround is implemented such that the app 'immediately deletes your original tweet and redisplays the compose screen with the text of your tweet already filled in' (Twitterrific, 2017). It deletes and replaces the tweet with another one, rather than editing the original tweet.

In addition to posting and editing content, many app developers build apps for downloading or saving content to end-consumers' devices. Some apps let end-consumers create and print photo albums, others merely download content onto their devices. Since Snaps and Stories are only available for a limited period, there are also apps for downloading these ephemeral content formats. Although end-consumers can replay Snaps once, there is no way for them to download or save them for later use; in fact, saving in general is actively discouraged and the official Snapchat client alerts end-consumers when other people create screenshots of their posts. Consequently, apps such as *Snitchchat*[120], *Snapsaver*,[121] and *Record snap story without being detected*[122] introduce workarounds to save or record Snapchat content without alerting other end-consumers. As these types of apps go against the platform's preferred action grammars, they form a likely source of contention between platform owners, third-party app developers, and the app store owners who have the capacity to remove apps that violate the platform's or the app store's terms of services. Apple's App Store Review Guidelines state that developers should not: 'include names, icons, or imagery of other mobile platforms in your app or metadata, unless there is specific, approved interactive functionality' (Apple Developer, n.d.),

118 BillApps, *InRepost- Repost for Instagram*, https://play.google.com/store/apps/details?id=com.billApps.repostForInstagram.

119 The Iconfactory, *Twitterrific 5 for Twitter*, https://itunes.apple.com/us/app/twitterrific-5-for-twitter/id580311103.

120 Microcore, *Snitchchat - The Snapchat Screenshot Tool*, https://play.google.com/store/apps/details?id=com.studiow.top.snitchchat.

121 V-Ware, *SnapSaver*, https://play.google.com/store/apps/details?id=com.v_ware.snapsaver.

122 PINEAAPPLE, *Record Snap Story Without Being Detected*, https://play.google.com/store/apps/details?id=com.dododev.storyrecord.

as this may lead to an app's removal from the App Store. Additionally, while all these social media now offer functionality for live broadcasting and video content streaming, none of them lets end-consumers download or save content, likely due to copyright restrictions. As a workaround, many apps rely on APIs to authenticate the user and subsequently download the content (e.g., graph.facebook.com, api.twitter.com, stream.twitter.com, i.instagram.com). In this case, the official APIs are not only used to authenticate and govern app developers, but also end-consumers' download behaviour.

In addition to the successful examples, we find apps that promise new functionality but fail to deliver on their promise. For example, activity and profile monitoring apps for Facebook, such as *Who Viewed My Profile*[123] and *Who Viewed My Facebook Profile*,[124] claim to give insights into user engagement, although that is not currently supported. Some apps for Facebook and Twitter use their APIs to retrieve friends or follower lists, which they can then store and compare over time. However, the API endpoints that we detected do not provide access to any information about who visited which profiles due to privacy protections. Consequently, these apps may use workarounds to create an illusion of functionality. Some app developers even confirm this themselves with disclaimers in the descriptions of their apps.[125] Notably, this explicitly goes against Apple's App Store guidelines, which state that it may remove apps from developers who are: 'marketing your app in a misleading way, such as by promoting content or services that it does not actually offer' (Apple Developer, n.d.).

Finally, some apps repurpose existing functionality to introduce or imagine alternative use practices. Perhaps the most prominent example is the repurposing of existing Facebook and Snapchat functionality for dating purposes. The implementations vary but include gender and sex-based username search (e.g., *Find Girls*

123 Loneman Labs, *Who Viewed My Profile? Followers Insight Plus*, https://play.google.com/store/apps/details?id=com.lonemanlabs.whoviewedmyprofile.facebook.

124 Who Viewed My Profile, *Who Viewed My Facebook Profile, Profile Tracker*, https://play.google.com/store/apps/details?id=com.WhoVisited.My.Facebook.app.

125 E.g., as the developers of *Who Viewed My Profile* note, 'We do our best to bring you who might have checked your Facebook profile recently; however as Facebook does not disclose who viewed data directly what our app shows you is just a good estimation'.

Username[126]), emoji and GIFs for romantic chatting (e.g., *Between*[127]), and matching people based on their profile pictures (e.g., *AddMe*[128] and *Tinder*[129]). These apps are inconsistent with Facebook's terms and policies, which require that the overall platform experience be maintained and not altered (Facebook for Developers, n.d.; Twitter Developer, n.d.). At the same time, Facebook announced in 2019 that it started testing its own service called Dating (Facebook Newsroom, 2019). The social media user experience constantly changes and evolves, and the programmability of social media platforms provides an important playground for app developers to experiment and build support for new user experiences and use practices—to the ultimate benefit of especially the platform owner, who can choose to scale them up or down.

5.6. [DISCUSSION] Governing mobile app ecosystems

We now reflect on the theoretical and methodological implications of the empirical analysis. Specifically, the 'app-centric' approach provides an app developer's perspective on the configurations and dynamics of platform governance and power that manifest between app stores, third-party app development, and social media platforms. The identified ways of regramming characterise some of the tensions that manifest themselves here.

5.6.1. *The configurations and dynamics of ecosystem innovation*

The analysis has provided a critical perspective on the configurations and dynamics—particularly the inevitable tensions and struggles—of platform-based ecosystem 'innovation'. The 'app-centric' approach surfaced various technical and non-technical, and official and nonofficial ways in which apps can connect or relate to social media platforms, offering a broader view on the developmental process and the app development practices of third parties. As a result, this gives a more nuanced perspective on the mutual relationships and interactions between platforms

126 Global Tech Social, *Find Girls Username, Friend for Snapchat Usernames*, https://play.google.com/store/apps/details?id=girls.username.girls_username_for_snapchat.

127 VCNC, *Between - Private Couples App*, https://play.google.com/store/apps/details?id=kr.co.vcnc.android.couple.

128 Return Zero, *AddMe - Friends & Usernames for Snapchat & Kik*, https://play.google.com/store/apps/details?id=co.addme.friends.

129 Tinder, *Tinder*, https://play.google.com/store/apps/details?id=com.tinder.

and third parties, including the dynamics of governance and power between them (cf. Eaton et al., 2015; Hurni et al., 2022). Nonetheless, 'core' platform owners hold significant control over their app ecosystems, even when apps challenge or seek to escape the purview of a platform's infrastructural control mechanisms.

We investigated not only the 'core' but also the 'periphery' of social media-related app ecosystems (cf. Rodón Mòdol and Eaton, 2021), where we find the contingencies of app development work. We observed how the boundaries of platforms are continuously being challenged and negotiated by third-party app developers, particularly through their developmental work, similar to that of business partners in Chapters 3 and 4. Third-party app developers and business partners both seek to extend or enlarge the scope of platforms' ecosystems in their favour, while platform owners hope to benefit from generativity—not only to generate profits, seek rents, or grow their user base, but also, from an evolutionary perspective, to increase adaptivity and the chances of survival generally (e.g., Tilson et al., 2010; [▸ Ch. 2]). Both forms of generativity help establish and entrench the 'core–periphery' ecosystem structure (Rodón Mòdol and Eaton, 2021). The use of APIs and SDKs other than the official technical PBRs provided by platforms themselves, points to the tensions that exist between third-party app developers, social media use communities, and their evolving usage contexts on the one hand, and the efforts of platform owners seeking to maintain platform control on the other hand. While requiring further empirical evidence, we noticed that all four social media platforms routinely changed or evolved their tools, products, and services with new functionality that was first introduced by third-party app developers (i.e., 'coring'), including from apps that originally violated platforms' terms and policies (e.g., reposting and anti-addiction usage tracking apps for Instagram, 'lite' clients and dating apps for Facebook). When making such changes, platform owners often mention that they 'listened' to feedback from their user communities. However, this process of adaptation also raises concerns when this 'listening' turns into anti-competitive behaviour by 'coring' or appropriating the innovations from third-party developers. Additionally, from a strategic perspective, digital platform owners can launch third-party functionality as their own innovations and benefit from the fact that use practices have already been established within the user community, which reduces any potential adoption risks on the side of the platform owner.

Furthermore, we explored social media-related *use practices* instead of *user's practices*, which are traditionally studied from 'human-centric' anthropological or ethnographic perspectives. Instead, the focus on use practices enables perspectives that are grounded in the use affordances of social media platforms, particularly the actions grammars they provide and support. The focus on use practices *vis-à-vis* medium-specific functions provides a nuanced perspective on the complex relationships and interactions between platform owners, third-party app developers, social media user communities in the process of technology appropriation. Because of this, the third-party app ecosystems of social media platforms reflect the changing and evolving contexts of social media use and meaning making. This is similar to what Duguay called 'off-label use' in a case study of Tinder, which revealed an interplay between the process of technology appropriation and platform owner's responses to disruptive off-label uses with changes in governance and infrastructure (Duguay, 2020). Instead of focusing on the off-label-use by end-consumers, this case study reveals the off-label-use by developers who appropriate platforms' action grammars to develop new use case scenarios and find workarounds in their development work. This also highlights the role of developers in co-creating and suggesting new use cultures through their appropriation of platforms' actions grammars. In both cases, workarounds or other adaptations may sometimes lead to larger planned changes in information systems (Alter, 2014), such as stricter governance and control mechanisms or the 'coring' of functions popularised by third parties or competitors.

The analysis further represents an empirical contribution to digital platform and infrastructure research (Constantinides et al., 2018; Gerlitz, Helmond, Nieborg, et al., 2019; Plantin and Punathambekar, 2019; Plantin et al., 2018). This research has undervalued the role of third-party apps and app development in relation to infrastructure, governance, and power, which invites a more nuanced, material, and empirical perspective on digital platforms as part of larger ecosystems (i.e., their own, but also those of other platform owners). By focusing on third-party app ecosystems and app development, we can surface some of the relations and material conditions of and between multiple platform ecosystems, which is essential to better understand the 'layers of governance relationships' (Gorwa, 2019) that (inter)mediate and shape the governance and power of digital platforms, not least in relation to one another as leading platforms further increase their dominance [‣ Ch. 4].

5.6.2. *Layers of governance relationships*

What makes the tensions between third-party developers and social media platforms even more delicate is that app development is not only governed and controlled by the respective social media platform but also by the mobile platforms (Android Platform and the iOS operating system), their associated app stores (Google Play and Apple's App Store), and integrated development environments [IDEs] (e.g., Android Studio and Apple's Xcode). In other words, there are multiple layers of governance relationships that overlap and interrelate in complex ways. Governance and control by social media platforms and by mobile platforms (including app stores) can interact and conflict with one another.

On the level of mobile platforms, this manifests itself in the ongoing battle between Facebook (as a leading social media and advertising platform) and Apple around its Identifier for Advertisers [IDFA], which is a unique device identifier on every iPhone and iPad used for targeting (and measuring the effectiveness of) mobile ads on iOS. With the launch of iOS 14 (October 2021), Apple gave end-consumers a choice to block its IDFA at the app-level, despite the interests of Facebook and other advertisers (as I mentioned in relation to 'identity resolution' services in Chapter 4). This battle thus also directly affects app developers who monetise their apps with mobile ads through advertising services such as Facebook's, which rely on the IDFA to target users in their apps.

On the level of app stores, both Apple's App Store (with iOS) and Google Play (with Android Platform) are uniquely positioned as 'gatekeepers'—called 'obligatory passage points' in the STS literature (e.g., Callon, 1984; Dieter et al., 2019; Fagerjord, 2015; [‣ Ch. 6])—where end-consumers go to find, purchase, download, and update their apps and where third-party app developers—including individual developers, businesses, and large social media platforms alike—go to distribute and monetise their apps. Because of powerful network effects, both market 'sides' are forced to converge on the same choice of platform, and thus move in lockstep with one another, while the app stores mediate their interactions and gradually establish their mutual dependence (e.g., Grenz and Kirschner, 2018; Murphy et al., 2014: 252). At the same time, both app stores meddle in third-party app development to shape (or 'orchestrate') the kind of ecosystem they want in the first place [‣ Ch. 2]. For instance, Morris and Morris described how rhetoric of success and logics of failure have become central to Apple's App Store. They argued that failure, not just success, is commercially generative and rhetorically valuable for Apple (Morris and Morris, 2019).

Moreover, there are also other governance mechanisms such as pricing mechanisms (e.g., app stores take 30% of sales, annual fees), quality mechanisms to improve trust and perceived risk by end-consumers (e.g., prevention of fraud and malware, ratings, reviews), accessibility control mechanisms (e.g., required developer accounts, app review guidelines and procedures, censorship), and resources and documentation (e.g., APIs, SDKs, reference documentation, guides). Importantly, app stores' terms and policies directly influence which apps are listed (and which are not) and the contents and functionality they are allowed to provide. We observed that Google and Apple both do regular 'housekeeping' to curate and remove unwanted apps from their stores (Perez, 2018b; Wang et al., 2018). Within the corpus, 3.95% of Android apps and 6.79% of iOS apps that were listed in the app store at the time of data collection were removed one month later.[130] Additionally,

130 However, this was in a month where both app stores announced that they had cleaned up their stores to remove fraudulent and malicious apps (Perez, 2018b). These removals were due to routine maintenance efforts as well as targeted app removals, including apps that violated social media

app stores use different algorithmic techniques for sorting, ranking, and clustering apps. For example, Google Play and Apple's App Store use different techniques to associate apps by the same topics, developers, or app store categories (e.g., 'Social', 'Health & Fitness', etc.). When we use app stores to demarcate source sets of apps (as in this study), we therefore need to also consider how their specifications influence app search query results, rankings, and similarity scores (Dieter et al., 2019). In fact, new tools, 'best practices', and businesses have emerged around so-called 'app store optimisation' ['ASO'] by individuals and app analytics companies (e.g., Vonderau, 2018; Walz, 2015), just as happened around 'search engine optimisation' ['SEO'] by webmasters and content creators since the late 1990s (Sullivan, 2004). Meanwhile, the 'core–periphery structure' of the Android and iOS mobile app ecosystems, which is the foundation for Google and Apple's infrastructural control and governance over those ecosystems, has remained largely unchallenged.

Furthermore, it is relevant to consider the role of app development tools and environments associated with Android Platform and the iOS operating system—that is, the larger set of platform boundary resources for app development. Android Studio and Xcode for iOS apps help stimulate (if not force) end-consumers and developers to converge on the same choice of digital platforms because of network effects. This is one aspect of their infrastructural power, which manifests especially in the developmental process (cf. Blanke and Pybus, 2020). iOS app developers are forced to use Xcode to compile their app code; there is no official alternative. The affordances available to app developers ultimately depend on platforms' architecture design specifications. For instance, we noticed quite some app-lock screen customisation apps for Android but not for iOS because such lock screen apps depend on functionality not accessible to third-party iOS app developers.

In the case of social media-related apps, there is an additional layer of governance relationships: Facebook, Instagram, Snapchat, and Twitter each also have their own terms and policies, pricing models (e.g., data access tiers, data licensing, in-app monetisation), privacy settings, community standards, app review guidelines and procedures, and their own APIs, SDKs, and documentation. Taken together, these different governance mechanisms establish and solidify the hierarchical relationships in the platform ecosystem by entrenching the 'core–periphery structure'. Such an unequal structure instils power in the core technical platform and seems to increasingly generate conflict between platform owners. In 2019, *TechCrunch* revealed that Apple revoked the enterprise app certificate that

platforms' terms and policies. As already discussed, app stores can and do sometimes remove apps that violate the terms and policies of another digital platform (e.g., Constine, 2019; Team Snapchat, 2014). App removals may thus be an outcome of app store governance or a combined effort of social media platforms and app stores, although we can only speculate about the details.

allowed Facebook to distribute internal iOS apps, which Apple blocked after Facebook breached an agreement (Constine, 2019). And since February 2020, Apple has repeatedly denied Facebook Gaming from appearing in its App Store, citing its own rules (e.g., Schiesel, 2020). Examples like these highlight the power struggles over who determines how mobile app ecosystems are governed.

The more that mobile apps are 'tethered to' (Zittrain, 2008), or interconnected with other systems and structures around the globe, the more difficult it is to isolate and understand the impacts of those app ecosystem governance mechanisms on specific markets, industries, and sectors of society. It has become challenging to understand data privacy risks, trace data traffic flows and reconstruct 'data lineages' (e.g., Binns et al., 2018; Dieter et al., 2019; Gerlitz, Helmond, Nieborg, et al., 2019; Weltevrede and Jansen, 2019; [▸ Ch. 4]), to prevent fraud and malware in specific apps, and for end-consumers and app developers to understand apps' terms and policies in the first place [▸ Ch. 2]. An exploratory study of app store policy changes and evolution from 2019 highlighted this complexity—not only of the language or readability of the respective policy documents (a common criteria) but also the networked structure of those policy documents, which commonly include hyperlinks to additional linked policy pages (sometimes behind login screens) (e.g., Helmond, van der Vlist, et al., 2019). Moreover, many (if not most) mobile apps depend on a multitude of platforms for different aspects of their functionality (e.g., social logins, maps and navigation, user-interface [UI] elements, cloud storage and computing services, content delivery networks, advertising networks, mobile analytics, etc.). This infrastructural layer is not always visible for end-consumers, and the long-term consequences are not necessarily considered by app developers. Mobile apps are very likely to contain third-party software libraries and technical integrations with a multitude of other platforms, particularly with Facebook and Google's infrastructural services and with digital marketing and advertising services (e.g., Binns et al., 2018; Blanke and Pybus, 2020). These third-party software libraries also have their own terms and policies, which rapidly leads to a large pile of policy documents for both developers and end-consumers to wade through—not just once but whenever any changes occur (Helmond, van der Vlist, et al., 2019). Consequently, an 'app-centric' approach gives a more comprehensive view of the complexity and challenges of governing mobile app ecosystems. For instance, it highlights the significance of mobile app permissions as a mechanism that distributes datafication and governance across the larger ecosystem (e.g., Pybus and Coté, 2021; [▸ Ch. 6]). Moreover, it foregrounds the layering of governance mechanisms by social media platforms, mobile platforms, and app stores.

5.6.3. *Infrastructure and communities of practice*

Finally, it is worth addressing the relationality between infrastructure and communities of practice (e.g., end-consumers and app developers), particularly in the appropriation of social media platforms. The analysis has shown that there is a specific relationship between the material conditions provided by the development infrastructure of a digital platform and the types of apps and use practices that emerge 'on top'. Both sides of the relationship between platforms and apps can give a different perspective on the governance and power of digital platforms. Therefore, an 'app-centric' approach like ours complements digital platform research on the governance mechanisms and power focused on the side of platform owners.

Importantly, the programmability of social media platforms reveals key 'sites' where platform politics, governance, and power manifest themselves, and where the different views (or imaginaries) of what a platform is *for*—views held by end-consumers, developers, businesses, and platform owners—are contested by third parties, enforced, and resolved by platform owners (cf. Schüßler et al., 2021; [▸ Chs. 1 and 2]). Consequently, to study the programmability of platforms is to surface the contested and governed boundaries of digital platforms and their larger ecosystems, as well as their *boundary dynamics*. For instance, Bucher has shown how the programmability offered by Twitter's API became an 'object of intense feeling' for app developers—an object invested with various forms of 'contestation and identification, desires and disappointments' (Bucher, 2013; cf. Mackenzie, 2006: 71). Mackenzie has argued elsewhere how the programmability of a platform can be analysed to better understand and contextualise a platform's evolving role in society—illustrated, for instance, by the shift in Facebook's programming practices towards 'predictive programmability' (and 'from API to AI') in the late 2010s (Mackenzie, 2019). Indeed, critical scholarly researchers could investigate more closely how the programmability of specific digital platforms is enacted to explicate how and when a platform may be programmable—and for whom and for which purposes (cf. Mackenzie, 2019; McKelvey, 2011).

The analysis of this study contributes by surfacing how third-party app developers interact and relate to the programmability of social media platforms; and inversely, how social media attempt to govern and control their app ecosystems—that is, their interactions and relationships with third-party apps and app developers. This view offers a unique perspective on how and what third-party app developers have built 'on top' of popular social media platforms' technical PBRs, and some of the contingencies involved in their app development work. Such views of the 'peripheries' of digital platform ecosystems are rare, though crucial in complementing the critical scholarly literature on 'core' digital platforms. For example, it is important for surfacing the actual governance and power dynamics that manifest between platform owners, different types of third parties, and, in this case, mobile platforms (including the app stores). Recently, the concerns of third-party app developers have gained more visibility, partly because of several high-profile court cases between Epic Games (a leading video game developer and publisher, e.g., known for *Fortnite*) and Google and Apple regarding the default payment systems for in-app purchases on their respective app stores. The UK Competition and Markets Authority [CMA] also announced a market study in June 2021 to explore Google and Apple's mobile platforms (i.e., Android Platform and the iOS operating system), their associated app stores (i.e., Google Play and the App Store), and also their Web browsers (Chrome and Safari) (Lomas, 2021). Their market study is focused on the potential harms of Google and Apple's 'effective duopoly' for end-consumers, leaving out the potential harms or concerns from third-party app developers. Since August 2021, the Netherlands Authority for Consumers and Markets [ACM] has focused on the relation between the developers of dating apps and the App Store regarding the use of third-party payment services in those apps (ACM, 2021), signalling an important interest from market and competition authorities in contested boundary dynamics.

5.7. Concluding remarks

This chapter asked [RQ3(a)] how governance and power are manifested in the developmental processes of social media-related mobile app ecosystems for Android (Google Play) and iOS (App Store).

To address this question, it studied the complex interactions and relationships between platform owners and third-party app developers, a relationship that is mediated by app stores. These relations between 'core' technical platforms and mobile apps revolve around the distinct programmability of digital platforms, which (inter)mediates and shapes these relations, and are governed by social media platforms as well as by Google and Apple's dominant mobile platforms. As such, the relationships between platforms and apps provide a unique perspective on the interplay between digital platforms' desires to support external contributions from third-party app developers (giving rise to their mobile app ecosystems and representing a source of infrastructural power), while simultaneously maintaining control over that app development. I have suggested the concept of regramming to enquire how app developers work with (and work around) the distinct affordances, action grammars, and constraints imposed by digital platforms for using their data and functionality. I invite further critical scholarly research to investigate how the programmability of a digital platform is enacted and governed in practice, and to consider both the platform owner's 'side' (e.g., how technical PBRs are designed and governed [▸ Ch. 2]) as well as the many different users of that 'platform' (e.g., the end-consumers, individual developers, business partners, etc. [▸ Chs. 3 and 4]).

Additionally, this study provides a unique view into the actual contents of the mobile app ecosystems related to four of the largest social media platforms (i.e., Facebook, Instagram, Snapchat, and Twitter). I considered how thousands of social media-related Android and iOS mobile apps complement the 'core' functionality of social media platforms, and whether they were technically integrated with these platforms. From an app developer's (or 'complementor's') perspective, these complements are better described as re-appropriations of a platform's data or functionality that may intensify, reduce, revive, or extend or transform existing functionality. I further note that the features of 'innovation' in platform ecosystems depend considerably on the design and governance of a platform's programmability, particularly through its technical PBRs and any associated terms and policies. Value often originates from outside the platform's boundaries, not necessarily from within it (as exemplified by M&As, as discussed in Chapter 3).

While everyone is invited to build apps and services 'on top' of their platforms, the mobile app ecosystems that I explored are not *open* ecosystems. That is, the four social media platforms studied here may be programmable (i.e., provide third-party access to an 'extensible codebase') but they are not quite *re-programmable* because third-party app developers are not empowered to alter their 'core' technical platforms (cf. Andreessen, 2007; McKelvey, 2011; Werning, 2017; Zittrain, 2008). Consequently, third-party apps may customise and appropriate social media data or functionality, but not alter the platform's 'core' in significant ways. The interactions and exchanges between social media-related apps and platforms are not equal either, or is the value created by some third-party apps necessarily captured by their developers. Most significantly, platform owners benefit from the generative entrenchment of the core–periphery ecosystem structure (Rodón Mòdol and Eaton, 2021), where they provide (and control) the 'core' technical platform that supports the evolution of interdependencies with the 'periphery'. Moreover, platform owners may reside in 'coring' functionality from third-party apps to augment their own apps and services with novelty (i.e., 'innovation') or otherwise block potential competitors in their tracks. Therefore, the governance of the app ecosystem relies to a large part on the orchestrated innovation strategies controlled by Big Tech companies with 'gatekeeper' power.

While the empirical materials of this study allow for additional comparative studies of these four social media-related app ecosystems, as well as between the Android and iOS-based app ecosystems (including their respective governance regimes), this was not the main aim of the present study. It could also be valuable to compare case studies beyond the four social media-related Android and iOS app ecosystems studied here. Furthermore, it is worth studying the evolution of these app ecosystems over time (including while they are emerging, as I explore in Chapter 6). Specifically, longitudinal empirical studies could provide more comprehensive and systematic insights into the evolutionary (governance and power) dynamics that manifest themselves between digital platforms, third-party app developers, and app stores. Moreover, empirical-historical studies of how app stores have (inter)mediated and shaped specific app ecosystems—through their terms and policies, review processes, app clusterings and rankings, and so on—are scarce.[131] ▾

131 I conducted some exploratory studies with colleagues from the App Studies Initiative (e.g., Helmond et al., 2018; Helmond, van der Vlist, et al., 2019).

6. App stores and the pandemic response

Governing the global ecosystem of COVID-19-related apps

THE PREVIOUS CHAPTER SURFACED SOME of the complex interactions and contested boundary dynamics that manifest around the 'programmability' of platforms. Specifically, it investigated the dynamics of platforms' governance and power that unfold in the social media-related app ecosystem, as it is built 'on top' of the Android Platform (owned by Google) and the iOS operating system (owned by Apple). The layers of governance relationships surfaced in the previous case study are also apparent in other mobile app ecosystems, including the ecosystem of mobile apps to fight the global coronavirus (COVID-19) pandemic. Therefore, the second chapter in Part III [RQ3(b)] asks: *How are governance and power manifested in the developmental processes of the COVID-19-related mobile app ecosystems emerging in the initial stages of the global pandemic crisis (also for Android and iOS)?*

Building upon the empirical approach and the insights of the previous case study, the current chapter thus investigates the ecosystem of COVID-19-related mobile apps. The unique focus of the study introduces governments, international (health) organisations, and citizens (as opposed to consumers) from countries and regions worldwide as additional stakeholders in this larger ecosystem. This leads Google and Apple to reconfigure aspects of their platform governance and surfaces tensions between private and public interests in the app ecosystem.

6.1. Introduction to the case study

On 11 March 2020, the World Health Organization [WHO] officially declared the coronavirus disease 2019 (COVID-19) outbreak as a global pandemic (WHO, 2020a).

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Pandemics are epidemics occurring on a scale that crosses international boundaries, affecting people around the globe. By definition, this signalled the moment when the COVID-19 disease outbreak was going 'out of control', threatening large populations worldwide, and implying the shift away from containment strategies towards exceptional governance and regulation to fight the 'unprecedented' crisis (French et al., 2018; Wamsley and Chin-Yee, 2021). The WHO further stated: 'it's a crisis that will touch every sector, so every sector and every individual must be involved in the fight' (WHO, 2020a). Given the central role of digital platforms and (mobile) apps in people's everyday lives (van Dijck et al., 2018; Morris and Murray, 2018), this call to action would also necessarily involve working with Big Tech companies. Almost immediately, however, concerns were raised by civil society organisations and academic researchers about the development of COVID-19 apps, from their potential surveillance capacities to doubts about their effectiveness (Ada Lovelace Institute, 2020; Kitchin, 2020; Privacy International, 2021). Apps built for digital contact-tracing evoked public debate and criticism across national contexts (e.g., Bhattacharya and Packalen, 2020; Ferretti et al., 2020). For large technology companies such as Google and Apple, therefore, getting 'involved in the fight' would include making carefully negotiated decisions about how to regulate the emerging COVID-19 pandemic response app ecosystems and how to balance the concerns and priorities of multiple stakeholders.

The (state-led) responses to the COVID-19 pandemic crisis have varied. While most countries were unsuccessful in containing the spread of the coronavirus disease, particularly in the first couple of months, Wamsley and Chin-Yee comment that 'the fragmentation of public health responses in liberal capitalist countries has been particularly notable' (e.g., Wamsley and Chin-Yee, 2021: 4; cf. Mellish et al., 2020). By contrast, East-Asian countries such as South Korea, Vietnam, China, Taiwan, and New Zealand seemed more successful in managing and containing the spread, which may, perhaps, be associated with greater state capacities (Kim et al., 2021; Mellish et al., 2020). Meanwhile, within Europe, the increasing dependency of citizens and public sectors on American digital platforms and technology companies also more fundamentally 'impacts the ability of institutions and governments to run societies based on democratic values' (van Dijck, 2021a). The 'unprecedented conditions' of the COVID-19 pandemic thus surfaced many complex issues and concerns regarding not only the COVID-19 pandemic itself but also the many different societal implications associated with the different local, national, and international responses to the pandemic in countries or regions worldwide. In all of this, Big Tech companies such as Google and Apple have occupied unique positions, raising questions and concerns around the nature and impacts of platform governance and power during this moment of uncertainty and crisis around the globe.

Critical questions regarding how platforms govern stem in part from a recognition that as intermediary, 'multi-sided' socio-technical systems, Big Tech companies such as Google and Apple have begun to resemble political actors, deploying a variety of layered and interrelated mechanisms to condition, control, and ultimately exploit the development and 'innovation' that occurs inside their ecosystems (van Dijck et al., 2018; Klonick, 2018; Suzor, 2018). App stores, for instance, use both technological and legal or regulatory means to govern their relationships with third-party app developers, end-consumers, business users, and other stakeholders (Eaton et al., 2012; Gillespie, 2015; Greene and Shilton, 2018; Tiwana et al., 2010; [▸ Ch. 2 and 5]), while navigating 'external' political forces and legal frameworks from a variety of national and supranational institutions (Gorwa, 2019). Moreover, from the perspective of a public policy platform, corporations are also increasingly understood as political actors beyond the strict terms of market power since they have become powerful 'gatekeepers' of societal infrastructure that requires new forms of regulatory engagement (Khan, 2018; Klonick, 2018; Suzor, 2018). This is especially the case due to their entanglement with public communication, education, and healthcare, among other domains (van Dijck et al., 2018). Indeed, as Busch et al. observed in a recent report of the Observatory on the Online Platform Economy [▸ Chs. 1 and 2], 'the COVID-19 crisis has made the societal and infrastructural role taken up by platforms even more apparent' (Busch et al., 2021: 4).

The 'unprecedented conditions' of the COVID-19 pandemic have produced equally exceptional responses from Big Tech companies concerning the development of COVID-19 apps (e.g., Google Play Console Help, n.d.; Rogers, 2021; Wamsley and Chin-Yee, 2021). Their interventions have, accordingly, shaped the complex and dynamic relations between software (app) developers, users, and governments. This chapter explores how platform governance shaped the emerging ecosystems of COVID-19 pandemic response (mobile) apps and directs attention to how the power of platforms matters in the global response to the pandemic and the global health crisis it has caused. It is first and foremost an exploratory study of these app ecosystems, which were only beginning to emerge at the time of data collection in the first months of the COVID-19 pandemic.[132]

While these COVID-19-related app ecosystems are unique in many ways, they are also like the app ecosystems studied in Chapter 5. That is, they comprise the

132 Notably, Micheli et al. (of the European Commission's Joint Research Centre [JRC]) published a study in March 2022 that is like this one. Their article explores 'to what extent a European approach can be identified in the COVID-19 mobile apps landscape that surfaced in the initial stages of the crisis' (2022). Like the findings of this study, the authors find specific trends in Europe that confirm a stronger emphasis on data protection compared to non-European COVID-19-related apps, as well as a greater involvement of the public sector.

collections of Android and iOS mobile apps and services ('complements') that third-party developers have built 'on top' of the core technical platforms of Google's Android Platform and Apple's iOS mobile operating system, respectively (cf. Hein et al., 2020; de Reuver et al., 2018; Tiwana, 2014 [▸ Ch. 1]). Consequently, the configurations and dynamics of platform governance and power may be similar but arguably involve higher stakes and more serious risks. However, it is still necessary to recognise how the Android Platform and the iOS operating system represent distinct app ecosystems, even if many larger software developers produce their apps for both popular mobile platforms to increase their consumer reach and market presence (de Reuver et al., 2018). As explained in Chapter 5, the distinct analytical affordances of each mobile platform (and associated app store) both enable and constrain the empirical research opportunities that are available, particularly regarding data collection.

The numerous socio-political risks and concerns associated with COVID-19 pandemic response apps suggest an obvious need for critical 'observability' of this domain of platform activity (Rieder and Hofmann, 2020). Rapid research outputs have assessed how the powerful global technology sector 'mobilised to seize the opportunity' and how the pandemic 'has reshaped how social, economic, and political power is created, exerted, and extended through technology' (Taylor et al., 2020). Critical commentators, moreover, have drawn attention to how specific protocological interventions by platform companies, such as the development of the Google/Apple Exposure Notification [GAEN] framework, demonstrated the significant asymmetries between national governments and platform companies controlling these processes (Veale, 2020). Likewise, Milan et al. explored the 'technological reconfigurations in the datafied pandemic' from the perspective of underrepresented communities (2021). Efforts to broadly map, document, and categorise COVID-19 apps, meanwhile, have mainly originated computer science and engineering disciplines, with a special interest in security and cryptography research (Ahmed et al., 2020; Levy and Stewart, 2021; Samhi et al., 2021; Wang et al., 2021). Additionally, these efforts originated from public health research with the aim to evaluate apps according to policy-related frameworks in 'mHealth', where mobile devices and apps are used for the practice of medicine and public health (Davalbhakta et al., 2020; Gasser et al., 2020). Other scoping studies of COVID-19 apps has been conducted by the European Commission (Tsinaraki et al., 2020), yet such research has not expressly studied the role of platforms and app stores in mediating and shaping socio-technical innovation and control in platform ecosystems (cf. Eaton et al., 2012; Eaton et al., 2015). Albright's study is notable by stressing how 'hundreds of public health agencies and government communication channels simultaneously collapsed their efforts into exactly two tightly controlled commercial marketplaces: Apple's iOS and Google's Play stores' (2020). However, a comprehensive empirical analysis of the specific ways that platform governance has played out in the emergence of the COVID-19 pandemic response app ecosystem has been missing. For example, studies so far have neither covered the entire global ecosystem, nor the full breadth of app-based responses to the pandemic that emerged.

We present an exploratory study of the emerging COVID-19 pandemic response app ecosystem across Google Play and Apple's App Store, which are the two leading app stores—and arguably duopolists—in most countries worldwide.[133] The study takes a 'multi-situated' approach (Dieter et al., 2019) to surface the distinct relations and material conditions of the pandemic response apps in ways that foreground platform governance and power. The study complements the analysis of Chapter 5 with a focus on the relationship between platforms and governments worldwide. Specifically, I investigate the following six aspects: (1) the developers of the identified pandemic response apps (i.e., *who*), uniquely including state governments and international (public) health organisations; (2) the geographical distribution of the apps (i.e., *where*), including the national distinctness of response app ecosystems; and (3) the types of responses offered by the apps (i.e., *what*). Additionally, I investigate (4) the *responsivity* of the app developers based on development activity patterns; (5) the discursive positioning of the apps towards (potential) end-consumers based on descriptions of the apps; and (6) the technological configuration and dependencies of the apps based on the embedded (third-party) software development libraries and frameworks (i.e., *how* the response is practically implemented).[134] The multi-situated approach helps surface some of the dimensions and mechanisms of platform governance by Google and Apple's mobile platforms and app stores, which have shaped the pandemic response app ecosystems in complex and subtle ways. Google and Apple's governance configurations directly

133 Google Play and Apple's App Store are the two largest (market-leading) platforms for app distribution and Android and iOS are also the two leading mobile OSs (Statista, 2021).

134 While I recognise the importance of the GAEN framework used to facilitate digital contract-tracing through mobile apps, it is not included in this study because it had not yet been widely implemented at the time of data collection. In fact, only 8 out of the 410 Android apps in the source set included the GAEN API for exposure notifications in their AndroidManifest.xml file by November, already several months after data collection. Similarly, while access to mobile device sensors (e.g., GPS sensors, Bluetooth adapters, etc.) is governed and controlled on the level of Google and Apple's mobile operating systems (i.e., on the level of Android and iOS) as well as through app permissions requested from users, this study focused primarily on the governance by app stores. While not discussed in this chapter, the collected data and information about the permissions requested by each app is also openly available in OSF.

influence the types of apps and responses that are available to citizens in countries or regions around the globe [‣ Ch. 2]. To be clear, the aim of this study is not an exhaustive or comparative study of Google and Apple's pandemic response app ecosystems; instead, it is to characterise the (critical) intermediary role played by both Big Tech companies during the first months of the COVID-19 pandemic when the pandemic response app ecosystem began to emerge (March–June 2020).[135] Consequently, this study is by no means conclusive—as no single study ever is. Still, we can begin to see the contours of an emerging mode of global platform governance, which is not merely functioning alongside state governments and international organisations but is actively enrolling them for longer-term strategic purposes.

In the next section, I first contextualise Google and Apple's initial responses to the COVID-19 pandemic. Second, I detail the empirical approach to identify and demarcate relevant COVID-19-related Android and iOS mobile app ecosystems, which is like the approach of Chapter 5. Third, I present the outcomes of the empirical analyses, focusing on each of the six aspects in turn. Fourth, I discuss the findings of this study in the light of a politics of the unprecedented in the COVID-19 pandemic response. We note that the app-based pandemic response has further consolidated Google and Apple's unique positions of power in the ecosystem and in relation to state governments and international health organisations.

6.2. [BACKGROUND AND POSITIONING] Google and Apple's COVID-19 pandemic responses

On 14 March 2020, three days after the initial pandemic declaration, Apple announced significant restrictive changes to its App Store policies. Apple would now evaluate all apps developed in response to the COVID-19 pandemic with a heightened degree of attention. Reiterating their mantra of the App Store as 'a safe and trusted space', Apple affirmed a commitment 'to ensure data sources are reputable' as 'Communities around the world are depending on apps to be credible news sources', reiterating their commitment to the App Store as 'a safe and trusted

135 The data that support the findings of this study are openly available in the Open Science Framework [OSF] at https://doi.org/10.17605/osf.io/wq3dr. Additionally, the available Android Package [APK] files of the COVID-19 Android apps covered in this study are openly available and preserved in the 'COVID-19 Apps' collection of the Internet Archive at https://archive.org/details/COVID-19_Apps. Data collection was conducted in June 2020, when most countries already had apps listed in the app stores (but also, in retrospect, with some apps still under development).

space' (Apple Developer, 2020; Apple Newsroom, 2020). This would mean only accepting authoritative apps 'from recognized entities such as government organisations, health-focused NGOs, companies deeply credentialed in health issues, and medical or educational institutions' (Apple Developer, 2020). For Apple, this also meant that 'Entertainment or game apps with COVID-19 as their theme will not be allowed' (Apple Developer, 2020). On the same day, Google published an editorial campaign Web page on Google Play, titled 'Coronavirus: Stay Informed', with a list of recommended apps for being 'informed and prepared' about the coronavirus disease, including apps from national centres for disease control and prevention [CDCs] worldwide, the American Red Cross, personalised news aggregator News360, the WHO, and Twitter (Google Play, 2020). Shortly before this 'Stay Informed' campaign, CEO Sundar Pichai (Alphabet and Google) had outlined measures in place across their range of apps and services to deal with the unique challenges of the COVID-19 crisis, stressing that Google Play policies already would prohibit app developers from 'capitalizing on sensitive events' and restrict the distribution of medical or health-related apps that are 'misleading or potentially harmful' (Pichai, 2020).

As early as 15 February, a month before the COVID-19 pandemic was officially declared, the WHO importantly stated that 'we're not just fighting an epidemic; we're fighting an infodemic' (Zarocostas, 2020: 676; cf. Gruzd et al., 2021; UN DGC, 2020). To combat COVID-19 disinformation and misinformation, the WHO had begun working closely with more than 50 major technology companies, including Google, to implement solutions to fight the emerging 'infodemic' (WHO, 2020b). This early stage collaboration, initiated by the WHO, resulted in ensuring that 'science-based health messages from the organisation or other official sources appear first when people search for information related to COVID-19' on the platforms of participating companies (WHO, 2020b; Zarocostas, 2020).

As the pandemic spread and intensified throughout the year, both Google and Apple continued to update their editorial and policy positions for managing COVID-19-related apps, while elaborating a set of regulatory mechanisms, and developing new standards and techniques to control what had become an exceptional niche of software development activity. In May 2020, Google Play released its official developer guidelines for COVID-19-related apps. Google positioned itself as information intermediary, 'connecting users to authoritative information and services' and also imposed limits on the commercialisation of COVID-19-related apps, which should 'not contain any monetisation mechanisms such as ads, in-app products, or in-app donations' (Tolomei, 2020). Similarly, Google restricted content that contained 'conspiracy theories, misleading claims, "miracle cures" or dangerous treatments, or any patently false or unverifiable information' (Google Play Console Help, n.d.). Similarly, Apple's App Store Review Guidelines were updated to require that any apps providing services 'in highly-regulated fields', such as healthcare, should be submitted by a legal entity that provides the services, and not by an individual developer'. Further, they would require that any medical apps 'must clearly disclose data and methodology to support accuracy claims relating to health measurements', and they introduced new policies for collecting health-related data (Apple Developer, n.d.). To ensure this, Apple claims that 'every app is reviewed by experts' based on its App Store Review Guidelines (Apple Developer, n.d.). Both app stores also added new pandemic-related requirements to their general app store policies and guidelines (e.g., around health and medical advice) and expedited the app review process so that COVID-19 apps could be approved quickly (Google Play Console Help, n.d.; Google Play Console Help, n.d.; Tolomei, 2020).

Taken together, such policy updates indicated a suspension of 'business-as-usual' for COVID-19 pandemic response apps during this moment of crisis, as particular mechanisms around competition and monetisation—which are typically central to app store economy—were altered by the leading app stores and technology companies to support the emergence of an exceptional app ecosystem to facilitate the app-based pandemic response. Moreover, these policy updates are implemented across different architectural layers: from unique modes of curation to special-purpose app development protocols (e.g., Exposure Notifications APIs for Android and iOS apps).[136] In this respect, the updates signal broader changes that ultimately extend throughout both platforms.

In April 2021, Google communicated about its public policy and its partnerships with 'international organisations' in the development of new technologies guided by multilateral frameworks 'like the United Nations [UN] Roadmap for Digital Cooperation, the UN Sustainable Development Goals and the UN Guiding Principles on Business and Human Rights'.

> Whether it's a pandemic, climate change, or the health of the global economy, many of the problems of our era can only be effectively addressed by collaboration across borders. In an interconnected world, such collaboration depends on international organizations that bring together governments, the private sector and civil society. And we think technology can help. (Bhatia, 2021)

Through these partnerships with international organisations, Google plans to develop technology-enabled responses on four 'fronts' to 'tackle the next generation of cross-border challenges that lay over the horizon': 'Slowing the pandemic and supporting economic recovery', 'Artificial intelligence and innovation', 'Sustainability', and 'Open internet and human rights'. While the COVID-19 pandemic may have been unprecedented, the pandemic response by Big Tech companies like

136 https://developers.google.com/android/exposure-notifications/exposure-notifications-api and https://developer.apple.com/documentation/exposurenotification.

Google is thus not unrelated to—and may even have *accelerated*—its strategic efforts to get (more deeply) involved and gain a foothold in a range of public sectors and (cross-border) challenges, including 'public health', 'disaster aid', 'climate action', 'renewable energy', 'human rights', 'gender equality', and more. Despite all this, there is growing scepticism about the involvement of these technology companies in the public sector and cross-border challenges like these, not least around the safeguarding of public values and the common good (e.g., van Dijck, 2021b; van Dijck et al., 2018). Additionally, there are specific concerns around Google and Apple's continuing push into healthcare, such as the implications of mHealth apps merging (public) health content with commercial content, which may also lead to conflicts of interests (e.g., Sax et al., 2018; Wetsman, 2021).

In what follows, I explore how these recent platform changes and policy updates initiated a unique mode of *pandemic platform governance* that is unfolding in response to the unprecedented circumstances of the pandemic—in a unique moment of crisis. It is unfolding through an interplay between a platform's affordances for app development, the emergence of app ecosystems around platforms, and the platform's regulatory mechanisms, which together simultaneously enable generativity and control (Eaton et al., 2012; Tiwana et al., 2010; [‣ Chs. 2 and 5]). These specific changes and policy updates both facilitate and govern platforms' 'generativity' (e.g., Zittrain, 2008), and thus platforms' capacity to *adapt* during this pandemic in relevant ways. Consequently, these changes and policy updates are critical in shaping the types of response apps that emerge 'on top' of Google and Apple's respective mobile platforms and app stores, thus highlighting the pivotal role of these two platforms in (inter)mediating and structuring the relationships and interactions between software app developers, citizens, international (public) health organisations, and governments in countries or regions worldwide.

6.3. [MATERIALS AND METHODS] Investigating pandemic response app ecosystems

App stores are the main site for accessing, downloading, monetising, and distributing mobile apps, as well as for receiving (from the end-consumer's perspective) the latest software updates for those mobile apps. Consequently, researchers can employ—or 'repurpose'—the unique capabilities of app stores to find, demarcate, and compare among (collections of) mobile apps (Dieter et al., 2019; [‣ Ch. 5]). The analysis is focused on the two most popular app stores worldwide: Google Play for

Android apps and Apple's App Store for iOS apps.[137] My co-authors and I queried both app stores for [COVID], [COVID-19], [corona], and related keywords across all 150 supported Google Play 'Locations' and all 140 App Store 'Countries and Regions' to build two distinct source sets that represent the pandemic response app ecosystems for Android and iOS, respectively.[138] Next, we collected all the returned apps, along with most available information about them, using custom-built scrapers.[139] We then compared both source sets to identify the unique apps ($N = 410$ Android apps and 253 iOS apps in total), which we analysed in multiple ways.

6.3.1. *Lines of enquiry*

We explore a total of six (complementary) lines of enquiry to gain a better understanding of Google and Apple's distinct and multi-faceted roles in shaping the global app-based response to the COVID-19 pandemic. We first determine the (types of) actors responsible for the development of the apps, and second, what (types of) responses to the COVID-19 crisis the apps offer or represent. This analysis is based on the available information in the app stores, including the app developer name and website and app descriptions and screenshots.[140] The categorisation schemes we used to analyse these (types of) actors and responses [‣ Appendix E: Table E 6.1 and Table E 6.2] were created based on an emergent categorisation strategy. Many apps

137 Google's Android Platform has a 71.18% mobile OS market share worldwide, followed by Apple's iOS with 28.19% (StatCounter Global Stats, n.d.). Because of Google and Apple tightly connecting their app stores to their mobile OSs, Google Play (except in China) and Apple's App Store have effectively become the main distribution channels for apps and app developers worldwide.

138 https://support.google.com/googleplay/android-developer/table/3541286 and https://searchads.apple.com/countries-and-regions/.

139 These tools were designed by the authors and implemented in collaboration with Stijn Peeters (Digital Methods Initiative, University of Amsterdam) and Jason Chao (Collaborative Research Centre 'Media of Cooperation', University of Siegen). Digital Methods Initiative, *iTunes App Store and Google Play Scrapers* (beta), http://penelope.digitalmethods.net/app-scrapers/. See also: App Studies Initiative, ASI Tools, http://appstudies.org/tools/.

140 For this study, we interpret the 'developer name' listed on the app store details page as the actor responsible for the development of that app. However, the actor listed as the 'developer' on the app details page is not necessarily, or not always, the same as the developer of that app (e.g., when the 'developer' merely listed the app in the app store, without having developed it).

were labelled by at least two research team members and were verified through random samples. In both cases, the apps can belong to more than one category because they may offer multiple responses or may be developed in collaboration between several actors.

Third, we analysed how *responsive* the app developers have been across countries based on information about software updates to all the Android and iOS apps in the source sets (N=7,297 version releases in total). These version histories were retrieved from App Annie, a commercial app market data and analytics firm (N=4,440 Android and 2,823 iOS version releases). This provides insights into generativity and adaptivity of the Android and iOS pandemic response app ecosystems on Google Play and Apple's App Store. Fourth, we also analysed the titles and textual descriptions of the apps to understand how developers have discursively positioned their apps in relation to potential end-consumers. These descriptions typically provide important information from app developers and are used by both app stores to determine relevant apps for users' search queries. Specifically, we examined terms and phrases related to the implemented techniques (to characterise the technological *implementation* of the response type) and whether developers were informing users about any associated data/privacy-related concerns (which were prominently discussed in the news at the time) [‣ Appendix E: Table E 6.3]. In short, these descriptions can provide important contextual information and may surface issues and concerns relating to specific apps, or to the app stores themselves.

Finally, we retrieved information about any embedded software libraries (also called software development kits [SDKs])—and requested permissions for all the Android apps (N=7,335 Android software libraries and 2,673 permissions) from AppBrain, another commercial app market data and analytics firm. These provide another perspective on the technological implementation of the response types (e.g., digital contact-tracing may be based on GPS [Global Positioning System], Bluetooth, or other). We were limited to Android apps in this part of the analysis because of the restrictions imposed by Apple, preventing inspections of the technological configuration of the iOS apps.

6.3.2. *Governing 'serious queries'*

Importantly, Google and Apple's app stores use distinct methods for surfacing, filtering, and curating the apps that appear for a given search query. App stores normally organise search query results through an algorithmic logic, complemented with an editorial logic for various 'Top charts' (e.g., 'Top apps', 'Top selling apps', 'Top grossing apps', etc.) and an 'Editor's Choice' section (Dieter et al., 2019; cf.

Gillespie, 2014).[141] For COVID-19-related search queries, however, Google Play solely relies on an editorial logic to surface apps. While the App Store returned ranked lists of the top-100 apps for each country that was queried, Google Play did not return such ranked lists. Instead, Google Play recognised the COVID-19-related searches and curated those searches to a select subset of approved apps. Moreover, this editorially-curated subset of apps is different for each 'location' (i.e., country), and users searching from other countries could not download, or even find, the apps from any other country. This would ensure that end-consumers download and install the right apps (i.e., those for the countries or regions they are based in, rather than apps with often similar titles from other countries or regions, or fraudulent and malicious apps). Rogers calls these types of search queries that return official information 'serious queries', which can be seen in a larger trend towards editorial intervention and 'editorial epistemologies' (2021). The fact that platform owners are manually editing search results for specific queries is even described as an 'exceptional information state' (Rogers, 2021: 7). For the purposes of this study, these types of search queries are particularly interesting to consider because they reflect platforms' ongoing efforts to govern (and moderate) misinformation and 'fake news' in the light of the 'infodemic' of misinformation and cybercrime that emerged during the COVID-19 crisis (e.g., UN DGC, 2020; WHO, 2020b).

We tried many different search terms related to the coronavirus disease, COVID-19, and the pandemic—an iterative process called 'query design' (e.g., Rogers, 2017). While proper search queries (e.g., [COVID], [coronavirus], [SARS-COV-2], etc.) almost always redirected to the editorially-curated subset of apps, we found that intentionally-misspelled search queries (e.g., [COVIID], [coronna], etc.) were not always recognised and redirected, returning an extensive list of relevant Android apps [‣ Table 6.1]. In other words, we attempt to circumvent (or work around) Google Play's method for detecting and redirecting COVID-19-related search queries to gain a comprehensive view of all the available apps (in all countries), and thus gain a sense of what governance entails in this setting. Using this approach, we collected two complementary source sets for Google Play: an *editorially-curated* set of response apps that is specific to each country and another, *algorithmically-curated* set of apps found through the intentionally-misspelled searches [‣ Table 6.2]. The apps in the latter source set were present in Google Play but its editorial curation prevented these apps from surfacing for proper searches.

141 https://play.google.com/store/apps/top and https://play.google.com/store/apps/editors_choice.

Table 6.1. Search queries for Google Play and Apple's App Store.

Input strategy	Search queries	Store
Properly-spelled	e.g., [COVID], [COVID-19], [corona], and [coronavirus]	Google Play; App Store
Misspelled	e.g., [COVID], [COVID-19], [COVID 19], [COVID19], [SARS-CoV-2], [2019-nCoV], [corona], [coronaviru], [coronavirus], [contact tracing], [contact tracking], [coronna], [COVD-19], [COVI-19], [COVID--19], [COVID-1], [COVID-119], [COVID-199], [COVID-9], [COVID-91], and [COVID19]	Google Play

In addition to the 'native' search queries within both app stores, we retrieved the results from additional site-specific search queries through a third-party search engine (i.e., Microsoft Bing).[142] This additional step was not only necessary to obtain a comprehensive view of the response app ecosystem, but also was critical for understanding how this ecosystem was being governed through the app store's search input field. Specifically, we noticed that the search query results for [covid] and [corona] surfaced more relevant apps than the misspelled queries did, likely due to the maximum number of 250 apps returned for any given app store search query.[143] Further, this additional method circumvents the search query detection and redirection mechanism on Google Play: it returns all app details pages found anywhere within the app store's Web domain, so long as they match any of the search queries. In short, this allowed triangulating and appending the original source sets and ensured that all apps related to the COVID-19 pandemic were included. Some irrelevant apps were identified and removed afterwards.[144]

142 In fact, it is worth noting that we only found out that Google Play was filtering (i.e., curating, localising) its search results because of the multi-situated approach, which involved external site-search queries for the purpose of cross-checking search results (i.e., triangulation).

143 The search queries on Microsoft Bing yielded 238 unique relevant apps (out of 1,055 apps in total, or 22.56%), against 164 relevant apps (out of 3,104 apps in total, or 5.28%) through the misspelled search queries on Google Play.

144 Such as apps by developers from the city of Corona in California or New Mexico, USA, apps by Corona Labs, a Californian developer firm and the name of an SDK, or apps about the Spanish Royal Crown [*corona tumular*]. Additionally, there are apps that were not included in the data set (e.g., the German *luca* response app) because they, intentionally or not, did not use any of the COVID-19-related search terms.

Table 6.2. Number of unique Android and iOS apps retrieved per method per source set.

Input strategy	Google Play		App Store	
	Search*	Other	Search	Other
Properly-spelled	247	–	253	–
Misspelled	163	–	–	–
*External [site:] search***	–	80	–	163

** Redirected search queries (i.e., the editorially-curated subset).*
*** External site-search queries using Microsoft Bing's [site:] search operator (i.e., [site:play.google.com/store/apps/*] and [site:apps.apple.com/*/app/*]).*

6.4. [ANALYSIS]

The global ecosystem of pandemic response apps

This section presents the empirical findings from the exploratory study of the emerging COVID-19 pandemic response app ecosystem across Google Play (Android) and Apple's App Store (iOS). It is relevant to study the app ecosystem in these multiple ways to gain a better understanding of how it is shaped and governed. Therefore, I will first consecutively present the six lines of enquiry, before discussing the empirical findings more specifically in the light of their platform governance and power implications.

6.4.1. *Developers of pandemic response apps*

We first examine the distribution of response apps in both source sets in terms of the (types of) actors who have developed and maintained them. Figure 6.1 presents this distribution of COVID-19-related apps across both app stores, distinguishing between the editorially-curated and non-editorial, or algorithmically-curated Android apps for the Google Play source set. Each node is one unique app and is colour-coded according to the types of actors we find and distinguish: governmental actors (e.g., state ministries, national centres for disease control and prevention [CDCs], etc.), civil society actors (e.g., NGOs and the Red Cross), health authorities (e.g., hospitals, nursing homes, medical colleges, etc.), academic actors (e.g., universities and academic research institutes), and various private actors [‣ Appendix E: Table E 6.1]. Additionally, some of the apps have been developed by, or in collaboration between, multiple actor types (10.6%, or 70 apps).

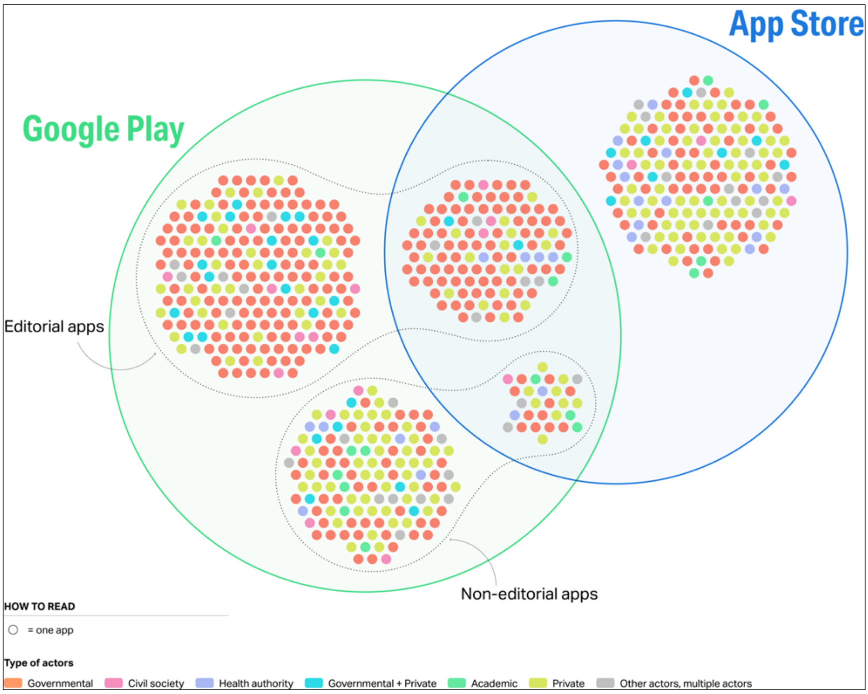


Figure 6.1. Comparison of demarcated source sets (Google Play and App Store) [hierarchical circle packing diagram].

Nodes: unique apps (N = 663 apps); areas: source sets or subsets. Light green: Android app ecosystem (Google Play source set); light blue: iOS app ecosystem (App Store source set). Data: Google Play and App Store. Graphic: DensityDesign Lab (Polytechnic University of Milan, IT). High-resolution figures are openly available in OSF at https://doi.org/10.17605/osf.io/wq3dr.

It is striking that many apps feature in only one of the two app stores. Apps shared across both app stores (*N* = 137 apps) tend to be produced by governmental actors. Still, there are also many government-made apps that are only available in one of the app stores.[145] About 70% (*N* = 134 Android apps) of the governmental apps within the Google Play editorially-curated subset do not have an iOS equivalent listed in Apple's App Store. While further analysis is needed to interpret these differences, one likely factor is the different market shares of the respective mobile OSs and app stores across countries worldwide. To illustrate, Android has a 95% market dominance in India (StatCounter Global Stats, n.d.), and this country produced the highest number of COVID-19 apps (*N* = 61 Android apps) overall. Another contributing factor is Android's more permissive (open) architecture, as compared

145 We found corresponding iOS apps for 137 of 410 Android apps (ca. 33.4%) and corresponding Android apps for 188 of 253 iOS apps (ca. 74.3%).

to Apple's restrictive (closed) iOS architecture style and governance (e.g., Eaton et al., 2012; Eaton et al., 2015; Sørensen et al., 2015; Tilson et al., 2012); specifically, the more permissive use of sensors on Android devices, which are key to developing contact-tracing applications.[146] The variance suggests divergent national strategies for the development or adaptation of COVID-19 apps across multiple platforms, which has important consequences for users who may be presented with a different selection of COVID-19 apps based on their (preferred) mobile OS and the associated app store. In effect, government-made COVID-19 apps were, for the most part, only available for Google's Android Platform and Apple's iOS operating system and are also not necessarily produced according to open standards. This is despite some state governments requesting apps to be built according to such open standards and protocols, thus attesting to Google and Apple's platform dominance (there was effectively no way around them).

There are also notable differences in the composition of the actors developing and maintaining COVID-19-related apps for Android and iOS [▸ Figure 6.2]. Government-made COVID-19 apps were the most prevalent in both app stores, thus positioning governments as key official and recognised app developers (i.e., 'complementors') outlined in the app stores' terms and policies.[147] However, they were significantly more prevalent in the Google Play source set (65%, 267 Android apps), and even more so in the editorially-curated subset (79%, 195 Android apps), compared to Apple's App Store (48%, 121 iOS apps). It thus seems that one outcome of Google's editorial curation strategy is an increased presence and visibility of apps built by governmental actors, yet curiously, 42% of government-made Android apps did not make it into the editorially-curated subset, and thus never surfaced for people's proper search queries (e.g., [COVID-19] or [corona]). This suggests that being a government actor alone is not necessarily sufficient reason to be included in the editorially-curated subset—or at least that there are apps that, for different reasons, did not meet the respective eligibility criteria for COVID-19 apps at the time of data collection (Apple Developer, 2020; Google Play Console Help, n.d.).

146 This difference may also explain part of Google's decision to govern 'serious queries' in ways that Apple did not (or did not need to).

147 Identifying actors as governmental was relatively straightforward in this case, because they would typically be listed as the 'developer' on the app's details page (e.g., as a 'ministry', a 'national centre', etc.).

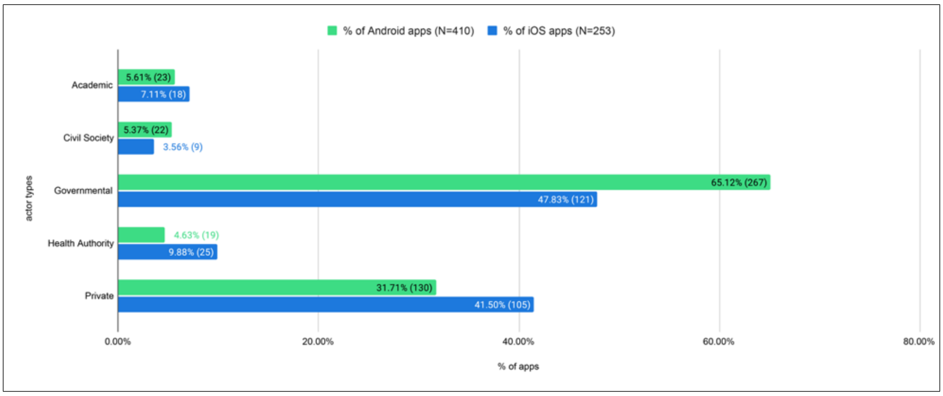


Figure 6.2. Actor types behind COVID-19-related apps (Android and iOS) [horizontal bar chart]. Apps can belong to multiple categories.

Data: Google Play and App Store. High-resolution figures are openly available in OSF at https://doi.org/10.17605/osf.io/wq3dr.

In contrast, apps produced by private actors were relatively more prevalent in Apple's App Store (41%) than in Google Play (32%). The privately-made iOS apps were predominantly from commercial actors who offered healthcare solutions. While most of these also existed as Android apps, they did not surface in the Google Play source set, signalling how Google and Apple used different criteria for retrieving health-sector companies and organisations as official and recognised app developers. Additionally, the unprecedented circumstances of the COVID-19 pandemic gave rise to developmental collaborations and partnerships between governmental and private actors for both platforms (N=26 Android apps and 12 iOS apps) apps. These collaborations were often explicitly mentioned in the app descriptions. Further, a smaller but significant number of apps have been developed with the involvement of academic researchers and institutions (e.g., *Covid Symptom Study*[148]), civil society actors (e.g., *Stopp Corona* from the Austrian Red Cross,[149]

148 Zoe Global Limited, *COVID Symptom Study*, https://play.google.com/store/apps/details?id=com.joinzoe.covid_zoe&gl=us; Zoe Global Limited, *COVID Symptom Study*, https://apps.apple.com/us/developer/zoe-global-limited/id1468130856.

149 Assistance Publique - Hôpitaux de paris (AP-HP), *Covidom Patient*, https://play.google.com/store/apps/details?id=fr.aphp.covidom&gl=fr; Assistance Publique-Hopitaux de Paris, *Covidom Patient*, https://apps.apple.com/us/developer/assistance-publique-hopitaux-de-paris/id508021332.

or the two apps from the WHO[150]), or health authorities (e.g., the French *Covidom Patient*,[151] to monitor COVID-19 patients after a hospital visit). While lesser in number, the presence of these other actor types contributes to the credibility and legitimacy of the larger app ecosystem.

6.4.2. *Geographical distribution of pandemic response apps*

After exploring the distribution of apps and actor types across platforms, we focused on their geographical distribution. This helps to determine the national distinctness of response app ecosystems, and it is also the main level at which governance is implemented by the app stores. The App Store's ranked lists of apps were less country-specific and show a high degree of overlap between countries or regions because of its (algorithmic) curation strategy. Google Play's results, whose editorial curation strategy surfaced only those COVID-19 apps that are relevant in the end-consumer's Google Play country,[152] showed a more distinctive geographical distribution [▸ Figure 6.3]. In the case of Google Play, we find that most countries offered a small selection of country-specific COVID-19 apps, along with two apps from the WHO that were available in nearly all countries (i.e., *OpenWHO: Knowledge for Health Emergencies*[153] and *WHO Info*[154]).

150 HPI Knowledge Engineering Team, *OpenWHO: Knowledge for Health Emergencies*, https://play.google.com/store/apps/details?id=de.xikolo.openwho&gl=ae; Hasso-Plattner-Institut, *OpenWHO*, https://apps.apple.com/us/app/openwho/id1183923481; World Health Organization, *WHO Info*, https://play.google.com/store/apps/details?id=org.who.infoapp&gl=ae; World Health Organization, *WHO Info*, https://apps.apple.com/us/app/who-info/id895463794.

151 Assistance Publique - Hôpitaux de paris (AP-HP), *Covidom Patient*, https://play.google.com/store/apps/details?id=fr.aphp.covidom&gl=fr; Assistance Publique-Hopitaux de Paris, *Covidom Patient*, https://apps.apple.com/us/developer/assistance-publique-hopitaux-de-paris/id508021332.

152 https://support.google.com/googleplay/answer/7431675

153 HPI Knowledge Engineering Team, *OpenWHO: Knowledge for Health Emergencies*, https://play.google.com/store/apps/details?id=de.xikolo.openwho&gl=ae; Hasso-Plattner-Institut, *OpenWHO*, https://apps.apple.com/us/app/openwho/id1183923481.

154 World Health Organization, *WHO Info*, https://play.google.com/store/apps/details?id=org.who.infoapp&gl=ae;

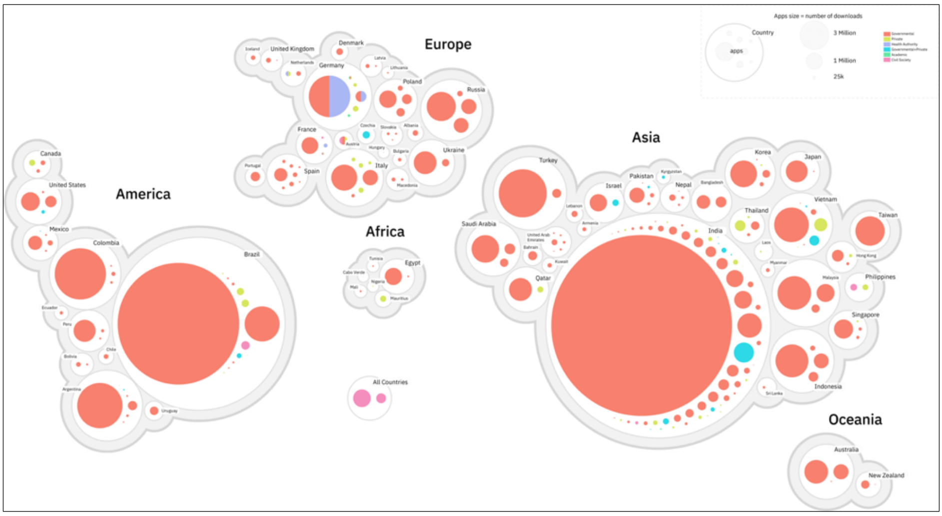


Figure 6.3. Geographical distribution of COVID-19-related Android apps by Google Play country [geographical circle packing diagram]. Nodes are unique apps and borders demarcate apps that belong to the same country.

Node size: scaled by count of app downloads; colour-coding: by actor type; layout: world map projection. Data: Google Play and App Store. Graphic: DensityDesign Lab. High-resolution figures are openly available in OSF at https://doi.org/10.17605/osf.io/wq3dr.

Measured in terms of downloads, most countries have a primary app within the country-specific apps by a government actor. There are, however, notable exceptions. While India has a dominant government-made app (*Aarogya Setu*[155]), which is mandatory for governmental and private sector employees, the country offered 61 apps in total—far more than any other country at the time of data collection. Upon closer inspection, we found that India had a multi-tiered response to the COVID-19 pandemic with many apps developed for specific regions within the country and developed by the country's local governments (cf. Bedi and Sinha, 2020). In contrast, countries such as Denmark, Iceland, Portugal, Taiwan, and Uruguay offered only one app (in addition to the global WHO apps), all of which are government-made. In other countries (e.g., Canada, Mauritius, Philippines, and Thailand), we found that the most prevalent apps were either non-governmental apps or involved

World Health Organization, *WHO Info*, https://apps.apple.com/us/app/who-info/id895463794.

155 NIC eGov Mobile Apps, *Aarogya Setu*, https://play.google.com/store/apps/details?id=nic.goi.aarogyasetu&gl=in; NIC, *AarogyaSetu*, https://apps.apple.com/us/app/aarogyasetu/id1505825357.

collaborations or partnerships between multiple actor types, including collaborations between governmental and private actors (e.g., Austria, Czechia, Germany, and Kyrgyzstan). Some countries surfaced multiple apps, reflecting their regional or state-based app-based responses to the pandemic, their multi-pronged response strategies (with multiple apps with distinctive functionality), or reflecting multiple competing response strategies within countries (e.g., governmental and non-governmental response strategies).

It is worth noting two final observations about the geographical distribution of COVID-19 apps. First, China is notably missing from this study because the country has effectively banned Google Play. China has relied on Health Code to tackle the COVID-19 pandemic, a so-called 'mini-programme' (or a 'nested' app; cf. Nieborg and Helmond, 2019) developed by (and integrated within) Alipay and WeChat, which generates a colour-based health code used to determine people's exposure risks and govern their freedom of movement (Liang, 2020). Instead of developing new COVID-19 apps, China thus decided to integrate Health Code into two of its already widely-used mobile (payment) apps. This strategy ensured that a large percentage of the overall Chinese population participated in the country's government-led COVID-19 pandemic app-based response.[156] Second, the two apps from the WHO surface for every country, except in the United States of America [USA]. Not only did the WHO apps not make it to the editorial list, but direct search queries for these apps redirected to the USA editorially-curated subset where the WHO apps did not feature. In April 2020, President Trump halted funding to the WHO, after criticism of the USA's response to the COVID-19 pandemic. A few months later, in July, President Trump moved forward to officially withdraw the USA's membership from the WHO. The omission of the two WHO apps in the USA may reflect broader geopolitical dynamics and suggests that the editorialisation of Google Play's app ecosystem may not be conducted by Google alone. The editorial lists reflect a generally benevolent platform strategy to steer users to what is perceived to be the most appropriate apps; however, in this case, we see the editorial logic used for more overtly political purposes with the emergence of censorship (even though these WHO apps exist in the store).

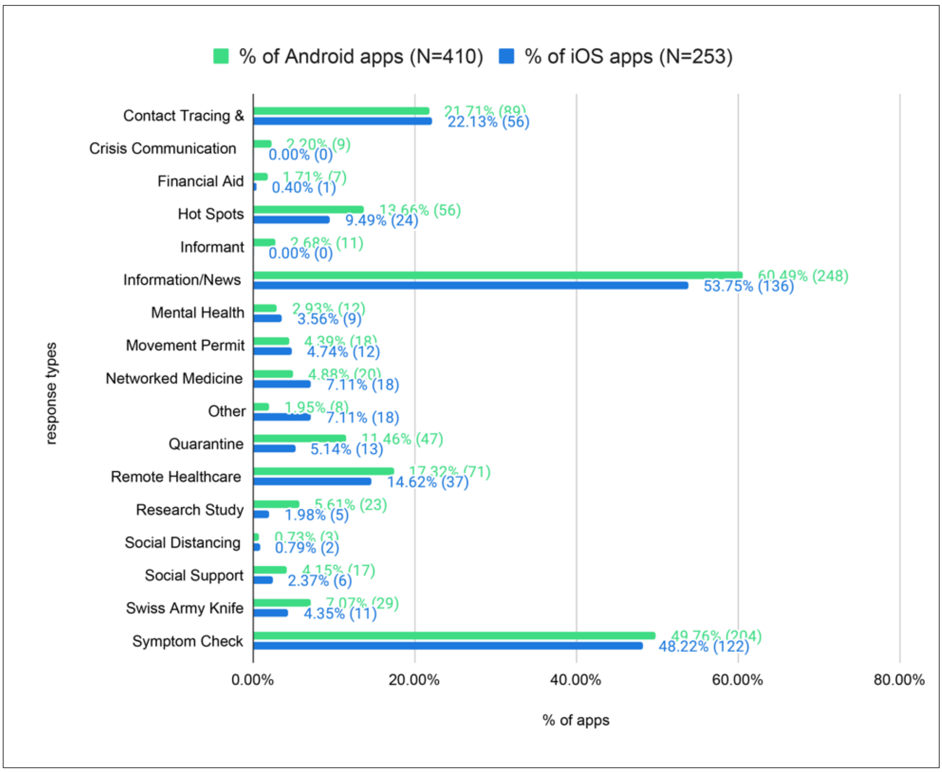
The apps from the WHO were not included in the editorially-curated subset and also could not even be found by anyone searching explicitly for it from the USA due to Google Play's search query redirect. The omission of the two WHO apps in the USA could, arguably, be related to the geopolitical tensions between the USA and the

156 While people assume around 60% adoption is needed, it actually remains unclear what percentage of the overall population in a country should adopt COVID-19 apps for digital contact-tracing and/or Exposure Notification to be effective (e.g., Howell O'Neill, 2020).

WHO at that time (i.e., President Trump pulled the USA out of the WHO in early June, accusing the WHO of being under China's control).

6.4.3. *Pandemic response types*

To understand the type of responses COVID-19 apps offer, we investigated what kind of apps these actors built. This allows identifying which response types are dominant, and which emerge with the distinct governance mechanisms of each store and the actors in each ecosystem. While digital contact-tracing apps have received by far the most attention in news reporting and the public debate, we found and categorised many additional response types for the purpose of the analysis [‣ Appendix E: Table E 6.2; Figure 6.4(a)]. For example, we found that over half of all apps (60% for Google Play; 54% for Apple's App Store) provided access to reputable sources of news and information on the COVID-19 pandemic ('Information/News'), developed by different actor types [‣ Figure 6.4(b) and (c)]. The prominence of these reputable ('official') sources of news and information, updates, and data may have been the result of collaborative efforts by the WHO and Big Tech companies to 'immunize the public against misinformation' by connecting end-consumers to the official sources (WHO, 2020b).



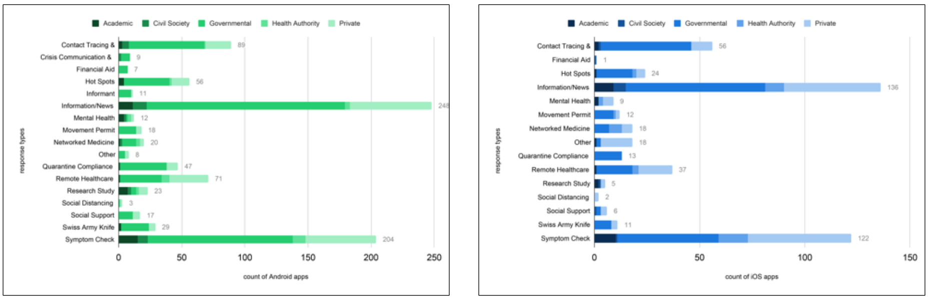


Figure 6.4(**a**) **to** (**c**). Comparison of response types represented by COVID-19-related apps (Android and iOS) [horizontal bar charts]. Apps can belong to multiple categories.

Data: Google Play and App Store. High-resolution figures are openly available in OSF at https://doi.org/10.17605/osf.io/wq3dr.

About a fifth of all apps (22%) fall into the category of 'Contact Tracing and/or Exposure Notification'. Most of these apps are built by governmental actors or in collaboration with private actors. Additionally, we found a variety of potential surveillance technologies beyond these digital contact-tracing apps: over 48% of all apps offer different kinds of symptom checkers or reporting tools, including diary-keeping or journaling apps and apps soliciting medical or personal data from users. These apps are connected to private actors, academic actors, or aligned with public healthcare. It is worth noting that a fair amount of the apps included in this study already existed well before the COVID-19 pandemic began, which means that some apps have been updated or adapted [‣ §6.4.4]. About 15% of all apps offered tools for remote healthcare developed by governmental or private actors. A smaller number of 'Swiss Army Knife' apps (7% for Google Play; 4% for Apple's App Store) represented multiple response types within the same app.

We also found new response types not accounted for in the literature, including 'Mental Health' and wellbeing apps to help deal with psychological pressures during the pandemic. We further found apps soliciting data for research studies, such as the German *Corona-Datenspende* app,[157] by donating data from various mobile devices for assisting in the ongoing scientific research about COVID-19. When comparing the two stores, we observed that 'Networked Medicine' apps (for healthcare workers to communicate and interact within a system) were, in relative terms, somewhat more prevalent in the App Store, while 'Crisis Communication & Management', 'Quarantine Compliance', and 'Informant' apps (to report people breaking COVID-19 rules to authorities) were mostly or only available in Google Play.

157 Robert Koch-Institut, *Corona-Datenspende*, https://play.google.com/store/apps/details?id=de.rki.coronadatenspende&gl=de.

Notably, 'Quarantine Compliance', 'Informant', 'Movement Permit', and 'Crisis Communication & Management' apps were primarily built by governmental actors. We found apps facilitating crowd-sourced state surveillance in Argentina, Chile, and Russia. These 'social monitoring' apps enable reporting on the suspicious behaviour of others. In Bangladesh and India, governmental apps called on citizens to report 'possibly affected people' to 'free the country' as part of their 'citizen responsibility'. And in India and Lithuania, we observed the gamification of a pandemic where users could participate in daily active health monitoring or symptom tracking practices to collect points to receive rewards or discounts.

So far, we may conclude that the app-based pandemic response is not only about contact-tracing apps but also includes other types of responses. The public debate, however, largely focused on digital contact-tracing apps. Additionally, these responses originate not only from governments but also from several other actor types around the globe (even if their activities were coordinated). These differences, along with the differences in Google and Apple's governance, have also led to variance in terms of how the pandemic response was organised and which types of apps and responses were available to citizens in specific countries or regions worldwide. In other words, the app-based response to the pandemic has been different depending on where one lives, and on which mobile platform or operating system is dominant. Because of the high stakes of the pandemic crisis, such differences are not just about consumer preferences, but shape the types of responses that are feasible and available across countries or regions (as determined by the app stores). Consequently, even when there is variation (and competition) in pandemic response types within the larger app ecosystem, these alternatives may still not be accessible to all end-consumers (or citizens).

6.4.4. *App development responsivity*

To analyse how rapidly the COVID-19 app ecosystem emerged and evolved, we additionally examined how responsive app developers have been to the pandemic. This provides yet another complementary perspective on the role of app stores as powerful shapes of the pandemic response app ecosystem, particularly regarding the temporal dynamics. We use the term *responsivity* as a proxy (or indirect measure) for the dynamics of software app updates (i.e., the number and pattern of software version releases) during the crisis and its openness to unprompted innovation).[158] That is, the openness 'to generate new valuable uses', which may themselves become sources of further innovation (Zittrain, 2008; [‣ Chs. 2 and 5]). Responsivity is measured by the number and pattern of software version releases).

158 Unfortunately, we were unable to retrieve data about software version releases for the App Store.

It captures a sense of how actively a specific country, or a specific developer (complementor), is working on those apps and how invested they are in the response that the app represents.

Figure 6.5 is a plot of all the Android apps per country, with all their software versions plotted on a chronological timeline. Every initial release (i.e., app launch) is represented by a light grey (transparent) circle and any subsequent app updates by same-coloured squares. The more frequent app updates were released per interval, the larger the size of the square plotted at that interval. We see that early COVID-19-related app development commenced almost immediately after the WHO's official declaration of the global pandemic on 11 March, with most countries launching their apps in March–April 2020. We also found that some of the apps already existed well before the COVID-19 crisis started, including apps that have been maintained since 2013. These apps from before the pandemic were primarily 'e-government' and apps (e.g., medical apps for communicating with health professionals) and apps providing general healthcare information. While conforming with the new platform policies of Google and Apple that prioritise releases from official and recognised entities, these repurposed apps signal the developers' agile response in using existing apps and app functionalities to deal with the COVID-19 crisis.

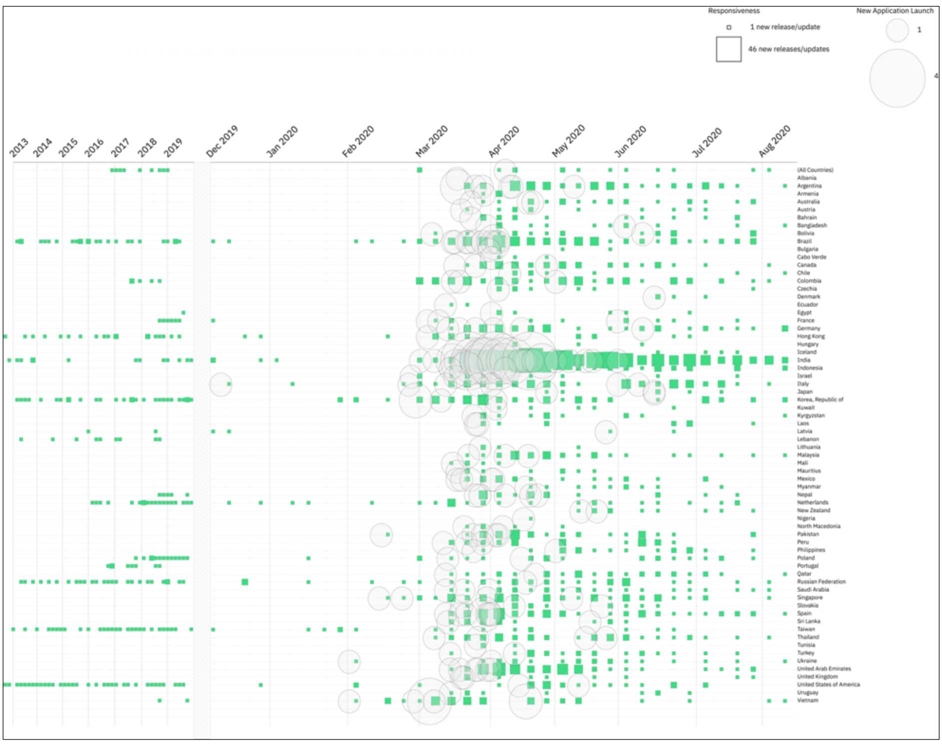


Figure 6.5. *Responsivity* in COVID-19-related app development, aggregated and sorted by country (Android only), 2013 – August 2020 [matrix plot diagram]. Light circles are the initial releases (i.e., app launches); colour-coded squares are any additional releases (i.e., app updates).

Node size: scaled by the total number of releases per interval. Data: App Annie. Graphic: DensityDesign Lab. High-resolution figures are openly available in OSF at https://doi.org/10.17605/osf.io/wq3dr.

Previous research on the evolution of Android apps from 2015 found that around 14% of apps are frequently updated on a bi-weekly basis (McIlroy et al., 2016), while developers abandoned the vast majority of apps shortly after their initial release (Tiwana, 2016). By contrast, surveying the average release and update patterns for the COVID-19-related apps in the source set suggests a high level of responsivity, particularly in Brazil, India, and the United Arab Emirates [UAE]. Specific cases such as Columbia's *CoronApp*,[159] which was the most frequently-updated app, reveals how agile (iterative) software development practices have coordinated with ongoing governmental injunctions to manage the unfolding pandemic. Inspecting the changelogs attached to each app update ('What's New') revealed efforts to synchronise app functionality with state emergency decrees.

Inversely, a relative absence of app development activity can also prompt further investigation into governance by app stores. Countries including Albania, Bulgaria, Denmark, Ecuador, and the United Kingdom [UK] showed limited responsivity, which may indicate national problems and delays in the development of COVID-19 apps, including due to public controversy, skepticism, or a lack of trust/trustworthiness (e.g., Simon and Rieder, 2021; Wetsman, 2021). In June 2020, the Danish Data Protection Agency prohibited its app from processing personal data until further notice (Amnesty International, 2020). The official Danish app (*Smitte|stop*[160]) has since relaunched after addressing multiple data/privacy-related concerns. England and Wales, meanwhile, initially experimented with an app that used a centralised approach to data collection, but this was eventually abandoned (Sabbagh and Hern, 2020). Therefore, a lack of responsiveness from certain countries or actors additionally can reflect cases of backlash and legal contestation, specifically related to data protection and privacy.

159 INS.GOV, *CoronApp - Colombia*, https://play.google.com/store/apps/details?id=co.gov.ins.guardianes&gl=co ; INS.GOV, *CoronApp-Colombia*, https://apps.apple.com/us/app/coronapp-colombia/id1502037648.

160 Sundhedsministeriet, *Smittestop*, https://play.google.com/store/apps/details?id=com.netcompany.smittestop_exposure_notification&gl=dk

A lack of responsiveness may also occur on the part of the platform owner. In fact, *The Markup* reported about discovered privacy flaws in contact-tracing apps developed through the aforementioned GAEN framework, despite Google and Apple providing assurances to 'people worried about sharing private health information with major corporations' (Ng, 2021). Moreover, 'not only does the Android version of the contact-tracing tool contain a privacy flaw, but when researchers from the privacy analysis firm AppCensus alerted Google to the problem back in February 2021, Google failed to change it'. This illustrates the lack of responsiveness on the part of Google to severe privacy issues reported as part of Google's own bug bounty programme. At the same time, one might perhaps expect that, by endorsing the institutional authority of public health organisations (particularly in Western and European countries), that Google and Apple would actively pursue public value policies, such as regarding information accuracy, privacy, and knowledge verification. This at least points to the tensions that exist between the corporate and commercial interests of Google and Apple on the one hand, and the public and governmental interests of countries worldwide on the other hand.

Finally, the degree to which the app stores actively enforce their terms and policies by delisting or banning apps from their app stores marks an important aspect of pandemic platform governance. While it is always difficult to establish whether an app was removed by its developer or by the app store platform owner (and the reasons for its removal), two large-scale studies found that after 1.5–2 years, almost half of all Android apps listed in Google Play (Wang et al., 2018) and iOS apps listed in the App Store (Lin, 2021) were no longer available. In the data set of this study, only 31 Android apps (8% of Google Play apps) and 15 iOS apps (6% of App Store apps) were no longer available eight months after data collection. This is even lower than the study by Samhi et al. on COVID-19 apps (2021), which observed that 15% of COVID-19 apps had been removed in the first two weeks after data collection in June 2020. COVID-19 apps are subject to 'an increased level of enforcement' during the app review process and are thus more likely thoroughly screened and removed sooner (Google Play Console Help, n.d.).

6.4.5. *Discursive positioning of pandemic response apps: Implemented techniques and data/privacy concerns*

Next, we analyse the discursive positionings of COVID-19-related apps towards end-consumers based on the two lists of relevant search terms and patterns. The language used by app developers to describe their apps (in app titles and long descriptions) is significant not least because it is used by Google to automatically govern the discoverability of COVID-19 apps (i.e., through its query-based governance mechanisms), as well as by end-consumers to find the apps at all (e.g., to make an informed decision as to the app's usefulness, before downloading and installing it). In fact, the app description field is all that app developers have available to them in the user interface to provide additional information, which makes it particularly significant to understand if and how the field is used in practice. Specifically, the descriptions may provide important information that can be scanned to surface issues and concerns about the aims, features, or implementation of the apps. Additionally, we noticed that the descriptions of apps were used to communicate legitimacy and trust to potential end-consumers (e.g., Simon and Rieder, 2021), using particular discourse related to the technological implementation (similar to what I observed in Chapter 5, where technological implementations were also sometimes explained in the descriptions of social media-related apps, and for similar reasons) and anticipated concerns regarding data/privacy (similar to what we observed in a previous study of secure messaging apps in the aftermath of Edward Snowden's global surveillance disclosures (Dieter et al., 2019; Helmond et al., 2016).

We analyse the titles and description of all apps in the data set to identify whether and how the public debate resonates among app developers around (1) the technological implementation of the various response types (i.e., the implemented techniques; not just for digital contract-tracing apps but for the entire corpus of apps) and (2) the associated data/privacy-related concerns [▸ Appendix: Table E 6.3]. Given the many different languages used, we also included the (Google-)translated versions of all app titles and descriptions. These app titles and descriptions address potential end-consumers in specific ways to inform them about the apps' functionality and use scenarios (and ultimately, to persuade them to download and install the app), as we also found in the ecosystem of social media-related apps [▸ Ch. 5]. We examined to what extent these textual descriptions, which the app developers themselves provide, explicitly reference any techniques and to what extent they address data/privacy-related concerns as measured in term frequencies. In short, we simply measure relevant term frequencies without delving further into interpretative analysis of these discourses.

The first list includes technique-related search terms and patterns and reveals how app developers perceived the functionality of their response apps, how they have implemented that functionality, and how they conveyed this to potential end-consumers. Figure 6.6(a) and (b) show the distributions of these terms and patterns in Android and iOS apps, respectively. It includes prominent terms, such as 'location', 'notification', 'track' and 'trace', alongside technological terms, including 'GPS', 'Bluetooth', 'alert', 'smart', and mentions of artificial intelligence and machine learning algorithms for identifying symptoms of COVID-19. We also detected related terms such as 'video', 'chat' and 'messaging', and 'bots'—techniques commonly used for remote healthcare and diagnostics purposes. Overall, the distribution of terms is largely similar across Google and Apple's pandemic response app ecosystems, suggesting similar discourses around the techniques used.

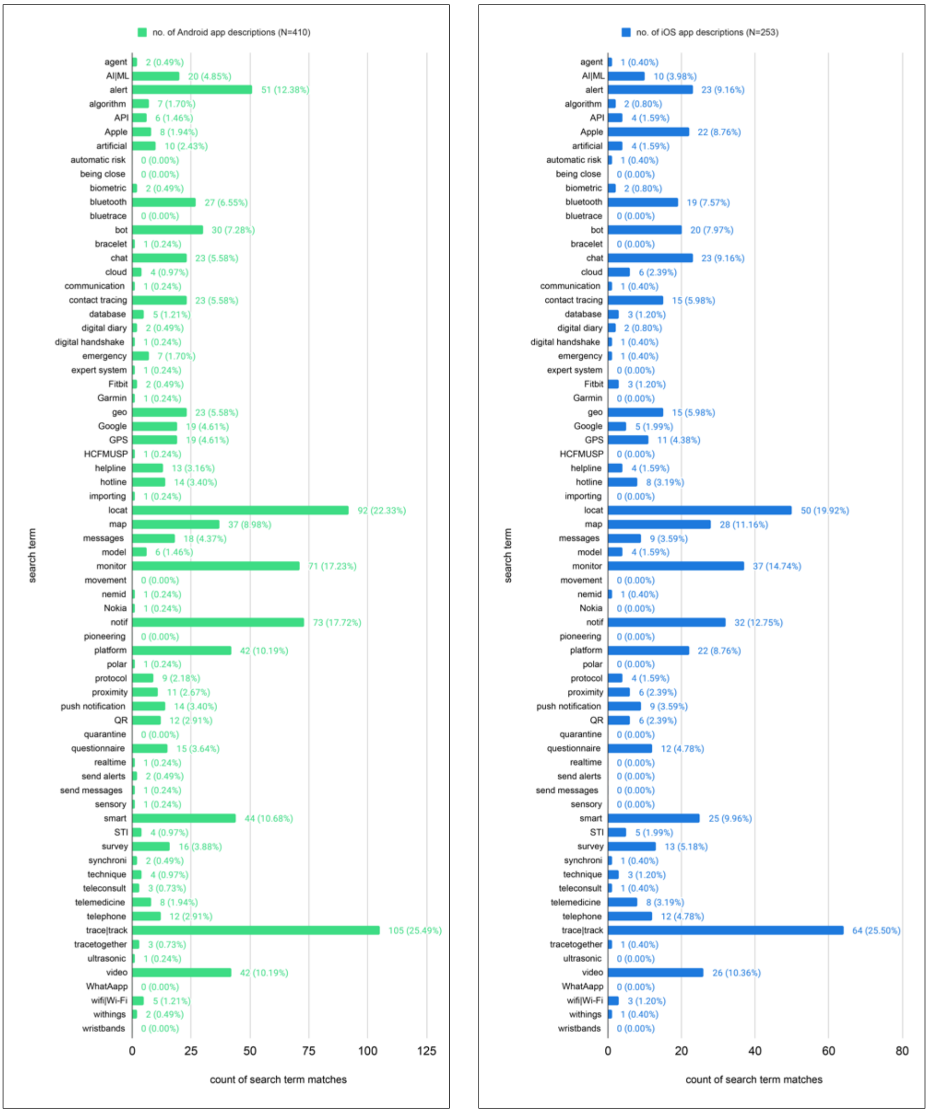


Figure 6.6(a) **and** (b). Counts of technique-related search term and pattern matches in COVID-19-related app titles and descriptions (Android and iOS) [horizontal bar charts]. Apps can belong to multiple categories.

Data: Google Play and App Store. High-resolution figures are openly available in OSF at https://doi.org/10.17605/osf.io/wq3dr.

The second list includes data/privacy-related search terms and patterns and reveals how app developers convey their efforts to inform or tackle data/privacy-related concerns to potential end-consumers. Figures 6.7(a) and (b) show a tendency among app developers to describe how their apps handle data collection and storage, including anonymisation, encryption, and local data storage. We also found claims made about apps that delete data, transmit data securely via HTTPS [HTTP

Secure], or process data in compliance with the EU General Data Protection Regulation [GDPR], for instance. As such, the apps express their compliance with app stores' policies and guidelines, which imposed additional requirements for the collection and use of personal and sensitive data to support research on COVID-19 (Apple Developer, n.d.; Google Play Console Help, n.d.). Overall, we note that the app-based pandemic response is principally framed as being data/privacy sensitive and compliant. 126 iOS (50%) and 158 Android (40%) app descriptions mention any of the data/privacy-related terms, suggesting that app developers have taken seriously the ongoing public debate about the potential privacy risks. It bears emphasising, of course, that the mere presence of these discourses does not mean the operations of these apps conform to such stated capacities and values (Kuntsman et al., 2019).

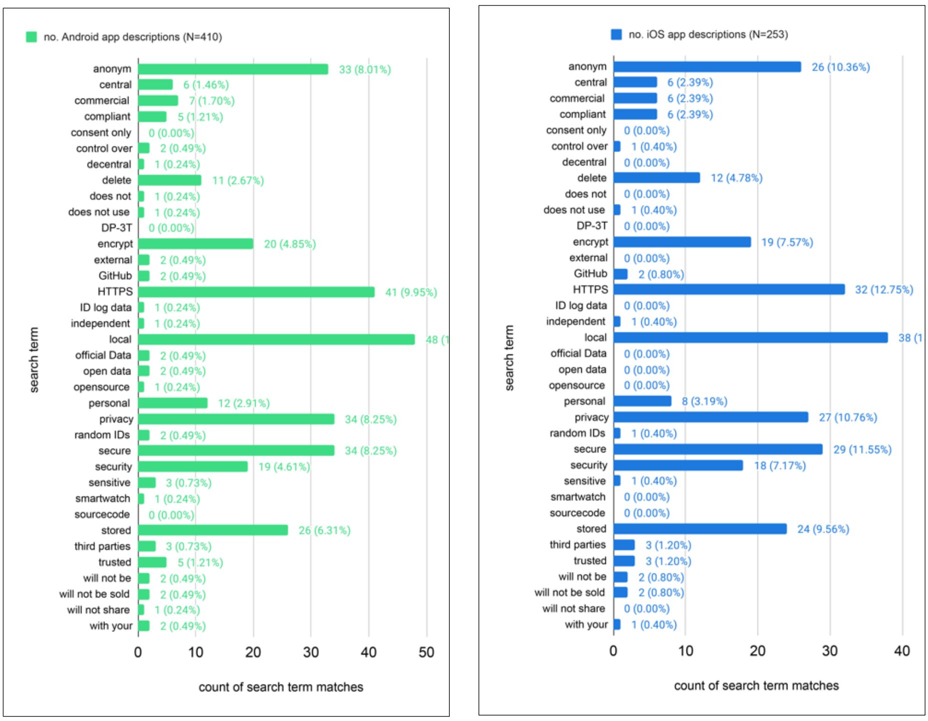


Figure 6.7(a) **and** (b). Counts of data/privacy-related search term and pattern matches in COVID-19-related app titles and descriptions (Android and iOS) [horizontal bar charts]. Apps can belong to multiple categories.

Data: Google Play and App Store. High-resolution figures are openly available in OSF at https://doi.org/10.17605/osf.io/wq3dr.

6.4.6. *App development dependency: Embedded software libraries and frameworks*

Finally, we inspected all COVID-19-related Android app packages—that is, all Android Package [APK] files—to analyse their technological configuration and developmental dependencies.[161] This is not only a complementary technical perspective on the technological implementation of pandemic response types in apps (particularly complementing the previous discursive enquiry) but also provides important insights regarding app development as a mode of production. As in the previous chapters, this aspect is particularly significant for the development of platform infrastructure by third-party software developers and to explain platforms' unique positions of power in the larger platform ecosystem.

Together with application programming interfaces [APIs], SDKs are key mechanisms of generativity and control in the evolution of digital platforms and infrastructures generally (Blanke and Pybus, 2020; Eaton et al., 2015; Tilson et al., 2012; [‣ Chs. 2 and 5]). Most app developers use specific software libraries and SDKs (i.e., collections of software libraries) to create apps with advanced functionalities, including social login and authentication, push notifications, or digital marketing and advertising. Additionally, SDKs may be used to tailor apps to specific platforms: apps for Android Platform or for the iOS operating system thus require different developer tools. In this environment, Google and Apple are key players in several ways. They do not only have ownership or control over the leading app stores (i.e., the means of app distribution and monetisation) and the mobile OSs (i.e., the means of app operation) to which are linked; they also provide many of the most-used development tools and frameworks (i.e., the means of app production). Both technology companies are thus uniquely positioned as gatekeepers—or again, 'obligatory passage points' (Callon, 1984; Dieter et al., 2019; Fagerjord, 2015; [‣ Ch. 5])—in the app-based pandemic response by countries worldwide.

We identified a total of 7,335 software libraries in the 410 Android apps in the Google Play source set (avg. = 19.2 libraries; median = 17 libraries). 28 Android apps (6.83%) returned no data from AppBrain and 79 (19.27%) contained no software libraries at all, indicating that those apps had not been developed with standard development tools and environments,[162] and may instead have been 'bootstrapped' (i.e., developed 'from scratch'). The high average and median number of software libraries in Android apps shows how reliant app development has become on these development tools [‣ cf. Figure 6.9]. Figure 6.8 shows that most of the libraries we

161 We were unable to detect embedded software libraries in iOS apps. Additionally, it is relevant to reiterate that the data collection for this study occurred before the Google/Apple Exposure Notification [GAEN] framework was fully developed and deployed. Consequently, the framework was not part of this study.

162 E.g., Android Studio, https://developer.android.com/studio

found are development tools (98.4%, 7,217 libraries), with only a few advertising libraries (1.06%, 48 libraries) and social libraries (0.54%, 40 libraries). The development tools are mainly for embedding graphical user interface [GUI] components, networking, app development frameworks, Java utilities, databases, and analytics tools [▸ Figure 6.8: 'Tags' column]. We generally found very few advertising network libraries due to Google's specific requirements for COVID-19-related apps, which restricts in-app advertising and monetisation.[163] Surprisingly, we found some of them within governments-made apps. For example, we detected Google's AdMob SDK in government-made apps from India, Qatar, and Singapore, and Outbrain's SDK in apps from Australia, Argentina, Italy, and the UAE.

163 'Apps that are subject to these requirements include but may not be limited to: / 1. Apps that provide medical, treatment, vaccine, testing, or other related information specifically for COVID-19. / 2. Apps that support COVID-19-related response, containment, research, or education/training efforts. / 3. Apps that support services used to respond specifically to COVID-19, for example, apps that provide social support (food stamps, payment), healthcare, loans, etc., specifically in response to COVID-19' (Google Play Console Help, n.d.).

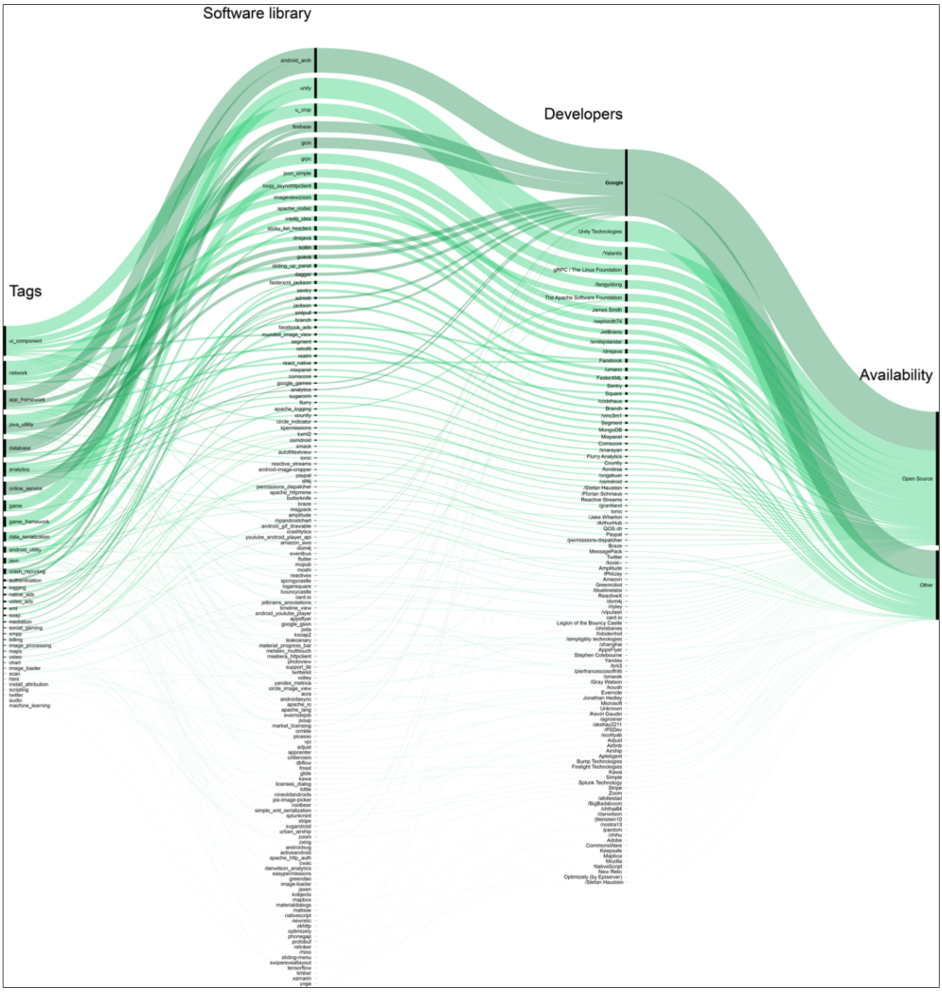


Figure 6.8. Software libraries embedded in COVID-19-related apps (Android only) [alluvial diagram]. Nodes are software library tags (left), library types, their developers (or owners), and their (open source) availability (right).

Node size: scaled by library frequency count (i.e., popularity). Highlighted are software libraries developed or owned by Google (dark green). Data: AppBrain. High-resolution figures are openly available in OSF at https://doi.org/10.17605/osf.io/wq3dr.

The 205 unique software libraries that we detected have been developed and maintained by 134 distinct actors, including 49 Google-owned software libraries that accounted for 4,289 (58.47%) of all the software libraries used. Over half of the Android apps (56%) relied on at least one of Google's libraries and the median Android app included 10, representing 59.46% of all libraries used in the median Android app.[164] We further identified 70 individual developers, many of them on GitHub, offering specific solutions such as for data conversion and serialisation or image cropping.

Figure 6.9 shows the (geographical) distributions of software library developers for each country, clustered by world continent. 303 (73.90%) of the Android apps used at least one open-source software library (including those by Google), with a median of 14 open-source libraries. While one might expect most Android software libraries to be Google-developed, it is nonetheless significant that a single technology company has accrued such dominance at the infrastructural level of technological integration—not only 'core' Android libraries but also those used to embed maps, video playback, in-app advertising and monetisation, or analytics services.[165] Previous research on 'technical integration' and dependency in the mobile ecosystem has shown that large technology companies like Google 'have decomposed and recomposed themselves for developers' and should, therefore, be considered as 'service assemblages' to account for the relations and material conditions of platforms (Blanke and Pybus, 2020) and also the associated app permissions as 'the technical objects of datafication' in the mobile ecosystem (Pybus and Coté, 2021).[166] The ownership relations of these software libraries at the 'microscopic', infrastructural level thus reflect larger strategic and economic dynamics around competition and infrastructural power, and some of the deeper ways in which pandemic platform governance, and platform power generally manifests itself.

164 While we have not analysed the app development dependencies of the iOS apps, it is worth noting that they will also include third-party software libraries and frameworks. Additionally, all iOS apps are built with Xcode, which is Apple's integrated development environment for macOS, iOS, iPadOS, watchOS, and tvOS.

165 https://developer.android.com/jetpack/androidx/releases/core, https://developers.google.com/maps/documentation/android-sdk/intro, https://developers.google.com/youtube/android/player, http://www.admob.com, and https://developers.google.com/analytics/devguides/collection/android/

166 https://developer.android.com/guide/topics/permissions/overview

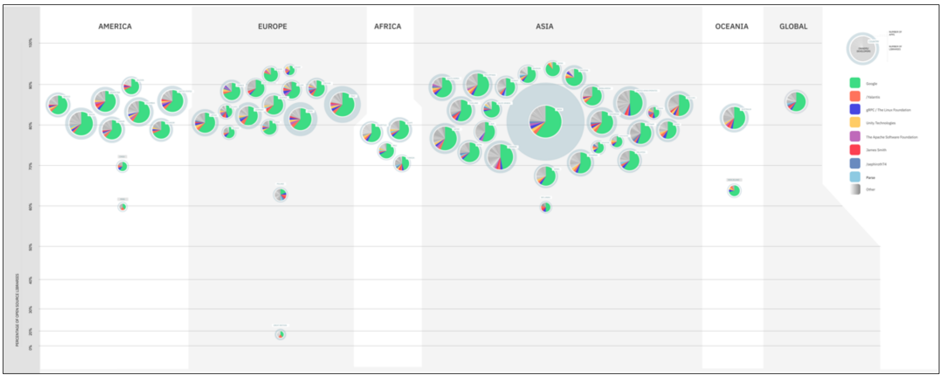


Figure 6.9. Developers behind software libraries embedded in COVID-19-related apps [geographical clustered and ranked pie charts], aggregated and sorted by country and world continent (Android only). Circles (mini pie charts) are library developer distributions per country.

Horizontal axis: continents; vertical axis: % of libraries that are open source (top is most, bottom is fewest); scale: logarithmic. Highlighted are software libraries developed or owned by Google (dark green). Data: AppBrain. Graphic: DensityDesign Lab. High-resolution figures are openly available in OSF at https://doi.org/10.17605/osf.io/wq3dr.

6.5. [DISCUSSION] Governing the COVID-19 pandemic response app ecosystem

The 'multi-situated' approach of this study uniquely provides insights into the emerging ecosystem of COVID-19 pandemic response apps, and how this ecosystem—that is, the app-based response to the pandemic—is being mediated and shaped by Google Play (for Android apps) and Apple's App Store (for iOS apps). Such an understanding recognises from the beginning that platform companies occupy a central role in app ecosystems, exercised through diverse mechanisms and agencies that operate across different layers (Gorwa, 2019), and mediated by the relationships between governments, citizens, and other actors. As such, the analysis did not focus on specific response apps, nor on the app-based responses of individual countries or regions, but on the entire global ecosystem of pandemic response apps. This provides both a sense of the breadth and the diversity of the app-based pandemic response, as well as the role of Big Tech companies in how the two dominant response app ecosystems have taken shape during the pandemic through acts of exceptional platform governance.

Crucially, Google and Apple are strategically positioned as central gateways in the larger mobile app ecosystem. Consequently, Google and Apple's respective platform governance configurations have inevitably shaped the app-based response to the COVID-19 pandemic in countries worldwide. We found that the global ecosystem of pandemic response apps involves a multitude of actors, including state governments, the private sector, academic and health authorities, and civil society actors. The relationships between these actors (and actor types) are (inter)mediated and shaped by the app stores in specific ways, which may have significant consequences in the longer term, although this was not the focus of this study. Instead, we examined how the COVID-19-related Android and iOS app ecosystems have been taking shape in the first months of the unfolding COVID-19 crisis, which represented unprecedented circumstances for app stores and online digital platforms generally. Consequently, Google and Apple both deployed novel strategies to govern and control their respective COVID-19-related app ecosystems, influencing which apps were allowed (and disallowed), by whom they were developed, or the types of responses and functionality they offered (and not offered, such as unique restrictions on in-app advertising and monetisation).

6.5.1. *The app-based pandemic response*

Despite the strengthened grips of both Google and Apple on their respective response app ecosystems, we were able to find a broad and diverse pandemic response app ecosystem in both cases, with many different actors and response types. Nevertheless, the findings of the exploratory analysis, and the exceptional responses of Google and Apple, warrant further investigation, particularly regarding the longer-term implications of what we have called pandemic platform governance.

First, we observed a broad alignment of state governments, international organisations, and technology companies all recognising a need to act—or get 'involved in the fight' (WHO, 2020a). Specifically, there has been an international coordinated response to the COVID-19 pandemic, involving national state governments and other actor types, despite the different interests, responsibilities, and values of those actors, including regarding Google and Apple themselves (e.g., regarding alleged anti-competitive practices, data protection and security breaches, fair taxation of Big Tech companies, content moderation policy for online disinformation and illegal content, etc. (e.g., Busch et al., 2021; Khan, 2018; Klonick, 2018; Suzor, 2018). The omission of the WHO apps from Google Play in the USA is notable in this respect precisely because it remains unclear why those apps are missing. Additionally, the COVID-19 pandemic has aligned powerful global and supranational actors around shared concerns. This includes not only the ongoing spread of the coronavirus disease but also the COVID-19 'infodemic', and the need to build or maintain legitimacy and trust in the deployment of (privacy-preserving and secure) digital contact-tracing apps (e.g., Simon and Rieder, 2021). For example, the public controversy around centralised, decentralised, or partially-decentralised contact-tracing protocols and frameworks in May–June 2020, particularly between the Decentralised Privacy-Preserving Proximity Tracing [DP-3T] and the (centralised)

Pan-European Privacy-Preserving Proximity Tracing [PEPP-PT] project, has divided countries and delayed the development of COVID-19 contact-tracing apps.[167] The public controversy around the appropriate technical implementation of digital contact-tracing foregrounded the different interests, responsibilities, and values of Big Tech companies and Western democratic governments in particular. Additionally, the discourse used by the different actors in their app descriptions reflected the need to provide additional information to increase legitimacy and trust for potential end-consumers, as we found in the analysis of discursive positioning [‣ §6.4.5]. While the tensions will remain, they are thrown into relief by the context of the crisis (as the omission of the WHO apps in the USA demonstrate), which allows for a unique empirical mapping of the asymmetries, power relations, and points of potential negotiation that shape platform governance more generally.

Second, pandemic platform governance has initially supported the development of app ecosystems, which, uniquely, (largely) exclude the commercial activity that normally characterises Google and Apple's app stores. Although COVID-19 apps further entrench the dominance of digital platforms overall, during this early period, we observed a heightening of their role as 'regulatory intermediators' within this specific niche by connecting citizens with apps and services of governments and other authorities (Busch, 2020). In the case of Google Play, for instance, this intermediation is steered through specialised editorial (and not an algorithmic) curation logic. Exceptional requirements and restrictions were implemented and app review processes expedited to 'enable official [COVID-19] apps intended to respond to the COVID-19 pandemic to publish on the Google Play Store' (Google Play Console Help, n.d.). How this role evolves over time, however, should remain subject to ongoing critical investigation.

Third, this repurposing of commercial digital platforms and infrastructures for ostensibly public ends intensifies the (inter)mediated relationships between global technology companies and national state governments. App stores temporarily ceded their role as facilitators of commercial activity and instead positioned themselves as critical global infrastructure: they organised and managed the emerging ecosystem of pandemic response apps across local, regional, or national contexts worldwide and provided the means of distribution (i.e., app stores), the means of operation (i.e., OSs), and the means of production (e.g., developer tools and libraries, but also the GAEN framework). Yet, there is limited public oversight. For their part, national state governments were effectively cast into a complementor role: they took responsibility for the development of Android and iOS response apps, sometimes in collaboration or partnership with other actors, yet always under material and regulatory conditions specified by Google and Apple's respective app

167 E.g., https://en.wikipedia.org/wiki/COVID-19_apps#List_of_frameworks.

stores (e.g., exemplified by the controversy around around centralised, decentralised, or partially-decentralised contact-tracing protocols). This highlights the tensions that inevitably exist (and thus manifest themselves) between public and private actors, including in the app development process. How governments adopted their (new) role as complementor varied in terms of the response types, their collaborations, or partnerships (actor types), and the efforts invested to build and maintain their apps (i.e., responsivity). Again, it is important to consider how these changes impact or transform the existing 'layers of governance relationships' between these key parties in the platform society (Gorwa, 2019), especially in the light of ongoing strategic efforts by Big Tech companies to get more involved in public sectors and the cross-border challenges of the 21st-century (e.g., Bhatia, 2021; van Dijck et al., 2018). This raises concerns about the anchoring of public values in the provision of essential services through the private sector (van Dijck, 2021b; Plantin et al., 2018).

Fourth, several aspects of the COVID-19-related app ecosystem contribute to legitimising the development and distribution of apps to respond to the COVID-19 pandemic. Within the descriptions of apps, we detected distinctive discourses around techniques used, including contact-tracing protocols and frameworks, as well as around data/privacy. Developers of apps thus signalled their technological competence, sometimes bordering on 'tech solutionism' (i.e., the belief that each problem has a solution based in technology) (e.g., Wamsley and Chin-Yee, 2021), as well as signalled their awareness of data/privacy and data protection concerns. Whether the apps abide by these stated claims is another question, yet it is telling that both solutionist and data/privacy-protection discourses are mobilised within this niche for purposes of legitimation (or reassurance). How these kinds of discourses might contribute to further blurring distinctions between figures of the user (end-consumer) and the citizen is a point for further research.

Lastly, the unprecedented circumstances of the pandemic, 'on top' of the conditions of generativity already provided by digital platforms, have facilitated a broad and diverse set of national responses around the globe. These responses all emerged in a short time-period. Mobile platforms and app stores, as market facilitators for the digital economy, are highly generative and responsive: they facilitate and rely upon the commercial activity of their complementors, which are largely commercial and sometimes governmental app developers. We observed a broad diversity of COVID-19-related response apps, despite both Google and Apple strengthening their grips because of the high stakes of the pandemic, and despite public controversy and criticism around COVID-19 apps. While the GAEN framework was an important move towards privacy-preserving contact tracing via mobile devices and apps, it is also problematic that countries worldwide depended on Google and Apple to allow for such a framework in the first place. That is, the GAEN system remains the only framework that could be implemented at the OS-level to allow for more efficient operation of Bluetooth in the background (specifically of Bluetooth Low Energy, which, importantly, is designed for very low power consumption).[168]

6.5.2. *Generativity and adaptation*

Notwithstanding the critical facilitator role of technology companies in the highly-regulated global response to the COVID-19 pandemic, we still have distinctive identifiable national response strategies, exceptions, and outliers. However, since these app ecosystems are in some ways exceptional, their generativity attains a distinct resonance. Because the current mode of pandemic platform governance has been global in its scope, the generativity of Google and Apple's mobile platforms could produce a scenario where Argentinian citizens were snitching on each other through informant apps,[169] German citizens could donate data to its public health authority (i.e., the Robert Koch Institute),[170] UK citizens participated in academic symptom research studies,[171] and USA citizens were uniquely denied access to the WHO's informational apps.[172] Consequently, mobile app ecosystems are at least

168 The GAEN framework is like the European DP-3T protocol but is implemented at the OS-level.

169 HPI Knowledge Engineering Team, *OpenWHO: Knowledge for Health Emergencies*, https://play.google.com/store/apps/details?id=de.xikolo.openwho&gl=ae; Hasso-Plattner-Institut, *OpenWHO*, https://apps.apple.com/us/app/openwho/id1183923481; World Health Organization, *WHO Info*, https://play.google.com/store/apps/details?id=org.who.infoapp&gl=ae; World Health Organization, *WHO Info*, https://apps.apple.com/us/app/who-info/id895463794.

170 Robert-Koch-Institut, *Corona-Datenspende*, https://play.google.com/store/apps/details?id=de.rki.coronadatenspende&gl=de; Robert-Koch-Institut, *Corona-Datenspende*, https://apps.apple.com/de/app/corona-datenspende/id1504705422.

171 Zoe Global Limited, *COVID Symptom Study*, https://play.google.com/store/apps/details?id=com.joinzoe.covid_zoe&gl=uk; Zoe Global Limited, *COVID Symptom Study*, https://apps.apple.com/gb/app/covid-symptom-study/id1503529611.

172 HPI Knowledge Engineering Team, *OpenWHO: Knowledge for Health Emergencies*, https://play.google.com/store/apps/details?id=de.xikolo.openwho&gl=ae; Hasso-Plattner-Institut, *OpenWHO*, https://apps.apple.com/us/app/openwho/id1183923481. While there is some uncertainty about the omission of the two WHO apps (Torres, 2020), the outcome is the same: in the critical months between April and July 2020, the

somewhat pliable to the local, national, and international differences that inevitably exist among countries or regions. Moreover, COVID-19 response apps, including those built or contributed by national state governments, were only available to users of Google's Android Platform or Apple's iOS operating system, which both reflects and further entrenched their dominance in the global mobile app ecosystem. There is effectively no way around them. As such, Google and Apple were not only strategically positioned in economic terms (e.g., as key facilitators of economic activity and transactions), but also in social and governmental terms as pivotal actors who were (inter)mediating the relationships between governments, international organisations, and citizens of countries worldwide during this moment of crisis. Such a pivotal position may have provided them with additional legitimacy and authority as global powers (*vis-à-vis* national or local governments).

Pandemic platform governance thus arguably foregrounds how technology companies, and mobile platforms, have accustomed themselves to their new role as facilitators of not only commercial but also public or governmental activity during an unprecedented global public health crisis. Beyond the government-made response apps, the unique political, economic, and social circumstances induced by the COVID-19 pandemic have accelerated the development and adoption of digital health and surveillance technologies within the public health domain, under the guise of technological innovation to combat the unique challenges of the COVID-19 crisis. Meanwhile, Wamsley and Chin-Yee note that 'appeals to technological solutions in the face of "unprecedented" crises often serve to obscure political ideologies and foreclose critical reflections on more democratic alternatives' (Wamsley and Chin-Yee, 2021). This observation highlights how 'innovation' in the context of mobile platforms serves to increase the adoption of already-existing digital platforms or technologies, more than the creation of entirely new tools, products, or services (that would potentially challenge or 'disrupt' the platform owner's market dominance). Instead, generativity (and 'innovation') serves the continuous and incremental *adaptation* of digital platforms and technologies, by diverse user and stakeholder groups, 'to countless needs and niches that the platform's original developers could not have possibly contemplated, much less had time to accommodate' (Andreessen, 2007; [‣ Ch. 5]). This is also exemplified by those apps that already existed in March 2020, and which were merely adapted to the needs induced by the onset of the pandemic, such as the two WHO apps covered in this study. It is also relevant to consider how the mobile app ecosystem itself adapted to the COVID-19 pandemic—that is, how the COVID-19 pandemic continues to impact the app ecosystem, as opposed to the other way around, including fundamental

USA was the only location from where the WHO Android apps could not be downloaded and installed.

changes in app downloads and usage generally (e.g., Perez, 2022). Both developments further entrenched the pivotal role of Google and Apple's mobile platforms and app stores as 'gateways' to the world's online digital (public or private) health products and services, which is reflected in the breadth of response types and the number of apps generally. By the same token, this further legitimises the authority of these app stores as 'mere' (disinterested) intermediaries.

By scoping the entire global ecosystem of COVID-19-related mobile apps, and not only digital contact-tracing apps or the 'editorial' apps filtered by Google, but we were also able to find and study the full breadth and diversity of pandemic response apps that were being developed (particularly beyond contact-tracing apps). Additionally, through the actor-types analysis, we found that the pandemic response is not only driven by governments but also involved other types of actors, depending on the specific countries or regions. Furthermore, the multiple lines of enquiry surfaced, and led to unique insights into the specific governance mechanisms used to manage the exceptional pandemic response app ecosystem and, to some extent, the 'infodemic'. Consequently, the exploratory take has surfaced some of the longer-term strategic considerations for Google and Apple in particular, regarding the articulation of boundaries between commercial and non-commercial (or 'serious') 'shelves' in their app stores though *ad hoc* governance measures, rudimentary editorialisation of users' 'serious queries', and specific terms and policies for COVID-19 apps. Going forward, it is worth considering whether such exceptional moments of pandemic platform governance should be maintained, not least because just two global technology companies effectively (inter)mediated and shaped the app-based pandemic response in countries or regions all around the globe. Additionally, these moments of exceptional governance should be considered in the light of, on the one hand, the longer-term strategic ambitions of Big Tech companies to get more involved in public sectors and tackle 'the next generation of cross-border challenges that lay over the horizon' (Bhatia, 2021) and, on the other hand, the growing geopolitical tensions between Western and non-Western powers in particular.

6.6. Concluding remarks

This second chapter of Part III asked [RQ3(b)]: how governance and power are manifested in the developmental processes of the COVID-19-related mobile app ecosystems emerging in the initial stages of the global pandemic crisis.

To address this question, it explored the role of app stores in mediating and structuring the app-based response to the COVID-19 pandemic crisis by governments and organisations in countries and regions worldwide. It has presented the outcomes of a first comprehensive study of the emerging pandemic response app ecosystems and how app stores' governance mechanisms have mediated and shaped these emerging ecosystems. The multiple lines of enquiries have surfaced how Google and Apple are uniquely positioned as 'gatekeepers' in the global response to the pandemic and the 'infodemic'. Specifically, the different analyses provide complementary perspectives on the critical facilitator role of technology companies in the highly-regulated global response to the COVID-19 pandemic, and how this (new) role has shaped the emerging ecosystem of pandemic response apps. This unique ecosystem may set a precedent—serve as an important example and reference point—for the role of (very) large and private technology companies in the face of the 'unprecedented' COVID-19 crisis. It is not, by itself, an issue or concern that companies like Google and Apple took a key role in the global pandemic response. However, it is worth reflecting on the longer-term strategic and political implications of the evolving relationships between such companies and the capacities of state governments, public health institutions, and health systems worldwide. Exploratory studies like this one are critical to better understand how the appeals to technological solutions, such as those involving mobile devices and apps, particularly in the face of an 'unprecedented' crisis, ultimately impact democracies in Europe and beyond in subtle ways (e.g., van Dijck, 2021a; Wamsley and Chin-Yee, 2021).

The original empirical materials and analyses of this study allow for additional and comparative studies of the specific app-based responses of individual countries or regions, even if this was not the main aim. Additionally, it could be relevant to further investigate and compare how other popular online digital platforms and services, including Google Search, Facebook, Twitter, and TikTok have responded to the unprecedented circumstances of the pandemic and the associated infodemic. This includes further investigations of the 'exceptional information state' (Rogers, 2021) because the editorial interventions of digital platforms, particularly around COVID-19-related search terms, are directly related to perceived trust in the returned search results (and the ranking or prioritisation of those results). Mechanisms and processes like these all tie into the establishment of trust and trustworthiness in today's global and interconnected digital economies and societies. Finally, it is important to learn from the current pandemic response regarding the 'incursion' of digital technology into public health systems around the world (Wamsley and Chin-Yee, 2021: 5) and the evolving relationships between technology, democracy, and inequality generally. ▾

7. Conclusion

On the ecosystems of platforms

(VERY LARGE) ONLINE DIGITAL PLATFORMS, such as Google, Apple, Facebook (now Meta), Amazon, and Microsoft have 'eaten the world' and have asserted themselves *as infrastructure* for the everyday life and practice of billions of people worldwide (cf. Andreessen, 2011; Moazed and Johnson, 2016; Parker et al., 2016; [▸ Ch. 1]). They do not only (inter)mediate many different social and economic processes, but also govern and control them in specific ways.

While these technology companies have continued to grow at record pace throughout the 2010s, the (negative) societal consequences of their growing power have become increasingly apparent. The power of 'network effects' is of particular significance for understanding this 'platformisation' across markets and sectors of society at unprecedented speed (e.g., van Dijck et al., 2018; Helmond, 2015a; Poell et al., 2019; Poell et al., 2021). Big Tech companies establish, integrate, and leverage powerful network effects at all levels and sides of their platforms to serve as a principal source of their economic strength, power, and influence in today's global and interconnected digital economies and societies. As their networks continue to grow and evolve in terms of users and uses, the pull of the most powerful 'nodes' in the larger network—that is, the Web and the Internet as a whole—has become overwhelming because of the network effects. However, as I have demonstrated in this dissertation, Big Tech companies have not done this alone; instead, they have facilitated and leveraged developmental processes involving different types of external users, stakeholders, and partners. While the influence and power of Big Tech companies is undeniable today, there is more to learn about *how exactly* these largest platforms have 'eaten the world', or how processes of platformisation unfold in practice—that is, their different types of infrastructures, economic processes, and governance mechanisms (Poell et al., 2019).

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7.1. Surfacing the configurations and dynamics of platform governance and power

In this dissertation, I have explored, visualised, and analysed the technological and structural features that underlie today's digital (platform) economy and society, with the main aim of better understanding *how governance and power are manifested in the developmental processes that constitute the ecosystems of (very large) digital platforms* [RQ]. Specifically, I have shown how platforms' governance and power can be located and studied in the developmental processes that constitute the ecosystems of such large online digital platforms, particularly by surfacing their distinct *materiality* and their *relationality*. These developmental processes typically involve different groups of users, including third-party software application ('app') developers, digital marketing and advertising developers, and business partners, whose collective development work is vital to understanding platforms' power.

The chapters (case studies) provide foundational concepts, methods, and tools to understand these configurations and dynamics [▸ Ch. 1: Table 1.1]. Taken together, they demonstrate the value of empirical and historical approaches to surface the relations and material conditions of digital platforms as, and as part of, larger ecosystems. This puts into the spotlight the developmental processes that constitute platform ecosystems and the infrastructural aspects of platforms' governance and power, which makes for a significant contribution to the academic literature on online digital platforms, platform governance, and platform power.

7.1.1. *The value of the ecosystem concept*

While studies of single (specific) digital platforms are important and relevant, they are limited for recognising the larger technological and structural features of governance and power. The case studies presented in this dissertation demonstrate the breadth and complexity of studying governance and power in the contemporary media environment (or the Web), which operates under a 'platform paradigm' (Burgess, 2021). I have suggested that this breadth and complexity necessitates drawing from the broader interdisciplinary academic literature on digital platforms and infrastructures, including from critical Communication and Media Studies [C&MS], Information Studies, and Sociology, as well as Business and Management Studies, Economics, and Information Systems [IS] research.

Specifically, this dissertation has demonstrated that the concept of (platform) *ecosystem* allows for a productive exchange across these different fields and disciplines, by integrating technical, market-based and 'innovation', and critical perspectives with empirical and historical approaches [▸ Ch. 1]. The concept invites researchers to recognise the distinct *materiality* and the *relationality*—specifically, the *relational construction*—of digital platforms, which emphasises how each of their user groups, stakeholders, and partners participate in the relational construction of platforms' ecosystems. This is crucial to understanding platforms' governance and power. It thus acknowledges the material importance of digital platforms' unique technical, sociotechnical, and organisational features (de Reuver et al., 2018; Tiwana, 2014), as well as the importance of 'platform boundary resources' [PBRS], particularly APIS and SDKS, in facilitating and governing external contributions from any of these external users, stakeholders, and partners (e.g., Dal Bianco et al., 2014; Eaton et al., 2015; Ghazawneh and Henfridsson, 2013). PBRS determine the extent to which a specific digital 'platform', as 'the extensible codebase of a software-based system' (de Reuver et al., 2018: 126), supports 'complements' (e.g., tools, products, and services) and 'complementors' (e.g., third-party app developers, businesses, and partners); that is, PBRS simultaneously facilitate and govern a digital platform's 'openness' to specific groups of users and uses. This means, as I have demonstrated throughout, that PBRS can be used to *locate*—situate and contextualise—governance and power in the very developmental processes that lead to the formation of platform ecosystems.

Additionally, the concept of ecosystem has shown to be useful for studying single digital platforms as, and as part of, larger configurations and environments, which they do not merely partake in but also actively *shape* (govern). It also provides ways of surfacing the relations, dynamics, and material conditions of those larger configurations or environments, which is necessary for locating governance and power in the integrated platform ecosystem (e.g., Blanke and Pybus, 2020; Broughton Micova and Jacques, 2020; van Dijck et al., 2019; [▸ Ch. 4]). Furthermore, Big Tech companies have long benefited from the strategic ambiguity around the definition of their digital 'platforms', their boundaries, and their involvement in different markets and settings. By surfacing the relations and material conditions of digital platforms, we can gain a better understanding of the unique position of power that that these technology companies actually occupy, and the relations they actually have (and do not have)—that is, we can surface their distinct roles and relationships in larger ecosystems, including any critical dependencies they may be sustaining as infrastructures (e.g., Blanke and Pybus, 2020; van Dijck et al., 2018; van Dijck, 2021b).

7.1.2. *Key points*

Each of the three parts of this dissertation has focused on distinct aspects of the construction of platform ecosystems and has highlighted specific mechanisms and dimensions of platform governance and power. Part I (comprising Chapter 2) has focused on application programming interfaces [APIS] as the material foundations of platform ecosystems. It unravelled the evolutionary trajectory of Facebook's popular Platform for Development through its APIS, which constitutes the very material foundation of the larger Facebook ecosystem, and which is inhibited by millions of software developers, businesses, advertisers, and partners around the globe. The case study surfaced the technicity of platform governance and infrastructural control mechanisms which do not only underpin Facebook's ecosystem but also other large platform ecosystems. The case is unique in its empirical-historical approach, allowing for novel insights into the historical relationality between platforms' APIs, governance, and power. For instance, Facebook has provided APIs since 2006, but as those APIs continue to change and evolve, they have incrementally become intricate configurations of governance and infrastructural control. The often subtle forms of governance and control that were observed are powerful precisely because they represent 'not a grand and spectacular strategy but a functional and often invisible reality' (Munn, 2020: 15) beneath contemporary platform ecosystems.

Parts II and III (comprising Chapters 3 to 6) both investigated such larger (platform and app) ecosystems, and how these 'functional and often invisible realit[ies]' are configured. Part II (Chapters 3 and 4) has revealed the additional importance of organisational relationships in constructing and governing platform ecosystems, particularly of business partnership strategies and mergers and acquisitions (M&As). These organisational relationships cannot be understood separate from the technological and structural relationships that form 'on top' of the APIs provided by platforms because API access is typically tiered and governed through partnerships [▸ Ch. 3]. Consequently, I have shown how the organisational relationship structures that are formed between platforms and partners can be analysed to locate strategic and infrastructural 'nodes' of power in larger ecosystems (e.g., Broughton Micova and Jacques, 2020; [▸ Ch. 4]).

Part III (Chapters 5 and 6) has articulated the additional complexities of governing mobile app ecosystems, particularly the relationships between platforms, app stores, and third-party Android and iOS software app developers. As such, it surfaced third-party app developer relations, the relations between mobile and social media platforms, and the geopolitics of these (layered) relations during the COVID-19 pandemic crisis. While platform owners seek to maintain control over the developmental process, Chapter 5 revealed how third-party software developers are probing the limits of platforms' 'interpretative flexibility' by building apps that appropriate social media platforms in ways that do not always comply with their terms and policies. Additionally, this study showed how software developers may use critical technical workarounds (and unofficial APIs and SDKs) to build their apps, thus further complicating the relationships between platform owners and third-party app developers. It has illustrated the tensions that inevitably exist in platform ecosystems, precisely because platforms are relational constructs that shape, and are shaped by, their user communities which consist of end-consumers, third-party app developers, business partners, and others. This also means that despite the powerful positions of platform owners, complementors are typically not powerless (e.g., Eaton et al., 2015; Hurni et al., 2022). In Chapter 6, I traced the emergence of a unique ecosystem of COVID-19-related pandemic response apps, as well as how the relationships between platforms, app stores, and mobile developers within this ecosystem have been reconfigured during the COVID-19 pandemic in 2020. The case revealed how both Google and Apple, as the dominant mobile platforms, adapted their app store governance mechanisms (including their app store terms and policies and app search query results) in the light of the 'unprecedented' nature of the pandemic. Amongst other measures, they increased their editorial intervention in their app ecosystems to balance generativity and control of their mobile platforms. More broadly, this particular case study has highlighted the generativity of app development and the important role of app stores as 'gatekeepers' of the COVID-19 pandemic response app ecosystem that emerged as part of the global response to fight the pandemic.

The five chapters (case studies) included in the parts have each surfaced the relations and material conditions—and material politics—of platform governance and power as they manifest themselves in different empirical settings. While these settings may at first glance seem diverse, they have been empirically studied and theorised as part of an integrated platform ecosystem (e.g., Broughton Micova and Jacques, 2020; Dieter et al., 2019; van Dijck et al., 2019; Lai and Flensburg, 2021).

Hurni et al. argue that in recent years platform ecosystems have become 'the dominant configuration through which innovative software products and services are co-created, marketed and distributed' (2022: 334–335; Gawer, 2021a). The case studies provide complementary perspectives on how and why 'platform ecosystems' have become the dominant configuration in the first place, including empirical and historical perspectives. They are relevant to gain a clearer view of governance and power dynamics as they manifest themselves: not only in specific component parts (e.g., in specific data practices or algorithmic techniques, as often highlighted), but also in the developmental processes—that is, in the *relational construction*—of ecosystems on the multiple 'sides' of platforms. Surfacing these relations and material conditions involved designing novel methods and tools for the study of developer tools, programming interfaces, partner programmes, and mobile apps and app stores. These methods and tools now enable further critical investigations like those presented in this dissertation to expand the understanding of platform power and *governance by* large platforms. They enable others to update or append the presented case studies, as an important way to document and monitor the continuous change and evolution of larger platform ecosystems.

An ecosystem strategy lets platform owners profit from the generativity of external contributors (including developers, business, marketers and advertisers, and partners) while maintaining centralised infrastructural control over the outcomes and evolution of the complements (e.g., Eaton et al., 2015; [‣ Ch. 2]). Consequently, this dissertation argues that ecosystems may be theorised and studied as platforms' (extended) *spheres of influence*, where the 'core' technical platform has a certain level of exclusivity in the larger ecosystem that can be enforced (i.e., controlled) through software-based infrastructure. However, while platforms may have considerable strategic and infrastructural power over their larger ecosystems, it is important to recognise that their power is not absolute. The dominance of a 'core' technical platform is necessarily incomplete and relies on the participation of large communities of complementors (i.e., dependents) to build complementary tools, products, and services ('innovate') 'on top' of the infrastructures and resources they offer. Consequently, Rodón Mòdol and Eaton suggest that the relationship between the 'core' and 'periphery' of a platform ecosystem is one of mutual generative entrenchment, where both the core and the periphery are gradually entrenched (Rodón Mòdol and Eaton, 2021). Importantly, the implications of these structures and structural dynamics are not just virtual but shape 'real' markets, labour relations, and industries around the globe (e.g., Narayan, 2019; Schüßler et al., 2021).

Additionally, each of the chapters has highlighted other aspects of the *relational construction* of digital platforms. I have shown how the construction of platform ecosystems, crucially, involves multiple groups of users, stakeholders, and partners. The collective development work of these different groups of users has been vital to the explosive growth and expansion of popular platforms throughout the 2010s, and has led to the formation and consolidation of the core–periphery structures that define contemporary platform ecosystems (Rodón Mòdol and Eaton, 2021; [‣ Chs. 3 and 4]). Consequently, digital platforms may be theorised and studied as multi-faceted, and sometimes 'contested' relational constructs that shape, but which are also *shaped by* the user communities and ecosystems on each of their 'sides' (e.g., Schüßler et al., 2021; [‣ Ch. 1]). This is an important nuance in understanding platforms' power in specific markets and sectors of society.

Furthermore, all of the chapters highlight how the *artefactual* (e.g., technical or infrastructural) and the *contractual* (e.g., terms and policies, partnership agreements) aspects of platform governance and power (Kenney et al., 2021) converge in what I have called 'governance configurations' [‣ Ch. 2]). Therefore, the power relations and dynamics that emerge in larger ecosystems may partly be located and theorised based on these governance configurations. I have shown how governance and power may be located in the design and evolutionary trajectories of platforms (and their APIs), in the technological integration networks that emerge between platforms and across larger ecosystems, in the external relationships between platforms and third-party software developers and business partners, and in the role of partner programmes and resources for different types of partners. The case studies thus help to gain a clearer view of the configurations and dynamics of governance and power in specific empirical settings, which is important in advancing a theory of platform power that acknowledges the interrelated and dynamic aspects of that power as part of an integrated platform ecosystem (van Dijck et al., 2019). The findings suggest the need to further distinguish between relevant mechanisms and dimensions of power, governance, and control. Often, what matters is not just *where* 'the line is drawn' between what is (and is not) allowed, as typically specified in platforms' terms and policies, but *how exactly* 'the line' is drawn and subsequently enforced (i.e., the implementation, or what I have called the 'technicity' of governance by platforms [‣ Ch. 2]). This term thus helps to recognise that governance (and thus power) exists not outside of platform ecosystems but is shaped by the technicity of the platform's architecture, architecture evolution, and interfaces. This distinction between governance principles (e.g., terms and policies, partner programmes, app store (review) guidelines, etc.) and governance mechanisms (e.g., design, implementation, integration, enforcement, etc.) has been central to each of the chapters and critical for understanding the infrastructural aspects of platforms' power. The distinction also underscores that 'good' governance is not just a matter of having the right principles or values but also of implementing the right mechanisms, and that an understanding of the technicity of governance is necessary for effective regulation. Moreover, it is important to consider those in the larger ecosystem, beyond only the very largest ('GAFAM') handful of technology companies.

7.2. Next steps for the study of (platform) ecosystems

In the remainder of this conclusion, I will outline opportunities for further research on digital platforms and infrastructures, based on the key research and methodological contributions of the case studies. They are suggestions and next steps towards a theory and empirical study of (platform) ecosystems, which several scholars have recently begun outlining. I first briefly summarise the key aspects they have highlighted, before positioning my own contributions to such a theory.

7.2.1. *Research implications for digital platforms and infrastructure*

This dissertation is, in the first place, a significant empirical and historical contribution to the study of digital platforms and infrastructures. To further advance the study of digital platforms and infrastructures and integrate the interdisciplinary research on digital platforms and infrastructures from different fields and disciplines, I suggest the need for an interdisciplinary theory of (platform) ecosystems. This helps to further situate and contextualise how governance and power dynamics manifest themselves in platform ecosystems, as well as to understand the external relationships and dependencies that platforms have (and do not have, or perhaps should have) to objects, institutions, infrastructures, and the world around them. Additionally, it helps to study the relationships and interactions between different platforms (e.g., between Facebook, Google, and Apple), and between different platforms and complementors (e.g., between Facebook and its third-party app developers or business partners).

Several scholars have highlighted the need for further research on platform ecosystems and have begun outlining its key elements. Scholars in Business and Management Studies, Economics, and Information Systems [IS] research are suggesting to theorise the features and dynamics of ecosystems (e.g., Granstrand and Holgersson, 2020; Haki, 2021; Hein et al., 2020; Hurni et al., 2022; Jacobides et al., 2018; de Reuver et al., 2018; Rodón Mòdol and Eaton, 2021; Tiwana, 2014; [▸ Ch. 1]). Based on a review of the literature, Jakobides et al. described ecosystems as 'new structures of economic relationships' (2018: 2258), where most of the research so far has focused on the role of the 'core' players (also called the 'lead firm', 'keystone' organisation, or 'ecosystem captain'), and not on the technological and structural features of the ecosystems themselves, including alignment structures, the relationship between modularity and coordination (or collaboration) in ecosystems, or the types of complementarities and ecosystems that exist (2018: 2260–2267). Similarly, Kapoor et al. observed in a systematic review that 'several aspects of platforms are often studied exclusively from their ecosystems, lacking integrative insights on the topic of platform ecosystems' (2021: 94). An integrative perspective on platform ecosystems is important to gain a better understanding of the relations that form among companies and organisations (e.g., cooperation or collaboration), how the emergence of the ecosystem relates to the critical facilitator role of the core technical platform (e.g., the importance of platforms' modular architectures, programming interfaces, and terms and policies), and how different types of value creation and capture unfold within and across ecosystems.

Likewise, critical C&MS scholars are also suggesting the need for a theory of (platform) ecosystems. For instance, van Dijck et al. recommend considering platform companies as part of an integrated platform ecosystem in the conceptualisation of platforms' power (2019). Birch and Cochrane suggested that ecosystems are 'important techno-economic sites of new and emerging forms of digital rentiership', in addition to reflecting the way that Big Tech companies understand their own operations (2021: 2; cf. Birch et al., 2021). Lai and Flensburg proposed the ecological metaphor of 'invasive species' in the mobile app ecosystem and called for empirical explorations of the contemporary mobile app ecosystem (2021). Similar to the case studies presented in Chapters 5 and 6, in their exploration, they identified some of 'the prime infrastructural resources that ground app-based communication (devices, operating systems, app stores, apps, third-party services, and data accesses) and their ownership structures to discuss how power is obtained, exercised, and amplified in the app ecosystem' (2021: 2301; cf. Dieter et al., 2019; Gerlitz, Helmond, Nieborg, et al., 2019). I have specified what this ecosystem entails empirically. They also emphasised the importance of the ecological metaphor of ecosystem for both theoretical and empirical explorations of the contemporary app ecosystem, and the political economy of mobile communication. Finally, Zuckerman suggested that the complex relationships between social media and professional news organisations are best understood as a 'complex media ecosystem with its own emergent behaviors that only become visible when studied from a perspective broader than considering a medium in isolation' (2021: 1495). Research in this direction could include the spread of 'fake news', misinformation, and disinformation, their entanglement with digital advertising infrastructure (e.g., Braun and Eklund, 2019; Nadler et al., 2018), or the process of 'deplatformisation', whereby platforms are pushed 'to the fringes of the ecosystem by denying them the infrastructural services needed to function online' (van Dijck et al., 2021).

As I have argued, the question of *how exactly* platform ecosystems are structured and governed is essential to better understand the features and dynamics that unfold in larger ecosystems, including the different types and sources of power that manifest themselves. The findings from the case studies presented in this dissertation suggest the need for an integrative perspective on: (1) the *technological and structural features* of ecosystems (e.g., the material conditions governed through platforms' boundary resources); (2) the *organisational features* of ecosystems (e.g., the organisational relationships governed through partnership agreements); and (3) the *dynamics and evolutionary features* of ecosystems (e.g., the provided resources and incentives that facilitate and constrain ecosystems' capacities to evolve, and their app 'markets' to thrive). I will briefly elaborate on these three focal points.

7.2.1.1. *The technological and structural features of ecosystems*

The first focal point concerns the technological and structural features of (platform) ecosystems. This includes the different types and structures of platform and app ecosystems, as well as how, when, and why they emerge, and the types of complementarities and interdependencies they feature.

We may distinguish between ecosystems that emerge from the infrastructure (or tools, products, and services) of a single platform or from the infrastructures of multiple platforms. On the one hand, ecosystems may grow from a single platform's infrastructure, such as the large (internal, or closed) ecosystems of Facebook and Google (CMA, 2020: Appendix E; [▸ Chs. 2 and 3]). In these ecosystems, the relationships and dependencies between complements and complementors who partake in the ecosystem are (inter)mediated and shaped by digital platforms, such as through the design and governance of a platforms' APIs. On the other hand, ecosystems may grow from the infrastructures of multiple platforms [▸ Chs. 3 and 4]. From an evolutionary perspective, the type of ecosystem that evolves from multiple platforms is not just the outcome of platforms' own strategic decisions (or their power), but is typically an interplay between the platforms' architecture design, governance, and complex environmental dynamics, including competition and regulation (Gawer, 2021b; Tiwana et al., 2010; [▸ Chs. 2 and 3]). In addition to merely using the infrastructures or tools, products, and services of core technical platforms, external users may also come to *depend on* these material foundations in their everyday life and practice. For instance, Poell et al. explored the implications of such platform dependencies in the cultural industries, covering the news, gaming, and social media creation (2021; [▸ Chs. 2 and 3]), although the implications will vary across markets and sectors of society. Importantly, distinguishing between ecosystems that emerge from the infrastructure of single or multiple platforms introduces another important area of research regarding non-Western ecosystems that may be built on a different logic. For instance, the Chinese platform ecosystems could be considered not to emerge 'on top' of platforms, but instead are nested in so-called 'super apps' (e.g., Nieborg and Helmond, 2019; Steinberg, 2020). This draws attention to different types of complementarities and interdependencies and the geopolitics of data flows between regulatory regimes [▸ Ch. 4].

Additionally, it is relevant to distinguish (and compare between) *closed* (or internal) and *open* platform ecosystems, because they lead to different types and structures of external relationships and dependencies. In practice, closed and open platform ecosystems tend to be interconnected with other ecosystems because of the many technological, API-based integrations that individual apps and services (complements) have. Mobile apps in particular are inhibited by many different APIs and SDKs to access and provide third-party services and thus serve as bridges from one ecosystem to another (e.g., Blanke and Pybus, 2020; Binns et al., 2018; Lai and Flensburg, 2021; [▸ Chs. 5 and 6]). The larger ecosystems that emerge from these integrations tend to have a 'core' and 'periphery' structure because large numbers of peripheral modules or complements (millions in the case of Big Tech companies) are all connected to the same few core technical platforms (de Reuver et al., 2018; Rodón Mòdol and Eaton, 2021; Tiwana, 2014). The design and use of PBRs is central to the analysis of the types and structures of platform ecosystems, because they shape (govern) the developmental capabilities and processes that can (and cannot) emerge (e.g., Ghazawneh and Henfridsson, 2013).

To better understand these critical roles, it is relevant to study what the cooperation and collaboration between companies and organisations in a platform ecosystem—as materialised, for instance, in the (observable) technological (API-based) integrations and organisational relationships—revolves around in practice. For instance, the larger ecosystem around social media revolved not just around data in general, but around the interaction and exchange of *audiences*—a much more specific resource that has facilitated a thriving economy of data-based tools, products, and services (e.g., Alaimo et al., 2020; Basole, 2020; [▸ Chs. 3 and 4]). Indeed, Facebook and other popular social media have turned the 'engagement' of end-consumers into assets, even more so than the data itself (e.g., Birch et al., 2021). In other words, it is insufficient to assume that all data is somehow valuable; instead, it is relevant to determine what types of data are valuable, for whom, under which circumstances, for what reasons, and so on. Additionally, it is crucial to determine how the data is (programmatically) accessed or shared by specific tools, products, or services, which includes studying the material conditions of app and business development and the 'technicity' of platform governance [▸ Chs. 2 and 3]. The governance of data ecosystems involves both artefactual (e.g., technical, or infrastructural) and contractual (e.g., terms and policies, partnership agreements) aspects, which I argue need to be studied together to understand how Big Tech companies have a unique position of power.

Additionally, it seems at least important to distinguish between 'platforms' (such as Android Platform, Facebook Platform, or Twitter) and 'aggregators' (such as Google Search, Netflix, or Airbnb) because they serve different functions in an ecosystem and have different types of dominant positions. Schrepel summarises the distinction as follows: 'platforms may partially close upstream access (on the developers' side) but offer a wide downstream choice (to consumers), while in contrast, aggregators typically open upstream access (submissions) but seek to offer only the most relevant downstream options' (2021: 1; Thompson, n.d.), and discusses the implications for digital antitrust law. By qualifying the types of relations between different players, it is possible to gain a clearer view of these distinct roles and where they converge. For example, Facebook is a 'platform' as well as an aggregator, just as Google and Twitter are. On mobile, the announced deprecation of Google's Android Ad ID (Chavez, 2022)—akin to Apple's recent changes to the Identifier for Advertisers [IDFA], which is now 'opt-in' instead of 'opt-out'—is expected to lead to further aggregation in the mobile app advertising ecosystem, with tougher privacy standards enabled by the 'Privacy Sandbox' [▸ Chs. 4: §4.5 and 5: §5.5].[173] In short, it is worth further theorising the differences between technology companies: as platforms, as aggregators, or as 'infrastructures', where these roles converge, and what that means. For instance, distinguishing between these roles, and understanding them as part of the power hierarchy (and competition), may be relevant to policymakers and competition and regulation authorities.

173 Provisional information about the design and implementation of the Privacy Sandbox on Android is available on the Android Developers website, see: https://developer.android.com/design-for-safety/ads.

7.2.1.2. *The organisational features of ecosystems*

The second focal point concerns the organisational features of (platform) ecosystems. This includes comparisons of ecosystems to 'markets' and other dominant forms of industrial organisation (Gawer, 2021a). Others have already noted the difficulties of using existing theoretical frameworks to assess the types and sources of platforms' power (e.g., Busch et al., 2021: 12–14; van Dijck et al., 2019). Busch et al., for instance, suggested that the foundational concept of 'market', and the associated notion of 'market power', might 'not be the best or even the appropriate unit of analysis to interpret correctly the behaviour of online platforms and their impacts on the economy and society' (Busch et al., 2021: 13; Jacobides et al., 2018). Additionally, like how distinct uses of the term 'platform' revealed different semantic areas and discursive politics (Gillespie, 2010). distinct uses of economic metaphors (e.g., 'markets', 'marketplaces' app 'stores', etc.), can also reveal the strategic claims made for what technology companies do and do not do, and how their place in the larger landscape should be understood (2010: 347). These semantic areas, however, do play a role in determining the appropriate policy, legal, and regulatory frameworks that apply regarding the *governance of* platforms (e.g., to platforms as 'services', as 'markets', as 'infrastructures', etc.). A theory and empirical study of (platform) ecosystems can provide additional insights into the actual configurations and workings of specific digital ('platform-based') markets and industries [▸ Ch. 4].

Notably, the digital platform-based markets covered in this dissertation are not open but regulated markets that are overseen and controlled by the core platform owners themselves (as opposed to government bodies), and with little oversight. This leads to 'struggles' and value conflicts, as others have shown (e.g., Schüßler et al., 2021; van Dijck et al., 2018: Ch.1; van Dijck, 2020). For instance, the economic actors who participate in these markets do not necessarily have equal opportunities or 'economic agency' (Claassen and Herzog, 2021) in relation to the core platform owners (i.e., the 'private regulators' (Boudreau and Hagiu, 2009)). Therefore, Busch et al. suggest that contemporary platform ecosystems are instead 'multi-actor' or 'multi-product' structures, wherein core platform owners derive value and competitive advantages from what these different actors or products can (and cannot) do, how they can relate or interact, how data can be accessed, linked, or used, and so on (Busch et al., 2021: 12–14; Jacobides et al., 2018). Consequently, the design and deployment of PBRs, such as APIs and SDKs, can be analysed in terms of the architectural and strategic decisions that digital platforms make to demarcate and control their resources (or assets), which they typically subject to different modes of governance (e.g., Gawer, 2021b; [▸ Chs. 2 and 3]). That is, different governance mechanisms apply to third-party developers, to businesses, and to partners and these mechanisms also tend to change and evolve in different ways. The outcome is similar to what Caplan and Gillespie described as a 'tiered governance' strategy in the case of YouTube, where different users face different rules, material resources, and procedures (2020: 6). These 'tiers' are crucial to understand how governance and power are distributed, particularly the infrastructural and strategic types of and sources of power (Broughton Micova and Jacques, 2020; [▸ Ch. 4]).

The larger implication is that the types of digital markets that are facilitated and controlled by digital platforms are increasingly *stratified* (that is, arranged into different hierarchical layers). Large digital platforms control the infrastructural layers beneath the digital markets and social structures that emerge and evolve 'on top' of them. Consequently, while there may be fierce competition and rivalry between the products or actors positioned on the same layers (e.g., among different Android or iOS mobile apps, products, and services), it is less likely to happen between the products or actors beneath that specific application layer (e.g., a challenger of Android Platform or the iOS operating system itself) because of the solidified advantages of the infrastructure providers, including the ability to leverage the power of network effects. Consequently, new apps, products, and services are predicated on the existence of mobile platforms like Android and iOS on the consumer 'side' and cloud services provided by Amazon, Google, and Microsoft on the ('back-end') infrastructure 'side' of the market.

This type of stratification is exemplified by the 'app/infrastructure stack', which comprises at least a physical (device) layer, a system layer, a code and execution layer, a network layer, an application package layer, and a layer of in-app (or in-game) services, where distinct governance and power dynamics unfold (Gerlitz, Helmond, Nieborg, et al., 2019). Market participation (and competition) is not equally distributed across these layers but is organised on the top-most application and in-app service layers. Similarly, the stratification of the larger ecosystem as a whole also draws attention to the dynamics of power concentration (e.g., van Dijck, 2021b; Lai and Flensburg, 2021). The recent introduction of Apple's App Tracking Transparency [ATT] in iOS version 14.5 (April 2021), which requires digital marketers and advertisers to ask explicit consent from app users to track them (Apple Developer, n.d.), illustrates the high stakes of this type of stratification: the ATT framework has already significantly impact Meta's (formerly Facebook's) earnings from digital advertising revenue and will continue to do so 'on the order of $10 billion' in 2022 alone (Meta Investor Relations, 2022: 10). The announcement of ATT's impact on Meta's earnings was made during the company's presentation of its financial results for the year 2021 for investors in February 2022 and caused an immediate (and historical) stock price drop of 26.6% (US$232 billion) in a single day. Such changes in the ecosystem have significant implications for Big Tech companies as competitive pressures among them increase. Furthermore, this also means that policymakers and regulators need to consider the appropriate level of intervention along the layers of the 'stack', which will have different (broader or narrower) implications. Further empirical and historical research could investigate the implications of this type of stratification as 'stacks' emerge and solidify in specific markets and sectors of society, such as in the digital marketing and advertising industry, in primary education (e.g., Kerssens and van Dijck, 2021), or elsewhere.

7.2.1.3. *The dynamics and evolutionary features of ecosystems*

The third focal point concerns the dynamics within and across multiple (platform) ecosystems, particularly regarding evolution, governance, and power.

This includes studies of the dynamics in single (specific) platform ecosystems. Such studies should focus on the configuration and composition of platforms' multiple 'sides', the interplay between them, and recognise the *co-evolution* of platform architecture, governance, and environmental dynamics (including social, competitive, and regulatory pressures to change). Others have made similar suggestions (e.g., Gawer, 2021a; Gawer, 2021b; Kovacevic-Opacic and Marjanovic, 2020; Rietveld et al., 2020; Tiwana et al., 2010; [‣ Chs. 2 and 3]). The interplay between the 'sides' for developers, businesses, and partners is particularly relevant (Helmond and van der Vlist, 2019), as are the sides for content 'creators' and publishers (e.g., Burgess, 2021; Caplan and Gillespie, 2020; Poell et al., 2021). Studying these different 'sides' also helps to gain a clearer view of platforms' many different activities (i.e., their 'scope'), which is important to understand how and where platforms currently have power (or look to increase their power going forward).

Additionally, this includes further case studies of the evolutionary dynamics of digital platforms and infrastructures in specific ecosystems. Scholars have shown how platforms pass through different stages in their evolutionary trajectories, including the launch and maturity phases (Gawer, 2021b; [‣ Ch. 3]). Previously identified evolutionary dynamics include 'coring', 'forking', 'distributed tuning' (Rodón Mòdol and Eaton, 2021: Table 1), 'platform envelopment' or 'capture' (Eisenmann et al., 2011; Partin, 2020), 'path dependency' and proprietary 'lock-in' effects (e.g., Alaimo et al., 2020), and 'generative entrenchment' (Rodón Mòdol and Eaton, 2021). Stratification is another evolutionary dynamic, whereby the relations between the peripheral modules or complements around core technical platforms are segmented and gradually solidified 'into a coherent hierarchical structure that standardizes their behaviour' (Rodón Mòdol and Eaton, 2021: 345). Chapters 2 and 3 have shown how business-facing APIs and partnerships are central to these evolutionary processes. Relatedly, the ongoing process of 'infrastructuralisation' (e.g., Constantinides et al., 2018; Plantin et al., 2018) can be theorised as a strategy to improve platforms' longer-term chances of survival, precisely because it means they become more widely accessible, shared, and indispensable in everyday life and practice (cf. Tiwana et al., 2010: 682–683; [‣ Chs. 3, 4, and 6]). This may also help to better understand the actual implications of competition or regulation for platforms' power in specific empirical settings.

Furthermore, scholars have expressly called for nuanced critical investigations of power (and power dynamics) in platform ecosystems, even if Big Tech companies' dominance is undeniable (e.g., Caplan et al., 2020; van Dijck et al., 2019; Eaton et al., 2015; Haki, 2021; Hurni et al., 2022; Schüßler et al., 2021; [‣ Ch. 1]). They suggest the need to recognise the paradoxes and mutual tensions that manifest themselves between core platform owners and peripheral complementors. Many power relationships are not unidirectional but mutual and paradoxical. Additionally, power is not only 'held', but also shared and dispersed in larger ecosystems through business partnerships and partner integrations. Platforms like Facebook and Google offer many different PBRs and partner programmes to facilitate and govern the developmental processes of external contributors, which, crucially, also serves the interests of the partners [‣ Ch. 4]. I have shown how and where they may be located in the developmental processes that constitute platform ecosystems, which involves third-party (external) software app developers, businesses, and partners. At the same time, further qualitative research about specific partnership relations and their (evolutionary) dynamics is necessary, such as through case studies on individual partners or through interviews [‣ Ch. 3].

Finally, there are larger research implications C&MS scholars related to the complexification of mediation processes in online digital platform ecosystems that far exceed the focus of this dissertation. Many contemporary mediated phenomena are best understood in a 'complex media ecosystem', which involves emergent behaviours that only become visible from a broader perspective (Zuckerman, 2021: 1495). This also applies to the complex relationships between different groups of users, markets and industries, social structures, institutions, and infrastructures in society and the economy—relationships that are often (inter)mediated and shaped by large digital platforms. Empirical and historical research strategies are vital to identify and chart the networks of relevant actors, as well as provide material evidence for policymakers and regulators. They should not need to rely on anecdotes, document leaks, or whistle-blowers to obtain an understanding of these large technical systems, or the scale and scope of their societal implications. The case studies, methods, and tools collected in this dissertation contribute to making this possible.

7.2.2. *Methodological implications*

In addition to its empirical and historical contribution, this dissertation also provides a significant methodological contribution to the study of digital platforms and infrastructures—and towards a theory of (platform) ecosystems. Specifically, I have designed methods and tools, and have conducted case studies that trace the boundaries of online digital platforms, and which could be used to articulate the ecosystems of platforms. This is important because it is by no means straightforward to demarcate and study a digital 'platform', or the reach of its 'tentacles' (e.g., Helmond, 2015b: 2), let alone its position (of power) in the larger ecosystem. APIs cannot be considered separate from the ecosystems 'tethered to' them, nor can mobile app ecosystems be considered separate from the core technical platforms they complement and 'run' (or operate) upon. The methods and tools provide empirical and historical resources and strategies to advance the study of (platform) ecosystems, particularly regarding the programming interface, the business ecosystems, and the mobile app ecosystems of digital platforms.

From a methodological perspective, the concept of ecosystem is valuable because it enables open-ended empirical and historical studies of digital platforms' current boundaries, based on 'what they actually do and are in practice' (Schüßler et al., 2021: 9). While most of critical research focuses on the relationships between platforms and end-consumers ('B2C'), an ecosystem research focus additionally calls attention to the relationships that exist between digital platforms and other companies and organisations on the business and developer 'sides' ('B2B'), which has received much less critical attention. This includes studies of the platformisation of digital supply chains and networks of specific markets and sectors of society, which are the 'global operating systems' for many different social and economic processes (e.g., Braun, 2015; Hockenberry et al., 2021; [▸ Ch. 4]). Moreover, the relationships and interdependencies that exist within these supply chains and networks are increasingly posing systemic risks and vulnerabilities in the most unexpected places (e.g., privacy and security risks, service breakdowns and outages, etc.).

One of the key methodological challenges is that there are no comprehensive directories of all the complements (software-based tools, products, and services) or complementors connected to specific platforms (e.g., for citizens, scholars, policymakers, or regulators to consult). Likewise, there are no comprehensive (web) archives of digital platforms, mobile apps, or ecosystems (Helmond and van der Vlist, 2019; Helmond and van der Vlist, 2021). The data sets and charts included in this dissertation could be appended to construct more comprehensive views of the ecosystem, and to identify further sources and locations, or 'nodes', of power in this ecosystem (Broughton Micova and Jacques, 2020). For instance, digital identity creation is a vital industry in what I called the 'audience economy' in Chapter 4, comprising thousands of individual companies and organisations that we know relatively little about. The companies and organisations in this sector, however, are collectively shaping the normative consensus about the meaning of public values around privacy in a market exploration process, including by developing competitive alternatives.

Additionally, the methods and tools that were developed for this research can be used to systematically trace and chart (or 'map') platform ecosystems while they are emerging or reconfigured over longer time periods to enable longitudinal studies of (platform) ecosystems.[174] Such studies would not only provide insights into specific ecosystems, but also represent a way of documenting the evolutionary trajectories of larger ecosystems and the positions of specific digital platforms within them. For instance, to study the emergence of relationships and interdependencies between platforms and infrastructures, the impacts (and 'ripple effects') of API changes and governance interventions on third-party app development, how 'M&A waves' (or 'M&A frenzy') shaped the digital (programmatic) advertising ecosystem (e.g., Hercher, 2021), or assess the responses (or lack of responses) to new laws and regulations (e.g., Kollnig et al., 2021). From another perspective, this would also contribute towards the 'observability' of digital platforms in ways beyond the algorithmic systems of specific digital platforms, as outlined so far (Rieder and Hofmann, 2020). Additionally, it could be foundational to other types of critical research that depend on knowledge of (platform) ecosystems. For example, the _Carbolytics initiative by Moll et al. (2022) or the GreenFrame tool by Marmelab raise awareness about the environmental risks and impacts of the advertising technology ecosystem by quantifying the carbon costs of Web tracking cookies. Here, 'ecosystem' is not just an ecological metaphor, but an actual environmental issue that links the digital and physical dimensions of platform infrastructure.

Finally, I have collected and demonstrated the value of different empirical materials, which are also openly available for others to reuse [‣ Data availability]. Despite the many known issues and challenges of empirical and historical digital platform research (e.g., Carter et al., 2021; Helmond and van der Vlist, 2019; Venturini and Rogers, 2019), I have shown that there are also many opportunities for critical investigations, so long as we know where to look for relevant materials (Helmond and van der Vlist, 2019; Helmond and van der Vlist, 2021; [‣ Ch. 1]). On the one hand, there are primary sources that enable enquiries into the ecosystems of digital platforms, including (publicly-accessible) Web sources from technology companies' own websites, 'boundary resources' for third-party software app development, archived Web sources held in international Web archives, and relevant leaked and court case documents. Chapters 5 and 6 further demonstrated the value of data from Google Play and Apple's App Store, as well as inspected the source code of mobile app packages. Secondary sources, such as newspaper articles and trade publications, can be useful to contextualise empirical and historical findings, as in Chapters 2 and 3. In short, there are a variety of relevant empirical materials that can be employed to identify and study the ecosystems of platforms, particularly the developmental processes that underlie them.

174 See: App Studies Initiative, ASI Tools, http://appstudies.org/tools/.

I began this dissertation with a bold provocation: that *there is no platform, there are just (platform) ecosystems*. If we look at contemporary online digital 'platforms' in terms of their distinct materiality and take their relational construction seriously, then the 'platform' breaks apart into many different and moving constitutive parts. These constitutive parts are created by many different types of developers, such as third-party app developers, digital marketeers, and advertisers, as well as business partners, but *how exactly* they are related is a matter of governance and power. In other words, my point is not that 'platforms' do not exist at all (they clearly do!), but rather that platforms' governance and power cannot be understood separate from the larger systems and structures—ecosystems—of which they are part, which they *shape* (govern and control) and are *shaped by*. Based on the findings of this work, the problem is not necessarily the design of specific components of these ecosystems, but rather how they come together to form larger ecosystems, and who benefits from them. Whatever the online digital media environment will look like years ahead from now, the way that its constitutive developmental processes are organised will be central to its future. ▾

Appendices

SEVERAL APPENDICES ARE INCLUDED TO provide additional methodological information related to the individual case studies of this dissertation (one appendix per chapter). Please note that a separate section is dedicated to data availability, which includes references to the research data sets associated with the individual case studies, as well as the high-resolution versions of all figures.

List of appendices with supplementary tables and figures linked to the chapters.

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A	Availability of archived sources in international Web archives	1
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D	Source social media and intermediary partner directories	4
E	Categorisation schemas and search patterns	6

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A. **Appendix**

Availability of archived sources in international Web archives

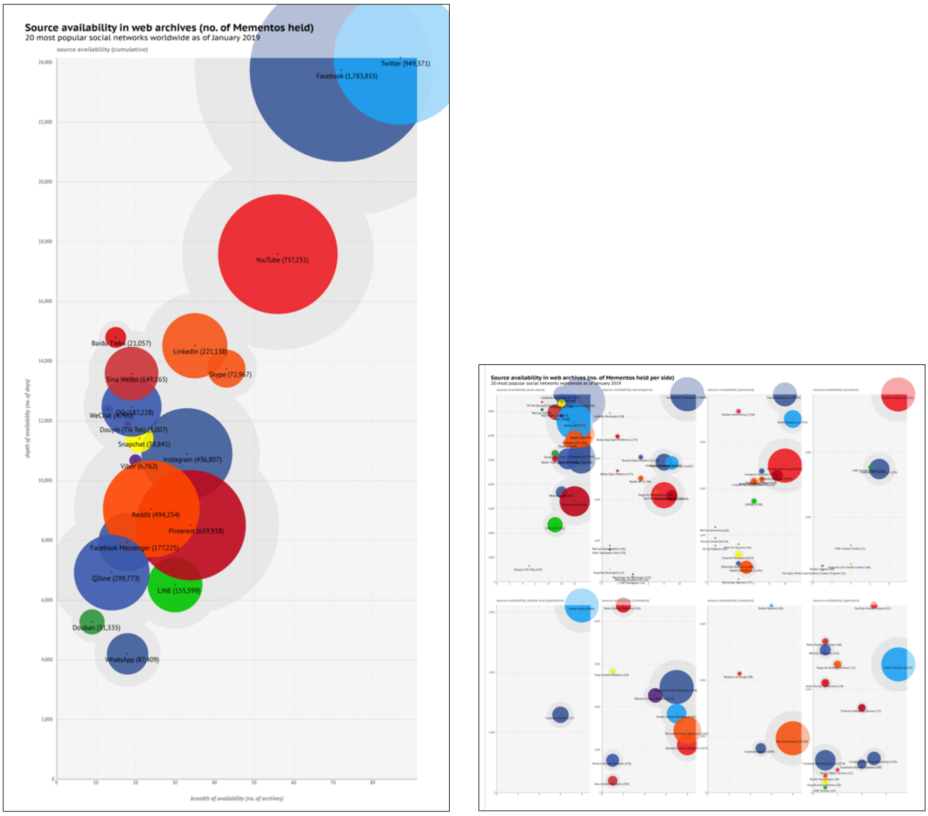

Figure A 1.1(**a**) **and** (**b**)**.** Availability of archived Web sources (N = 110 URLs) in Memento-compatible international Web archives (N = 21): (a) cumulative per social network and (b) by user group [plot diagrams, small multiples].

X-*axis: breadth of availability (no. of archives);* Y-*axis: depth of availability (no. of days); size: by no. of Mementos held; colour-coding: by platform owner (brand colour). Data: Internet Archive and various Web archives. Source: reproduced from (Helmond and van der Vlist, 2019: Figure 1(a) and (b)).*

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B. Appendix

Original 'live' and archived Web sources (I)

Table B 2.1. References to original 'live' and archived Web sources.

Citation	Type	Reference
FB-2020	*Business*	(2020, August 11) Simplifying targeting categories. Available at: https://www.facebook.com/business/news/update-to-facebook-ads-targeting-categories/.
FB-2021*	*Business*	(2021, March 23) Facebook ads: Online advertising on Facebook. Available at: https://www.facebook.com/business/ads.
FD-2006a	*Developers*	(2006, October 10) Facebook Developers News. Available at: https://web.archive.org/web/20061009080928/https://developers.facebook.com/news.php.
FD-2006b	*Developers*	(2006, December 13) A user's overview of the Facebook Development Platform. Available at: https://web.archive.org/web/20061213220159/http://developers.facebook.com/background.php.
FD-2007	*Developers*	(2007, February 17) Extended permissions. Available at: https://web.archive.org/web/20070217011936/http://developers.facebook.com/news.php.
FD-2008	*Developers*	(2008, September 6) Extended permissions. Available at: https://web.archive.org/web/20080906150906/http://wiki.developers.facebook.com/index.php/Extended_permissions.
FD-2009	*Developers*	(2009, June 18) Application Verification Program. Available at: https://web.archive.org/web/20090618153142/http://developers.facebook.com/verification.php?tab=faq.
FD-2010a	*Developers*	Purdy D (2010a, October 16) Operation Developer Love. In: *Facebook for Developers*. Available at: https://developers.facebook.com/blog/post/417/.
FD-2010b	*Developers*	(2010b, April 23) Extended Permissions. Available at: https://web.archive.org/web/20100423170819/http://developers.facebook.com/docs/authentication/permissions.
FD-2010c	*Developers*	(2010c, May 8) Extended Permissions. Available at: https://web.archive.org/web/20100508225433/developers.facebook.com/docs/authentication/permissions.
FD-2010d	*Developers*	(2010d, August 31) Developer roadmap. Available at: https://web.archive.org/web/20100831180503/http://developers.facebook.com/roadmap.
FD-2010e	*Developers*	(2010e, December 5) Authentication. Available at: https://web.archive.org/web/20101205122001/http://developers.facebook.com/docs/authentication/.
FD-2010f	*Developers*	(2010f, December 12) Platform Upgrade Guide. Available at:

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Citation	Type	Reference
		https://web.archive.org/web/20101205155259/http://developers.facebook.com/docs/guides/upgrade.
FD-2011a	*Developers*	(2011a, August 31) A stable Platform. Available at: https://developers.facebook.com/blog/post/550/.
FD-2011b	*Developers*	(2011b, October 11) Breaking change policy. Available at: https://web.archive.org/web/20111011011437/https://developers.facebook.com/roadmap/change-policy/.
FD-2014a	*Developers*	Spehar J (2014a, April 30) The new Facebook Login and Graph API 2.0. In: *Facebook for Developers*. Available at: https://developers.facebook.com/blog/post/2014/04/30/the-new-facebook-login/.
FD-2014b	*Developers*	Sharma M (2014b, October 30) Graph API v2.2 and updated iOS and Android SDKs. In: *Facebook for Developers*. Available at: https://developers.facebook.com/blog/post/2014/10/30/graph-api-v2.2/.
FD-2014c	*Developers*	(2014c, May 21) Facebook Platform Changelog. Available at: https://web.archive.org/web/20140521164802/https://developers.facebook.com/docs/apps/changelog.
FD-2016	*Developers*	(2016, January 20) Targeting Specs. Available at: https://web.archive.org/web/20160120033705if_/https://developers.facebook.com/docs/marketing-api/targeting-specs/v2.4.
FD-2017a	*Developers*	Oakes Dunn A (2017a, September 20) In: *Facebook for Developers*. Self-reported targeting. Available at: https://developers.facebook.com/ads/blog/post/2017/09/20/self-reporting-targeting/.
FD-2017b	*Developers*	Bala D (2017b, December 4) Targeting exclusions. In: *Facebook for Developers*. Available at: https://developers.facebook.com/ads/blog/post/v2/2017/12/04/targeting-exclusions-blog-post/.
FD-2017c	*Developers*	(2017c, February 25) Targeting Specs. Available at: https://web.archive.org/web/20170225150830/https://developers.facebook.com/docs/marketing-api/targeting-specs.
FD-2018a	*Developers*	Oakes Dunn A (2018a, February 28) Changes to targeting availability for 'interested in'. In: *Facebook for Developers*. Available at: https://developers.facebook.com/ads/blog/post/2018/02/27/targeting-availability-interestedin/.
FD-2018b	*Developers*	Chen J (2018b, July 2) Marketing API tier simplification. In: *Facebook for Developers*. Available at: https://developers.facebook.com/ads/blog/post/v2/2018/07/02/marketing-api-tier-simplification/.
FD-2018c	*Developers*	Archibong I (2018c, April 4) API and other Platform product changes. In: *Facebook for Developers*. Available at: https://developers.facebook.com/blog/post/2018/04/04/facebook-api-platform-product-changes/.
FD-2018d	*Developers*	Papamiltiadis K (2018d, May 1) Enhanced developer App Re-

Citation	Type	Reference
		view and Graph API 3.0 now live. In: *Facebook for Developers*. Available at: https://developers.facebook.com/blog/post/2018/05/01/enhanced-developer-app-review-and-graph-api-3.0-now-live/.
FD-2018e	*Developers*	Papamiltiadis K (2018e, December 10) Facebook Launches Verification for Individual Developers. In: *Facebook for Developers*. Available at: https://developers.facebook.com/blog/post/2018/12/10/verification-for-individual-developers/.
FD-2018f	*Developers*	(2018f, April 4) April 4, 2018. Available at: https://developers.facebook.com/docs/graph-api/changelog/non-versioned-changes/apr-4-2018#login-4-4.
FD-2018g	*Developers*	(2018g, May 1) Version 3.0: App Review. Available at: https://developers.facebook.com/docs/graph-api/changelog/version3.0#new-app-review.
FD-2018h	*Developers*	(2018h, March 9) Targeting. Available at: https://web.archive.org/web/20180309021752/https://developers.facebook.com/docs/marketing-api/buying-api/targeting.
FD-2020	*Developers*	(2020, February 3) Version 6.0. Available at: https://developers.facebook.com/docs/graph-api/changelog/version6.0.
FD-2021a*	*Developers*	(2021a, March 23) Developer Policies. Available at: https://developers.facebook.com/devpolicy/.
FD-2021b*	*Developers*	(2021b, March 23) Release. Available at: https://developers.facebook.com/docs/development/release.
FD-2021c*	*Developers*	(2021c, March 23) Changelog. Available at: https://developers.facebook.com/docs/facebook-login/changelog.
FD-2021d*	*Developers*	(2021d, March 23) Overview. Available at: https://developers.facebook.com/docs/facebook-login/overview.
FD-2021e*	*Developers*	(2021e, March 23) Permissions with Facebook Login. Available at: https://developers.facebook.com/docs/facebook-login/permissions/overview.
FD-2021f*	*Developers*	(2021f, March 23) App Review. Available at: https://developers.facebook.com/docs/facebook-login/review.
FD-2021g*	*Developers*	(2021g, March 23) Changelog. Available at: https://developers.facebook.com/docs/graph-api/changelog/.
FD-2021h*	*Developers*	(2021h, March 23) Overview. Available at: https://developers.facebook.com/docs/graph-api/overview/.
FD-2021i*	*Developers*	(2021i, March 23) Graph API User. Available at: https://developers.facebook.com/docs/graph-api/reference/user/.
FD-2021j*	*Developers*	(2021j, March 23) Audiences. Available at: https://developers.facebook.com/docs/marketing-api/audiences.
FD-2021k*	*Developers*	(2021k, March 23) Special Ad Category. Available at: https://developers.facebook.com/docs/marketing-api/audiences/special-ad-category/.
FD-2021l*	*Developers*	(2021l, March 23) Permissions Reference. Available at: https://developers.facebook.com/docs/permissions/reference.

Citation	Type	Reference
FD-2021m*	*Developers*	(2021m, March 23) Permissions Reference: Instagram Permissions. Available at: https://developers.facebook.com/docs/permissions/reference#instagram_permissions.
FD-2021n*	*Developers*	(2021n, March 23) Permissions Reference: Facebook Login Permissions. Available at: https://developers.facebook.com/docs/permissions/reference#login_permissions.
FD-2021o*	*Developers*	(2021o, March 23) Facebook Platform Terms. Available at: https://developers.facebook.com/terms/.
FL-2019a	*Leaks*	Campbell D (2019, November 6) Facebook leaks. Available at: https://www.duncancampbell.org/facebookleaks.
FL-2019b	*Leaks*	Campbell D (2019, November 6) Facebook leaks (pp. 2–70). Available at: https://dataviz.nbcnews.com/projects/20191104-facebook-leaked-documents/assets/facebook-sealed-exhibits.pdf.
FL-2019c	*Leaks*	Campbell D (2019, November 6) Facebook leaks: Exhibit 43 (p. 1064). Available at: https://dataviz.nbcnews.com/projects/20191104-facebook-leaked-documents/assets/facebook-sealed-exhibits.pdf.
FL-2019c	*Leaks*	Campbell D (2019, November 6) Facebook leaks: Exhibit 62 (p. 962). Available at: https://dataviz.nbcnews.com/projects/20191104-facebook-leaked-documents/assets/facebook-sealed-exhibits.pdf.
FL-2019e	*Leaks*	Campbell D (2019, November 6) Facebook leaks: Exhibit 78 (p. 802). Available at: https://dataviz.nbcnews.com/projects/20191104-facebook-leaked-documents/assets/facebook-sealed-exhibits.pdf.
FL-2019f	*Leaks*	Campbell D (2019, November 6) Facebook leaks: Exhibit 104 (pp. 1356–1393). Available at: https://dataviz.nbcnews.com/projects/20191104-facebook-leaked-documents/assets/facebook-sealed-exhibits.pdf.
FL-2019g	*Leaks*	Campbell D (2019, November 6) Facebook leaks: Exhibit 125 (p. 1460). Available at: https://dataviz.nbcnews.com/projects/20191104-facebook-leaked-documents/assets/facebook-sealed-exhibits.pdf.
FL-2019h	*Leaks*	Campbell D (2019, November 6) Facebook leaks: Exhibit 175 (p. 3482). Available at: https://dataviz.nbcnews.com/projects/20191104-facebook-leaked-documents/assets/facebook-sealed-exhibits.pdf.
FNe-2019a	*Newsroom*	Sandberg S. (2019a, March 19) Doing more to protect against discrimination in housing, employment and credit advertising. In: *Facebook Newsroom*. Available at: https://about.fb.com/news/2019/03/protecting-against-discrimination-in-ads/.
FNe-2019b	*Newsroom*	Lucio A (2019b, November 4) Introducing our new company brand. In: *Facebook Newsroom*. Available at: https://about.fb.com/news/2019/11/introducing-our-new-company-brand/.
FP-2021a*	*Policies*	(2021a, March 23) Advertising Policies. Available at: https://www.facebook.com/policies/ads/.

Citation	Type	Reference
FP-2021b*	*Policies*	(2021b, March 23) Advertising Policies: 3. Discriminatory practices. Available at: https://www.facebook.com/policies/ads/prohibited_content/discriminatory_practices.
IE-2014	*Engineering*	(2014, June 25) Migrating from AWS to FB. Available at: https://instagram-engineering.com/migrating-from-aws-to-fb-86b16f6766e2.

* *'Live' Web sources (accessed 23 March 2021).*

C. Appendix

Original 'live' and archived Web sources (II)

Table C 3.1. References to original 'live' and archived Web sources.

Citation	Type	Reference
FB-2014	*Business*	(2014, October 7) The Audience Network is now available to more marketers worldwide. Available at: https://www.facebook.com/business/news/audience-network-launch.
FB-2015	*Business*	(2015, March 24) New resources for Facebook marketers. Available at: https://www.facebook.com/business/news/education-resources-for-marketers.
FB-2018a*	*Business*	(2018a, November 8) About Custom Audiences. Available at: https://www.facebook.com/business/help/744354708981227.
FB-2018b*	*Business*	(2018b, November 8) Become a Facebook Marketing Partner. Available at: https://www.facebook.com/business/marketing-partners/become-a-partner.
FB-2018c*	*Business*	(2018c, November 8) Facebook Ad Technology Specialty Requirements. Available at: https://www.facebook.com/business/marketing-partners/adtech-speciality-requirements.
FD-2007	*Developers*	Vora A (2007, October 15) fbFund info and submission process. In: *Facebook for Developers*. Available at: https://web.archive.org/web/20090618172234/http://developers.facebook.com/news.php?blog=1&story=38.
FD-2008	*Developers*	Ling B (2008, July 25) New ways for us to partner together. In: *Facebook for Developers*. Available at: https://web.archive.org/web/20090618161116/http://developers.facebook.com/news.php?blog=1&story=144.
FD-2009	*Developers*	Thayer K (2009, December 16) Introducing the Preferred Developer Consultant program. In: *Facebook for Developers*. Available at: https://developers.facebook.com/blog/post/346/.
FD-2010a	*Developers*	(2010a, December 5) Ads API. Available at: http://web.archive.org/web/20101205131945/http://developers.facebook.com/docs/adsapi.
FD-2010b	*Developers*	(2010b, December 5) Mobile applications. Available at: https://web.archive.org/web/20101205131421/http://developers.facebook.com/docs/guides/mobile/.
FD-2012a	*Developers*	Yi J (2012a, April 18) The New Preferred Marketing Developer Program. In: *Facebook for Developers*. Available at: https://developers.facebook.com/blog/post/2012/04/18/the-new-preferred-marketing-developer-program/.
FD-2012b	*Developers*	(2012b, May 1) How to get the badge. Available at: https://web.archive.org/web/20120501084120/https://developers.facebook.com/preferredmarketingdevelopers/get_badge/.

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Citation	Type	Reference
FD-2015	*Developers*	Lu C (2015, November 11) Announcing the Marketing API Accelerator and Virtual Hack. In: *Facebook for Developers*. Available at: https://developers.facebook.com/ads/blog/post/2015/11/11/announcing-accelerator-and-virtual-hack/.
FD-2018a	*Developers*	Ho C (2018a, March 5) New directory tool for Facebook Marketing Partners. In: *Facebook for Developers*. Available at: https://developers.facebook.com/ads/blog/post/2018/03/05/solutions-explorer-directory/.
FD-2018b	*Developers*	Archibong I (2018b, April 4) API and Other Platform Product Changes. In: *Facebook for Developers*. Available at: https://developers.facebook.com/blog/post/2018/04/04/facebook-api-platform-product-changes/.
FD-2018c	*Developers*	Archibong I (2018c, May 1) Investing in the Facebook Developer Community. In: *Facebook for Developers*. Available at: https://developers.facebook.com/blog/post/2018/05/01/investing-in-facebook-developer-community/.
FD-2018d	*Developers*	White S (2018d, October 29) Introducing the Facebook Marketing Consultants program. In: *Facebook for Developers*. Available at: https://developers.facebook.com/ads/blog/post/2018/10/29/introducing-fmc-program/.
FD-2018e*	*Developers*	(2018e, November 8) Versioning - Marketing API - Documentation. Available at: https://developers.facebook.com/docs/marketing-api/versions/.
FIR-2018	*Investor Relations*	(2018, October 30) Facebook Q3 2018 earnings. Available at: https://investor.fb.com/investor-events/event-details/2018/Facebook-Q3-2018-Earnings/default.aspx.
FIR-2019	*Investor Relations*	(2020, January 29) Facebook Q4 2019 Earnings. Available at: https://investor.fb.com/investor-events/event-details/2020/Facebook-Q4-2019-Earnings/default.aspx.
FMP-2015	*Marketing Partners*	(2015, February 22) Facebook Marketing Partners. Available at: https://web.archive.org/web/20150222032351/http://facebookmarketingpartners.com/.
FNe-2007	*Newsroom*	(2007, May 24) Facebook Platform launches with 65 developer partners and over 85 applications for Facebook. Available at: https://newsroom.fb.com/news/2007/05/facebook-platform-launches-with-65-developer-partners-and-over-85-applications-for-facebook/.
FNe-2013	*Newsroom*	Boland B (2013, February 28) Facebook to acquire Atlas from Microsoft. In: *Facebook Newsroom*. Available at: https://newsroom.fb.com/news/2013/02/facebook-to-acquire-atlas-from-microsoft/.
FNe-2014	*Newsroom*	Boland B (2014, July 2) Facebook to acquire LiveRail. In: *Facebook Newsroom*. Available at: https://newsroom.fb.com/news/2014/07/facebook-to-acquire-liverail/.
FNo-2006	*Notes*	Fetterman D (2006, August 15) Facebook Development Platform launches…. In: *Facebook Notes*. Available at: https://www.facebook.com/notes/2207512130.

Citation	Type	Reference
FNo-2011	*Notes*	(2011, November 14) Preferred Developer Consultant Program. In: *Facebook Notes*. Available at: https://www.facebook.com/notes/facebook/preferred-developer-consultant-program/281113178594498/.
FPMDC-2013	*PMD Center*	(2013, January 18) PMD Center. Available at: http://web.archive.org/web/20130118122604/http://www.facebookpmdcenter.com:80/.
FS-2012	*Studio*	(2012, September 21) Announcing a new Designation for top marketing developers. Available at: https://web.archive.org/web/20120923004937/http://www.facebook-studio.com/news/item/announcing-a-new-designation-for-top-marketing-developers.
I-2015a	Interviews	(2015, February 4) Mobile Measurement Qualified Company.**
I-2015b	Interviews	(2015, February 4) Mobile Measurement Qualified Company.**
I-2016	Interviews	(2016, February 13) Facebook Marketing Partner.**

* *'Live' Web sources (accessed 8 November 2018).*
** *Anonymised interviewee.*

D. Appendix

Source social media and intermediary partner directories

Table D 4.1. List of source social media partner directories.

Social network	Partner directory name and count of partners
Baidu Tieba [百度贴吧]	'DU advertising Platform (DAP) Partners' (10); Baidu Partners [合作伙伴] (5); Star Enterprise [星级企业] (40); KA Agents [KA代理商] (50)
Facebook	'Facebook Marketing Partners' (216); 'Facebook Instant Articles Partners' (18); 'Facebook Live Solutions Partners' (26); 'Facebook Broadcast Solutions Partners' (17); 'Facebook Audience Network Partner Program' (6); 'Facebook Workplace Partners' (80); 'FbStart Accelerate Benefits' (23); 'FbStart Bootstrap Benefits' (20); 'FbStart for Social Good' (5); 'Internet.org Mobile Operator Partnership Program' (46)
Facebook Messenger	'Messenger Platform Development Provider' (42)
Instagram	'Instagram Partner Program' (89)
LinkedIn	'LinkedIn Marketing Partners' (52)
Pinterest	'Pinterest Marketing Partners' (44)
Sina Weibo [新浪微博]	Sina Weibo Excellent Partners [优秀合作伙伴] (12)
Skype	'Skype for Business Partners' (135)
Snapchat	'Snapchat Partners' (79)
Tumblr	'A-List Tumblr Partners' (19); 'Tumblr Preferred Data Partners' (5)
Twitter	'Twitter Official Partners' (63); 'MoPub Third Party Partners' (8); 'MoPub Certified Rich Media Vendors' (11); 'MoPub Supported Mediation Partners' (14); 'MoPub Accelerate Partners' (4)
Viber	'Viber Trusted Partner Integrations' (12)
WeChat/Weixin [微信]	'WeChat Pay International Business Partners' (143)
YouTube	'YouTube Creator Services Directory' (250); 'YouTube Measurement Program' (YTMP)' (5)

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Table D 4.2. List of source audience intermediary partner directories per owner.

Company name	Partner directory name and count of partners
Acxiom; LiveRamp (owned by Acxiom)	'Partners' (87); 'Partners' (424)
AdMaster	AdMaster Partner [合作伙伴] (83)
Adsquare	'Integrated Platform Partners' (37)
AppsFlyer	'Partners' (2,599)
Brandwatch	'Brandwatch Partnerships' (6)
Conversant	'Conversant Partners' (19)
comScore	'Partners' (36)
Crimson Hexagon	'Crimson Hexagon Partnerships' (12)
DataXu	'DataXu Partners' (258)
Driftrock	'Integrations' (5)
Epsilon	'Data Driven Marketing Solutions Partners' (6)
Experian	'Marketing Services Audience Targeting' (32); 'Technical Provid-ers' (57)
Factual	'Factual's AdTech Partners' (32)
Flowics	'Flowics Partners & Integrations' (8)
Gridsum	Gridsum Partner [合作伙伴] (5)
Invoca	'Invoca Connect Apps' (27)
Isentia	'Isentia Partners' (12)
Kantar (owned by WPP)	'Kantar Partners' (8)
Kochava	'Kochava-Certified Integration Partners' (1,632)
Lithium	'Lithium Partnerships Program' (22)
Linkfluence	'Linkfluence Partners' (9)
Lotame	'Lotame Integrations & Partnerships' (34)
Lytics	'Lytics Integration Partners' (76); 'Lytics Solution Partners' (8)
Marchex	'Partner Integrations' (11)
Marketo	'Marketo Premier Partner Program' (364)
Merkle (owned by Dentsu Aegis Network)	'Partners' (25)
Microsoft Dynamics 365 (owned by Microsoft)	'Dynamics 365 Partners' (756)
mParticle	'Certified Partners (6); Integrations' (132)
Neustar	'Partners' (14)
Nielsen	'Nielsen Connected Partner Program' (39)
NTT Data	'NTT Data Partner' (10)

Company name	Partner directory name and count of partners
Oracle Marketing Cloud; Oracle Data Cloud; BlueKai; Eloqua (Oracle)	‘Oracle Marketing Cloud Partner Ecosystem’ (793)
PushSpring	‘PushSpring Partners’ (38)
Quantcast	‘Quantcast Data Partner’ (5)
Quantium	‘Partners’ (11)
Sailthru	‘Sailthru Compass Partners’ (84); ‘Partner Integrations’ (10)
Salesforce Marketing Cloud; Salesforce DMP; Krux (Salesforce)	‘Salesforce AppExchange: Marketing Cloud’ (21); ‘Salesforce DMP Ecosystem Partners’ (219)
SAP Hybris (SAP)	‘Partners’ (183)
Segment	‘Integrations Catalog’ (312)
Social Fulcrum	‘Platform Partners’ (2)
Spredfast	‘Spredfast Partner Program’ (21)
Sprinklr	‘Sprinklr Integration APIs’ (38); ‘Sprinklr Partners’ (5)
Zapier	‘App Directory’ (1,308)

E. Appendix

Categorisation schemas and search patterns

Table E 6.1. List of actor types (categorisation schema).

Category	Description
Academic	Universities and academic research institutes.
Civil society	Non-governmental organisations [NGOs] or other civil society actors.
Governmental	Governmental organisations (e.g., international, national, provincial, etc.).
Health authority	Health institutions (e.g., hospitals, nursing homes, medical colleges, etc.).
Private	Private companies or other commercial actors (e.g., firms, retail banks, etc.).

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Table E 6.2. List of response types (categorisation schema).

Category	Description
Contact-tracing and/or Exposure Notification	For tracing who you are in contact with and notifying them in case of contact with suspected cases/infected individuals.
Crisis communication	Set up by a crisis-based institution, more than mentioning corona-virus specifically, they mention disaster communication or disaster management in their description.
Financial aid	Apps that provide a platform for financial transactions to the people or institutions in need during the pandemic.
Hot spots	Apps giving the users real time regional data whether the location is safe from infection or not, numbers of vacant hospital beds, hospitals which provide ventilators, access to relief centres.
Informant	Apps where users can report on the activities of others, including non-compliance with regulations, quarantine, but also excessive price increases and shortages.
Information and/or news	*Information:* Apps providing (official) information, educational visual materials, safety measures, hygiene instructions, procedures for contacting healthcare officials, quarantine, travel restrictions, government guidelines, regulations (concrete data), fact-checking (combating myths and disinformation), helpline numbers and contact details, self-assessment for symptom checklist. *News:* Comprises apps that are providing the latest news updates, notifications and up-to-date or 'live' information on the evolution of the virus and regional or global outbreaks of the virus, including data and statistics.
Mental health	Apps providing information and (evidence-based) coping strategies to help people manage their feelings, stress, and anxiety during the COVID-19 pandemic.
Movement permit	Apps which have an app for movement permits, which may support a QR code scanner for security personnel to verify or QR generator for individuals to obtain for travelling within a city, region, country or crossborder. Including voluntary or involuntary movement registration.
Networked medicine	For healthcare workers or technicians to communicate and interact within a system; for healthcare and non-healthcare facilities to assist in planning and optimising their use of resources; tools for patient communication; instructions for intubation.
Other	Other apps, including apps to help businesses re-open.
Quarantine compliance	For the (real-time) monitoring of whether individuals are complying with quarantine restrictions.
Remote healthcare	For remote diagnosis, prescriptions, or tele-consultation to contact health services or have doctor appointments.
Social support	Apps that provide for requesting/contributing/donating resources such as cooked food, shelter, instant reach for emergency lines or social networking in times of isolation or staying indoors, etc.
'Swiss army knife'	Apps that attempt to include 'everything', compact apps including more than one prominent feature (e.g., simultaneously containing reporting, tracking, tele-consultation, news update).
Symptom check	For reporting symptoms or reporting information for test request apps. For daily or regularly tracking your symptom inputs.

Table E 6.3. List of search patterns used to analyse Android and iOS apps.

<table>
<tr><th>Terms set</th><th>Search patterns*</th></tr>
<tr><td>Technique-related</td><td>[agent], [AI|ML], [alert], [algorithm], [API], [Apple], [artificial intelligence|machine learning], [automatic risk classification], [being close], [biometric], [bluetooth], [bluetrace], [bot], [bracelet], [chat], [cloud], [communication tool], [contact tracing], [database], [digital diary], [digital handshake], [emergency number], [expert system], [Fitbit], [Garmin], [geo], [Google], [GPS], [HCFMUSP], [helpline], [hotline], [importing contacts], [locat], [map], [messages], [model], [monitor], [movement permission], [nemid], [Nokia], [notif], [pioneering applications], [platform], [polar], [protocol], [proximity], [push notification], [QR], [quarantine enforcement], [questionnaire], [realtime], [send alerts], [send messages], [sensory], [smart], [STI], [survey], [synchroni], [technique], [teleconsult], [telemedicine], [telephone], [trace|track], [tracetogether], [ultrasonic], [video], [WhatAapp], [wifi|Wi-Fi], [withings], and [wristbands]</td></tr>
<tr><td>Data/privacy-related</td><td>[anonym], [central], [commercial purposes], [compliant], [consent only], [control over], [decentral], [delete], [does not record], [does not use], [DP-3T], [encrypt], [external], [GitHub], [HTTPS], [ID log data], [independent security experts], [local], [official data], [open data], [opensource], [personal information], [privacy], [random IDs], [secure], [security], [sensitive], [smartwatch], [sourcecode], [stored], [third parties], [trusted sources], [will not be shared with], [will not be sold], [will not share], and [with your consent]</td></tr>
</table>

* *All search patterns were codified as (mostly case-sensitive) regular expressions.*

Glossary of abbreviations

Glossary of abbreviations and acronyms of importance.

Abbreviation/ acronym	Definition and examples
ACM	(Netherlands) **Authority for Consumers and Markets**, the national competition regulator of the Netherlands. [‣ cf. FTC; CMA]
API	**application programming interface**, a type of software interface that enables connections between multiple software-based systems for the exchange of data and functionality. [‣ PBR; cf. GUI; SDK] *Examples: Facebook's Graph API, Facebook's Marketing API, Twitter's Ads API.*
APK	**Android Package**, the file format (with the file extension '.apk') used by Google's Android Platform operating system for Android apps.
ASI	**App Studies Initiative**, an international research network.
ATT	(Apple's) **App Tracking Transparency**, a framework that must be used by developers when their app 'collects data about end users and shares it with other companies for purposes of tracking across apps and web sites' (Apple Developer, n.d.). [‣ IDFA]
C&MS	**Communication and Media Studies**, a set of academic disciplines and fields of study in the humanities or social sciences.
CDC	(USA) **Centers for Disease Control and Prevention**, the national public health agency of the USA.
CDP	**customer data platform**, a service and type of (audience) intermediary (digital platform) that offers a unified customer database that is accessible to other systems (e.g., to target specific users and context). [‣ cf. DMP] *Examples: ActionIQ, Blueshift, Microsoft Dynamics 365 Customer Insights, Lytics, mParticle, Salesforce Interaction Studio, Segment, Tealium AudienceStream CDP, Zeta.*
CMA	(UK) **Competition and Markets Authority**, the national competition regulator of the UK. [‣ cf. ACM; FTC]
COVID-19	**coronavirus disease 2019**, the infectious disease caused by the SARS-CoV-2 virus.
CRM	**customer relation management**, a service and type of (audience) intermediary that administers interactions with a company or organisation's customers, typically involving data analysis. *Examples: Adobe, Salesforce, Spredfast, Sprinklr.*
DMP	**data management platform**, a service and type of (audience) intermediary (digital platform) that offers a database that is accessible to other systems (e.g., to target specific users and context). [‣ cf. CDP] *Examples: DataXu, Google Audience Center, Lotame, LiveRamp, MediaMath TerminalOne, Oracle DMP, Salesforce DMP.*

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Abbreviation/ acronym	Definition and examples
DSP	**demand-side platform**, a system and type of (audience) intermediary (digital platform) that aggregates digital advertising inventory from multiple advertising exchanges, used by advertisers to buy advertising impressions (i.e., audiences). [‣ cf. SSP] *Examples: Adform, Adobe, AppNexus, BrightRoll, Criteo, DataXu, MediaMath, Sizmek, Quantcast, The Trade Desk.*
FB–CA	**Facebook–Cambridge Analytica**, a 'data scandal' in the late 2010s around the collection and use (for political advertising) of personal data belonging to millions of Facebook users without their consent.
FBX	**Facebook Exchange**, a (now-deprecated) proprietary real-time bidding [RTB] advertising exchange system from Facebook.
FTC	(USA) **Federal Trade Commission**, the national competition regulator of the USA. [‣ cf. ACM; CMA]
GAEN	**Google/Apple Exposure Notification**, the framework developed by Google and Apple to facilitate digital contact-tracing on their operating systems during the COVID-19 pandemic. [‣ COVID-19; OS]
GAFAM	**Google**, **Amazon**, **Facebook**, **Apple**, and **Microsoft**, or the set of five largest and most dominant 'Big Tech' companies.
GAPI	(Facebook) **Graph API**, a set of APIs from Facebook, used by third-party software developers to create applications 'on top' of its Platform. [‣ API; cf. MAPI]
GDPR	(EU) **General Data Protection Regulation**, a regulation on data protection and privacy in the European Union.
GPS	**Global Positioning System**, the navigation system built into most mobile devices.
GUI	**graphical user interface**, a type of interface that allows end-users to interact through a graphical display. [‣ cf. API]
HTTP	**Hypertext Transfer Protocol**, the basic Internet protocol for transferring resources between devices and servers over the Web.
IAWM	(Internet Archive) **Wayback Machine**, a user interface to the digital archive of the World Wide Web that allows users to retrieve Web pages from the past, created by the Internet Archive in 1996.
IDFA	(Apple's) **Identifier for Advertisers**, a unique random identifier assigned by Apple to every device, used by advertisers to target specific devices. Starting in iOS v14.5, end-users are prompted to 'opt-in' or 'opt-out' of IDFA-sharing. [‣ ATT]
IS	**Information Systems**, an academic field of study in the social or engineering sciences.
MAPI	(Facebook's) **Marketing API**, a set of APIs from Facebook, used by advertisers to create and manage advertising campaigns programmatically. [‣ API; cf. GAPI]
OS	**operating system**, the basic software that manages and interfaces between all the software and hardware on a computational device. *Examples: Google's Android Platform, Apple's iOS.*
OSF	**Open Science Framework**, a free and open-source research and data management system.

Abbreviation/ acronym	Definition and examples
PBR	(**platform**) **boundary resource**, the set of resources offered by a digital platform that enable third-party software developers to create applications, defining (governing) the boundaries between the platform owner and its larger ecosystem. It is also a concept, used in IS and STS scholarship, to analyse third-party software development. [‣ API; SDK]
PMD	(Facebook's) **Preferred Marketing Developer**, a (now-deprecated) partner programme from Facebook.
SDK	**software development kit**, a set of software development tools offered by a digital platform that facilitate the creation of applications. [‣ PBR; cf. API] *Examples: Facebook's SDKs for iOS, for Android, for JavaScript).*
SEC	(USA) **Securities and Exchange Commission**, the national securities industry agency of the USA.
SNS	**social networking service** (or **social networking site**), a type of online service (or website) that people use to build social networks or relationships with other people. *Examples: Facebook, Instagram, Snapchat, Twitter.*
SSP	**supply-side platform**, a system and type of (audience) intermediary (digital platform) that aggregates digital advertising inventory from multiple publishers, used by publishers to monetise their advertising inventory. [‣ cf. DSP] *Examples: AdMob, AppNexus, Amobee, BounceX, MoPub.*
STS	**Science and Technology Studies**, an interdisciplinary academic field of study.
WHO	(UN) **World Health Organization**, the intergovernmental public health agency of the United Nations.

Data availability

The data that support the findings of this study, along with most of the high-resolution figures, are openly available in the Open Science Framework [OSF] at https://doi.org/10.17605/osf.io/6cj5x. The main OSF project page includes several 'linked components', which refer to the specific datasets associated with each of the case studies. They each have a detailed description of the information available in each dataset, as well as the publications they belong to.

References to openly available research datasets by chapter.*

Ch.	Type	Reference
2	API Reference documentation	van der Vlist FN, Helmond A, Burkhardt M and Seitz T (2022) *Historical Facebook Platform 'boundary resources' for application development, 2006–2020*. OSF, Center for Open Science, March 1. DOI: 10.17605/osf.io/wfxyp.
3	Documentation	van der Vlist FN and Helmond A (2019) *Historical Facebook Platform 'boundary resources', 2006–2018*. OSF, Center for Open Science, March 20. DOI: 10.17605/osf.io/47zyc.
4	Partner networks	van der Vlist FN and Helmond A (2021) *Business and data partnerships of the 20 most-used social media platforms*. OSF, Center for Open Science, May 22. DOI: 10.17605/osf.io/wq3dr.
5	App details	van der Vlist FN, Helmond A, et al. (2022 [2019]) *Social media-related Android (Google Play) and iOS (iTunes Store) app ecosystems*. OSF, Center for Open Science, April 16. DOI: 10.17605/osf.io/n3mpj.
6	App details	van der Vlist FN, Helmond A, Chao THJ, Dieter M, Tkacz N and Weltevrede E (2021) *[COVID-19]-related Android (Google Play) and iOS (App Store) app ecosystems*. OSF, Center for Open Science, June 23. DOI: 10.17605/osf.io/ekum8.
	App packages	Chao THJ, Helmond A, et al. (2021) *COVID-19 Apps* (Collection). Internet Archive, June 18. Available at: https://archive.org/details/COVID-19_Apps.

* *See also: App Studies Initiative, ASI Data, http://appstudies.org/data/.*

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Further resources

FURTHER RESOURCES INCLUDE A LIST of research software tools and a public Zotero Group Library with all references.

List of research software tools

Several research software tools were designed and developed from the individual case studies of this dissertation, particularly related to the study of apps. These tools are openly available via the App Studies Initiative, along with instructional worksheets I co-authored.

References to openly available research software tools.*

Category	Type	Reference
Collection (Android; iOS)	Network inspection	(2020, September) *AppTraffic* (beta). ASI Tools. THJ Chao et al. (Devs), Collaborative Research Centre 'Media of Cooperation', University of Siegen. Available at: https://aptraffic.phil.uni-siegen.de/.
Collection (Android)	Code inspection	(2021) *AppInspect* (beta). ASI Tools. THJ Chao et al. (Devs), Collaborative Research Centre 'Media of Cooperation', University of Siegen. Available at: https://appinspect.phil.uni-siegen.de/.
Collection (Android)	Web 'scraper'	(2020, June) *Google Play Scraper* (beta).** DMI/ASI Tools. SCJ Peeters, THJ Chao, et al. (Devs), Digital Methods Initiative, University of Amsterdam. Available at: https://tools.digitalmethods.net/app-scrapers/.
Collection (Android)	Code inspection	(2018, January) *App Tracker Tracker* (beta). DMI/ASI Tools. EV den Tex et al. (Devs), Digital Methods Initiative, University of Amsterdam. Available at: https://tools.digitalmethods.net/beta/appTrackers/.
Collection (Android)	Web 'scraper'	(2016, January) *Google Play 'Similar' Apps* (beta). DMI/ASI Tools. EV den Tex et al. (Devs), Digital Methods Initiative, University of Amsterdam. Available at: https://wiki.digitalmethods.net/Dmi/ToolGooglePlaySimilar/.
Collection (iOS)	Web 'scraper'	(2020, June) *iTunes App Store Scraper* (beta).** DMI/ASI Tools. SCJ Peeters, THJ Chao, et al. (Devs), Digital Methods Initiative, University of Amsterdam. Available at: https://tools.digitalmethods.net/app-scrapers/.
Collection (iOS)	API-based	(2018, July) *iTunes Store* (beta). EK Borra et al. (Devs), DMI/ASI Tools. Digital Methods Initiative, University of Amsterdam. Available at: https://wiki.digitalmethods.net/Dmi/ToolItunesStore/.

DOI: 10.33540/1284

Category	Type	Reference
Analysis	Text	(2017, December) *LE-CAT: A Lexicon-Based Categorization and Analysis Tool*. J Tripp, FN van der Vlist, et al. (Devs), Centre for Interdisciplinary Methodologies, University of Warwick, and Collaborative Research Centre 'Media of Co-operation', University of Siegen. Available at: https://sisko.cim.warwick.ac.uk/app/lecat.
Visualisation	Flows	(2021, September 17) *PyCatFlow: A Python Package for Visualizing Categorical Data Over Time* (v0.0.8). M Burkhardt and H Natta (Devs), Collaborative Research Centre 'Media of Cooperation', University of Siegen. Available at: https://doi.org/10.5281/zenodo.5531785.

** See: App Studies Initiative, ASI Tools, http://appstudies.org/tools/.*
*** Password is required.*

Zotero Group Library

All references included in this dissertation (except the archived Web sources listed in the Appendices) are openly available in a public Zotero Group Library at: https://www.zotero.org/groups/4676709/the_platform_as_ecosystem.

Summary

The platform as ecosystem
Configurations and dynamics of governance and power

THIS DISSERTATION INVESTIGATES THE DIGITAL 'platforms' that form and shape our contemporary online media environment. It posits how not merely the platforms themselves but especially their larger 'ecosystems' are important for understanding the unique features of platform governance and power. Platform ecosystems have become the dominant technological, organisational, and governance model for digital platforms over the past fifteen years. It reveals how platforms derive considerable power from these ecosystems, which are understood and theorised as their spheres of influence. The main purpose of this research is to better understand *how governance and power dynamics are manifested in the construction of platforms' larger ecosystems*.

To address this purpose, the dissertation develops a number of novel empirical and historical approaches for studying platform ecosystems that are based on the distinct materiality and relationality of digital 'platforms' as ecosystems. These approaches provide novel insights into the configurations and dynamics of platform governance and power in larger ecosystems.

The materiality of platforms consists of all kinds of traces and materials that have been left behind as part of their routine functioning, both as operational technologies and as (publicly-traded) companies. These include software tools and technical documentation for software developers, marketers, and advertisers, blog posts and help pages, terms and conditions for users and developers, and more. These materials provide unique research opportunities to surface the material and relational properties of digital platforms to better understand the larger power structures of platforms. This involves the use of so-called 'platform boundary resources', which are the software tools, materials, and regulations that enable third-parties to develop applications and services 'on top' of digital platforms. These resources facilitate third-party software development and thus contribute to innovation in the platform ecosystem. This dissertation uses these resources to surface and study the relations and material conditions of leading digital platforms, including Facebook (and Instagram), Twitter, Google, and Apple.

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The relationality—or the *relational construction*—of platforms highlights the various relations that platforms engage in, and uphold, with a variety of third parties, such as software and app developers, business partners, digital marketers and advertisers, and other types of users and developers. That is, 'platforms' are adaptive to the needs of different types of users, who help determine and shape what the platform is and becomes through their collective development work ('innovation'). It argues that because of these connections, platforms are always part of larger systems and structures, which digital media and platform scholars view and study as 'ecosystems'. Platforms' boundary resources provide unique opportunities to surface and study the technical and organisational relationships that platforms engage in. They offer important insights into how the relationships and interactions between platforms and other parties in the ecosystem are created, mediated, and governed by platforms. In addition, these materials help to understand how various third parties *collectively* contribute to the ongoing expansion of platform ecosystems, from which the 'core' platforms typically benefit the most. It is important to better understand these relationships and interactions between platforms and third parties, because they show that power dynamics are often complex and subtle, in part because these third parties help construct (and benefit from) the larger platform ecosystem.

Each chapter following the Introduction chapter presents a case study that makes a unique empirical, historical, and methodological contribution to surfacing, analysing, and visualising platforms' unique position of power as part of larger ecosystems. Chapter 2 shows that so-called application programming interfaces [APIs] (which software developers use to build applications or services 'on top' of platforms) are essential for understanding how platform governance and power dynamics are manifested within platform ecosystems. Indeed, these APIs form the material foundations of platform ecosystems and are important mechanisms through which platforms can exercise 'infrastructural power'. The chapter presents the results of a historical study of 'Facebook's Development Platform' for building software applications, using historical Web sources on Facebook's various APIs. These sources are used to examine the 'technicity'—or the material-technological features— of platform governance. It shows how platforms design and use their APIs to shape and influence their relationships with third parties. At the same time, these APIs are also shaped and influenced by external pressures on the platform, such as social, competitive, and regulatory pressures to change.

The four subsequent case studies all focus on the larger 'ecosystems' of powerful (American) platforms and the business and mobile applications ('apps') built 'on top' of their material foundations (APIs) by different types of software developers. Chapter 3 builds on the previous chapter with a study of the co-evolution of Facebook's platform architecture and the technological integrations and business partnerships that have enabled Facebook to become central to the larger platform ecosystem. This chapter also uses historical Web resources to reconstruct how Facebook's boundaries have evolved (and expanded) by establishing technological and organisational relationships with third-party software developers, marketing and advertising developers, and business partners. These relationships can be understood as part of a broader strategy that has allowed Facebook to accelerate its entry into the digital marketing and advertising industry with the help of its business partners and through strategic acquisitions. The role of these technological integrations and business partnerships have often been understudied in the academic literature and in the context of regulation. However, this study demonstrates that these aspects are critical to understanding how technological and organisational dependencies emerge in the platform ecosystem in the first place.

Chapter 4 further argues that these technological and business integrations and partnership strategies are not only important, but essential to understanding how platforms gain strategic and infrastructural power from their position within the platform ecosystem. The chapter presents the results of a large-scale study of the partnerships and partner integrations of the twenty largest (most widely used) social media platforms. The study uses boundary resources to map the business ecosystem of these platforms and to expose the complex technological and organisational structures of the digital economy. Social media have a lot of power because of their unique position within this digital economy. The network analysis and visualisations provide important insights and ways into understanding the positions of platforms within their larger platform ecosystems and are essential for locating strategic and infrastructural (centralised) 'nodes' of power within them.

Chapter 5 explores the complex interactions that arise around the 'programmability' of social media and mobile platforms, or the extent to which third-party developers can influence platform development (and *vice versa*). This process is not only driven by platforms, but also to a significant extent by the influence of powerful app stores, such as Apple (App Store) and Google (Google Play). Moreover, the limits of this programmability are constantly being challenged by software developers. The chapter presents a detailed study of these dynamics as they play out in the app ecosystem around powerful (social media) platforms such as Facebook, Instagram, Snapchat, and Twitter. It shows that there are constant tensions between software developers who are building apps that do not always conform to the terms of services of these platforms, while the platforms try to maintain control over this development process for their own platform ecosystems. It shows how platforms deal with this tension and that not only platforms, but also app stores and software developers can influence the development of app ecosystems.

The last case study, Chapter 6, focuses on the role of Google and Apple as powerful 'gatekeepers' of the mobile platform and app ecosystem during the initial phase of the global pandemic caused by the coronavirus (COVID-19). During this crisis, app stores played a central role in mediating the response to the pandemic (in terms of apps) and the international relationships between governments, international (health) organisations, and civil society organisations. The study provides a comprehensive large-scale analysis of apps developed worldwide in the context of the pandemic response. This reveals a tension between different types of interests: on the one hand, the private and commercial interests of platform and app store owners, and on the other hand, the public interests of governments, civil society and health organisations, and citizens in countries and regions worldwide. The analysis thus reveals the material conditions of platform governance and power in the larger app ecosystem. Moreover, the study shows how Google and Apple adapted and deployed their own governance during the crisis. The unprecedented nature of the crisis meant that both app stores employed more editorial interventions because of the high societal stakes. Such reconfigurations (about what is acceptable or not) may also have longer-term implications for the development of the global app ecosystem.

The five case studies each make an original contribution to the interdisciplinary literature on Media Studies, especially on digital platforms and infrastructure (i.e., Platform Studies). They show how the material foundations or infrastructures of platform ecosystems relate to platform governance and power. Collectively, they provide important empirical and historical insights into the technological and structural characteristics, the organisational features, and the dynamics and evolutionary features of platform and app ecosystems. A better understanding of these characteristics is not only of interest to scholars but can also help policymakers and authorities worldwide regulate powerful Internet companies. In this regard, it is particularly important to consider the shift from individual 'platforms' to the 'ecosystems' of platforms, within which the power of platforms manifests.

Additionally, because these ecosystems are not visible by default, they always need to be located and made visible before they may be analysed, contextualised, critiqued, or regulated. The dissertation contributes novel approaches, empirical materials, and techniques to help articulate, visualise, and analyse the ecosystems of platforms in terms of their technological, organisational, and dynamics or evolutionary characteristics. ▾

Nederlandse samenvatting

Het platform als ecosysteem
De configuraties en dynamieken van governance en macht

Dit proefschrift betreft de digitale platforms die onze hedendaagse online mediaomgeving vormen en vormgeven. Het beargumenteert dat niet alleen de platforms zelf, maar vooral hun grotere 'ecosystemen' belangrijk zijn om de unieke kenmerken van hun invloed en macht goed te begrijpen. Platform-ecosystemen zijn de afgelopen vijftien jaar het dominante technologische, organisationele en bestuurlijke model geworden voor digitale platforms. Hiermee ontlenen platforms een groot deel van hun macht aan deze ecosystemen die kunnen worden begrepen en bestudeerd als invloedssferen. Het belangrijkste doel van dit onderzoek is om beter te begrijpen *hoe governance en machtsdynamieken zich manifesteren in de ontwikkeling van platform-ecosystemen*.

Het proefschrift ontwikkelt een aantal nieuwe empirische en historische benaderingen voor het bestuderen van platform-ecosystemen die zijn gebaseerd op de unieke materiële en relationele eigenschappen van digitale 'platforms' als ecosystemen. Deze benaderingen geven zo inzicht in de configuraties en dynamieken van platform governance en macht binnen het grotere ecosysteem.

De materiële eigenschappen van platforms bestaan uit allerlei verschillende sporen en documenten die zijn achterlaten als onderdeel van hun reguliere functioneren, zowel als operationele technologieën en ook als (beursgenoteerde) bedrijven. Het gaat dan bijvoorbeeld om software-tools en technische documentatie voor softwareontwikkelaars of marketeers en adverteerders, blogs en help-pagina's, de algemene voorwaarden voor gebruikers en ontwikkelaars, en meer. Deze materialen bieden unieke onderzoeksmogelijkheden om de materiële en relationele eigenschappen van digitale platforms bloot te leggen, en daarmee ook de grotere machtsstructuren van platforms beter te begrijpen. Hiervoor wordt ook gebruik gemaakt van zogenaamde *'platform boundary resources'*, oftewel de diverse software-tools, documenten en voorwaarden die diverse externe partijen gebruiken om applicaties en diensten 'bovenop' digitale platforms te ontwikkelen. Deze hulpmaterialen faciliteren de ontwikkeling van software door derden en dragen op die manier bij aan de innovatie van het platform-ecosysteem. In dit proefschrift worden deze bronnen gebruikt om de relaties van toonaangevende digitale platforms,

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waaronder Facebook (inclusief Instagram), Twitter, Google en Apple te onthullen en te bestuderen.

De relationele eigenschappen van platforms leggen juist de nadruk op de verschillende verbindingen die specifieke platforms aangaan met allerlei externe partijen, zoals software- en app ontwikkelaars, bedrijven, marketeers, adverteerders en andere soorten gebruikers. De verschillende soorten gebruikers van platforms bepalen als mede-ontwikkelaars mede hoe het systeem eruitziet en zich verder ontwikkelt. Vanwege deze verbindingen maken platforms altijd deel uit van grotere systemen en structuren die door digitale media- en platformwetenschappers worden gezien en bestudeerd als 'ecosystemen'. Eerdergenoemde *boundary resources* bieden unieke mogelijkheden om de technische en organisationele relaties die platforms hebben te onthullen. Ze bieden belangrijke inzichten in hoe de verhoudingen en interacties tussen platforms en andere partijen in het ecosysteem door platforms tot stand komen, worden bemiddeld en vormgegeven. Daarnaast helpen deze materialen om te begrijpen hoe diverse externe partijen gezamenlijk bijdragen aan de steeds verdere uitbreiding van platform-ecosystemen, waarvan de centrale platforms zelf vaak het meeste profiteren. Het is belangrijk om de verhoudingen en interacties tussen deze verschillende partijen beter te begrijpen, omdat het laat zien dat machtsdynamieken vaak complex en subtiel zijn, onder meer doordat derden ook meebouwen (en profiteren) van het grotere platform-ecosysteem.

Elk hoofdstuk na de Introductie presenteert een deelstudie die een empirische, historische en methodologische bijdrage levert om de unieke machtspositie van platforms als integraal onderdeel van platform-ecosystemen te leren zien en begrijpen. Hoofdstuk 2 toont aan dat zogenaamde *application programming interfaces* [APIS] (die softwareontwikkelaars gebruiken om applicaties of diensten bovenop platforms te bouwen) essentieel zijn om te begrijpen hoe platform-*governance* en machtsdynamieken zich manifesteren binnen platform-ecosystemen. Deze API's vormen namelijk de materiële fundamenten van platform-ecosystemen en zijn ook belangrijke mechanismen waarmee platforms hun 'infrastructurele macht' kunnen uitoefenen. Het hoofdstuk presenteert de uitkomsten van een historische studie naar de ontwikkeling van Facebooks 'platform' voor het bouwen van softwareapplicaties en maakt daarvoor gebruik van historische webbronnen over Facebooks diverse API's. Met deze bronnen wordt de *'technicity'*, oftewel de materieel-technologische kenmerken, van platform-governance onderzocht. Het laat zien hoe platforms hun API's ontwerpen en inzetten om hun relaties met diverse externe partijen te kunnen vormgeven en beïnvloeden. Tegelijkertijd worden deze API's ook weer gevormd en beïnvloed door de externe druk die van buitenaf op het platform wordt uitgeoefend, bijvoorbeeld onder druk van gebruikers, concurrenten of regelgevende instanties.

De vier daaropvolgende deelstudies richten zich allemaal op de grotere 'ecosystemen' van machtige (Amerikaanse) platforms en de bedrijfsmatige en mobiele applicaties ('apps') die door verschillende soorten softwareontwikkelaars bovenop hun materiële fundamenten (API's) zijn gebouwd. Hoofdstuk 3 bouwt voort op het vorige hoofdstuk met een studie naar de co-evolutie van Facebooks platform-architectuur en de technologische integraties en zakelijke samenwerkingsverbanden waarmee Facebook zich een centrale plek heeft kunnen verwerven in het grotere platform-ecosysteem. Ook dit hoofdstuk gebruikt historische webbronnen om te reconstrueren hoe Facebooks *boundaries* zich hebben ontwikkeld (vooral steeds verder hebben uitgebreid) door het aangaan van technologische en organisationele relaties met externe softwareontwikkelaars, marketing en advertentie ontwikkelaars en zakenpartners. Deze relaties kunnen ook worden begrepen als onderdeel van een bredere strategie waarmee Facebook met behulp van haar zakenpartners en door strategische overnames haar intrede in de digitale marketing- en advertentie-industrie heeft kunnen versnellen. De rol van deze technologische integraties en zakelijke samenwerkingsverbanden blijft in de wetenschappelijke literatuur en in het kader van regulering vaak onderbelicht. Deze studie toont echter aan dat deze aspecten van cruciaal belang zijn om te begrijpen hoe technologische en organisationele afhankelijkheden in het platform-ecosysteem in eerste plaats zijn ontstaan.

Hoofdstuk 4 bouwt hierop voort en laat zien dat deze technologische en zakelijke integraties en partnership-strategieën niet alleen belangrijk, maar zelfs essentieel zijn om te begrijpen hoe platforms strategische en infrastructurele macht verwerven uit hun positie in het platform-ecosysteem. Het hoofdstuk presenteert de uitkomsten van een grootschalige studie naar de partnerschappen en partnerintegraties van de twintig grootste (meest gebruikte) sociale mediaplatforms. De studie maakt opnieuw gebruik van *boundary resources*, dit keer om het zakelijke ecosysteem van deze platforms in kaart te brengen en daarmee de complexe technologische en organisationele structuren van de digitale economie bloot te leggen. Sociale media hebben veel macht vanwege hun unieke positie binnen deze digitale-economie. De netwerkanalyse en visualisaties bieden daarom belangrijke inzichten en manieren om de posities van platforms in het grotere platform-ecosysteem te kunnen begrijpen en zijn ook noodzakelijk om strategische en infrastructurele (gecentraliseerde) machtsknooppunten in deze ecosystemen te lokaliseren.

Hoofdstuk 5 onderzoekt de complexe interacties die ontstaan rondom de *'programmability'* van sociale media en mobiele platforms, oftewel de mate waarin externe ontwikkelaars invloed kunnen uitoefenen op de ontwikkeling van platforms (en *vice versa*). Dit proces wordt niet enkel gestuurd door platforms, maar ook in belangrijke mate door de invloed van machtige *app stores*, zoals die van Apple (App Store) en Google (Google Play). Bovendien worden de grenzen van deze programmeerbaarheid ook voortdurend door softwareontwikkelaars betwist. Het hoofdstuk presenteert een gedetailleerde studie van deze dynamieken, zoals die zich afspelen in de app-ecosystemen rondom machtige (sociale media)platforms zoals Facebook, Instagram, Snapchat en Twitter. Het laat zien dat er voortdurend spanningen zijn tussen softwareontwikkelaars die apps bouwen die niet altijd in overeenstemming zijn met de voorwaarden van deze platforms, terwijl platforms proberen controle te behouden voor hun eigen platform-ecosystemen. Het laat zien hoe platforms omgaan met dit spanningsveld en dat niet alleen zij, maar ook app stores en softwareontwikkelaars invloed kunnen uitoefenen op de ontwikkeling van app-ecosystemen.

De laatste deelstudie, Hoofdstuk 6, gaat over de rol van Google en Apple als machtige 'poortwachters' van het mobiele platform- en app-ecosysteem in de beginfase van de wereldwijde pandemie als gevolg van het coronavirus (COVID-19). Tijdens deze crisis vervulden app stores een centrale rol in het bemiddelen van de reactie op de pandemie (op het gebied van apps) en ook van de internationale verhoudingen tussen overheden, internationale (gezondheid)organisaties en maatschappelijke organisaties. De studie biedt een uitgebreide grootschalige analyse van de apps die wereldwijd werden ontwikkeld in het kader van de reactie op de pandemie. Aan de ene kant manifesteren zich hier de private en commerciële belangen van platform- en app store eigenaren en aan de andere kant de publieke belangen van overheden, maatschappelijke- en gezondheidsorganisaties en burgers in verschillende landen en gebieden over de hele wereld. De analyse brengt daarmee de materiële eigenschappen van platform governance en macht in het grotere app-ecosysteem aan het licht. Bovendien laat de studie zien hoe Google en Apple hun eigen governance hebben aangepast en ingezet tijdens het verloop van de crisis. De exceptionele aard van de crisis betekende dat beide app stores meer redactionele interventies hebben toegepast, omdat er maatschappelijk veel op het spel stond. Dergelijke verschuivingen (over wat acceptabel is of niet) kunnen ook op langere termijn gevolgen hebben voor de ontwikkeling van het mondiale app-ecosysteem.

De vijf deelonderzoeken leveren zo elk een originele bijdrage aan de interdisciplinaire literatuur over mediastudies en in het bijzonder over digitale platforms en infrastructuur, oftewel de platformwetenschap. Ze laten zien hoe de materiële fundamenten of infrastructuren van platform-ecosystemen zich verhouden tot platform-governance en macht. Ze leveren daarmee gezamenlijk belangrijke empirische en historische inzichten op over de technologische en structurele kenmerken, de organisationele kenmerken en de dynamiek en evolutionaire kenmerken van platform- en app-ecosystemen. Een beter begrip van deze kenmerken is niet alleen van belang voor wetenschappers, maar kan ook beleidsmakers en autoriteiten helpen bij het reguleren van machtige internetbedrijven. Hierbij is het met name van belang om stil te staan bij de verschuiving van individuele 'platforms' naar de ‘ecosystemen’ van platforms, waarbinnen de macht van platforms zich manifesteert.

Bovendien kunnen zulke platform-ecosystemen niet zomaar worden geobserveerd, maar moeten altijd eerst worden opgespoord en blootgelegd. Pas daarna kunnen platform-ecosystemen worden geanalyseerd, gecontextualiseerd, bekritiseerd of effectief worden gereguleerd. Het proefschrift draagt daarom nieuwe benaderingen, empirische bronmaterialen en onderzoeksmethoden bij waarmee de ecosystemen van platforms kunnen worden blootgelegd, gevisualiseerd en geanalyseerd. Het gaat dan in het bijzonder om de technologische, organisationele en dynamische of evolutionaire kenmerken. ▾

Curriculum vitae

FERNANDO N. VAN DER VLIST is a scholar of new media and digital culture (Media Studies) and Internet-related research in the humanities. He has been a PhD Candidate at Utrecht University's Media and Culture Studies department (NL) since 2019 and a Research Associate in the DFG-funded Collaborative Research Centre 1187 'Media of Cooperation' at the University of Siegen (DE) since 2016. As of August 2022, he is a postdoctoral researcher at these same institutions. Additionally, he is part of several international research groups and networks, including Utrecht University's focus area 'Governing the Digital Society', the App Studies Initiative (as co-lead), the Digital Methods Initiative (University of Amsterdam), and the Public Data Lab.

Since 2014, Fernando has held several academic research and teaching positions in Media Studies at the University of Amsterdam, Utrecht University, and the University of Siegen. He was a Lecturer in New Media and Digital Culture at the University of Amsterdam's Media Studies department from 2015–2018, and a Lecturer in Digital Methods at Utrecht Data School (Utrecht University) in 2016. In 2016, he also consulted for the ERC-funded research project CONNECTINGEUROPE on the use of digital methods for studying digital diaspora and migration online.

Fernando obtained his Research Master's (MA) degree in Media Studies from the University of Amsterdam in July 2015, and his Bachelor's (BA) degree in Media and Culture in July 2013 (*Cum Laude*). His Master's thesis investigated social media data as grounds for algorithmic techniques of prediction, and his Bachelor's thesis studied the 'technicity' of collaborative (open-source) software development on GitHub. Additionally, he holds a professional Bachelor's (BDes) degree in Graphic Design from the Willem de Kooning Academy (Rotterdam University of Applied Sciences), awarded in June 2012. During his studies, he worked as a teaching and research assistant at the University of Amsterdam's Media Studies department (2014–2015) and at design studios based in Amsterdam (2011–2012).

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Digital 'platforms' owned and operated by powerful Big Tech companies have shaped and impacted social, economic, and political life in significant ways. Yet, platforms remain an ambiguous phenomenon. What exactly are these platforms? How can we identify and understand the features of their power?

The platform as ecosystem explains how not merely the platforms themselves but especially their larger 'ecosystems' are important for understanding the unique features of platform governance and power. Platform ecosystems have become the dominant technological, organisational, and governance model for digital platforms over the past fifteen years. These ecosystems comprise many different types of users including end-consumers, software developers, marketers and advertisers, and business partners who build software tools, products, and services of their own 'on top' of the interfaces provided and controlled by leading platforms. These users each help build and expand platform ecosystems while negotiating governance and control by central platforms.

This dissertation examines different aspects of platform ecosystems to determine how platforms' material foundations or infrastructures relate to governance and power. It develops several novel empirical and historical approaches for studying the distinct material and relational features of digital platform ecosystems. This reveals how platforms derive considerable power from their ecosystems and provides unique empirical and historical insights into the technological, organisational, and evolutionary features of platform (and mobile app) ecosystems. These approaches and insights are relevant to digital media and platform researchers and help policymakers, regulators, and authorities worldwide dealing with the challenges of governing digital economies and societies.

Fernando N. van der Vlist is a scholar of new media and digital culture (Media Studies) and Internet-related research in the humanities. He has been a PhD Candidate at Utrecht University's Media and Culture Studies department (NL) since 2019 and a Research Associate in the DFG-funded Collaborative Research Centre 1187 'Media of Cooperation' at the University of Siegen (DE) since 2016.

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