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Banking in the cloud: Mapping Big Tech's Global Digital Technology Networks

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Abstract:

Witnessing the inroads of Big Tech into finance, this paper maps the growing dependence of incumbent banks on public cloud infrastructures. Although 'cloud interfacing' has become crucial amid platform finance, the intersections between what we conceptualize as Global Digital Technology Networks and Global Financial Networks have received little attention. We mobilize social network analysis to (i) map the geographically variegated patterns of public cloud adoption in banking and their geopolitical implications; (ii) the corporate networks supporting banks' cloud migration, and (iii) the urban networks of command-and-control undergirding cloud banking, connecting established financial centres with tech valleys old and new.

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1. Introduction

Both regulators and commentators have been raising concerns about the growing reliance of the financial sector on Big Tech public cloud[2] infrastructure. Gillian Tett (2023) suggests that "a new threat to financial stability lurks in the cloud", pointing to what other *Financial Times* commentators call "finance's Big Tech problem" (Financial Times, 2022). Similarly, financial regulators including the Bank for International Settlements (BIS) (Carstens et al., 2021), the Financial Stability Board (2019), and national regulators have warned about the "growing reliance of a large number of financial institutions on technology services provided by a small number of big- techs" (Crisanto et al., 2022: 21). Rather than storing and analyzing commercial data on their own privately-operated servers, banks increasingly store these data 'in the public cloud', implying that their data is transferred to third parties, scattered over a network of data centres located across the globe. These public cloud infrastructures are controlled by a handful of Big Tech firms, with US Big Techs Amazon, Google and Microsoft featuring as global market leaders.

Discussions about cloud services, artificial intelligence (AI), and the myriad applications relying on hyperscale data centres seem niche and technical, yet these technologies increasingly underpin the operations of our economies and societies. Accordingly, if we want to understand how the global economy is spatially articulated, we need to acknowledge the growing importance of tech firms and associated processes of platformization. Some speak of the emergence of "platform capitalism" (Srnicek, 2016), the rise of a "platform society" (Van Dijck et al., 2018), or "platform urbanism" (Graham, 2020). In the literature on global production networks (GPNs), meanwhile, there is a growing acknowledgement that digitization is crucial, instigating a more differentiated focus on why digital value chains matter, and how these shape and are enabled by uneven development (Howson et al., 2022). Likewise, for those studying the orchestration of global circuits of value, there is a growing recognition that clouds and digital technology matter (Trincado-Munoz et al., 2023). In financial geography there is growing scholarship on financial technology (FinTech) and its organisational, industry, and geographical implications (Lai and Samers, 2021).

While all these agendas have made significant headway in incorporating the central role of technology, what is lacking is a systemic conceptualization of the interface between global finance, production, and technology, and how their intersections shape platformizing capitalism. Further, while there has been growing attention to the insertions of digital platforms in production spaces, a systematic approach is currently lacking, when talking about the finance and tech interface. Research on FinTech has paid significant attention to the role of FinTech start-ups, while paying less attention to the Big Tech elephant in the room (Bassens and Hendrikse, 2022).

Our paper aims to do two things. First, it sets out to offer a more integrative and encompassing conceptualization of the global production-finance-tech interface. It analytically distinguishes between existing macro-frameworks of world city networks (WCNs) or the more narrowly defined global financial networks (GFNs), GPNs, and what we here conceptualize as *Global Digital Technology Networks* (GDTNs). These GDTNs seek to analyse the distinct geographies of tech, including command and control over data access, storage, and regulatory arbitrage. Second, we broach the theme empirically by focusing on the growing entanglements of GDTNs and GFNs as finance is undergoing platformization. We specifically focus on the adoption of public cloud services in banking, as these

[2] The key distinction between private and public cloud is that while in the former case a single organisation (e.g. JPMorgan Chase) controls and maintains servers and all underlying infrastructure, in the latter case external cloud providers (e.g. Amazon Web Services or Microsoft Azure) deliver computing resources over a network (e.g. internal memory, CPU, data storage) as a fully managed service (Amazon Web Services, 2024). This means that a bank using private cloud is in full control of the computing infrastructure that it uses for its various applications, while a bank using public cloud surrenders control over some of its computing infrastructure to an external public cloud provider.

infrastructures are deemed indispensable for the platformization of banking. Our dataset of press releases enabled a systematic global mapping of the corporate structure of cloud provision networks as one instance of the entanglements of GFNs and GDTNs amid platform finance. The data also allowed to distil the core structure of the global urban network of that cloud banking and GFN/GDTN interface.

To this end, section 2 reviews existing frameworks that acknowledge the centrality of tech amid contemporary capitalism and proposes the notion *Global Digital Technology Networks* as a distinct analytical concept. Section 3 operationalizes our empirical focus on cloud adoption among banks and outlines the methodology underpinning our paper. Section 4 describes our findings regarding cloud adoption by banks, the structure of the corporate networks, and the urban geographies undergirding our cloud banking network. Section 5 discusses the implications of the charted infrastructural dependence of finance on the tech cloud. Section 6 concludes.

2. Literature review

2.1. Hyperscaling finance, 'interfacing' with Big Tech

Witnessing regulatory concerns about the inroads of tech firms into financial services, this paper scrutinizes the mounting dependence of banks on the cloud infrastructures and services provided by Big Tech (Fernandez et al., 2020; Hendrikse et al., 2022). While such relations are nothing new, what is new is the post-2008 growing need to 'platformize' financial services. Platformization captures the emergence of a "distinct mode of capitalist enterprise that aggregates and analyses data and deploys digital infrastructures in order to extract value from intermediation" (Langley and Leyshon, 2021: 379). The cloud has become an operational necessity for banks seeking to act as platforms, connecting their customers with an ecosystem of innovative FinTech providers. At the front-end banking platforms interface with (retail) customers, allowing integrated and customized services drawing on the tracking and analysis of banking data. At the back end, platforms allow to harmonize information and communication technology (ICT) operations among the bank and an ecosystem of FinTech firms (Hon and Millard, 2018). The interdisciplinary literature on FinTech captures the platform-driven transformation of finance along multiple dimensions (Wójcik, 2021a, b). Amongst others, attention has been called to how financial services are being reintermediated (Lai, 2020; Langley and Leyshon, 2021) around new market entrants – be they FinTech start-ups or larger tech companies, but also how incumbent financial players, including large universal banks, are being 'self-disrupted' and transformed for the age of platform finance (Hendrikse et al., 2018; 2020).

Since incumbent banks typically operate legacy ICT systems that may not be compatible with the logics of "platform capitalism" (Srnicek, 2016), platformization has given way to a growing reliance on hyperscalable public cloud infrastructures for the storage, management, and processing of mounting volumes of data (Narayan, 2022). Public clouds offer "computing resources over a network, typically the internet, scalable with demand" (Hon and Millard, 2018: 5), coming with various servicing models, such as Software as a Service (SaaS), Infrastructure as a Service (IaaS), and Platforms as a Service (PaaS), with different nuances as to what is taking place within the bank and on a remote server. Bassens and Hendrikse (2022) show that European Union (EU) regulators are increasingly concerned about the 'interfacing' between European financial institutions and American Big Tech firms, because of data protection, financial stability, or geopolitical sensitivities. At the same time, Big Tech lobbies argue that their cloud infrastructures allow for the flexible usage of raw computing power, resulting in effective cost reductions, whilst making banks less prone to cyberattacks. The key question is to what *extent* is finance becoming reliant on Big Tech's infrastructural core (Hendrikse et al., 2022, cf. Van Dijck et al., 2018).

Even though it is clear that Fin and Tech interfacing is the new normal, there is little systematic insight into the degree to which financial institutions have become reliant on Big Tech, which Big Tech and FinTech intermediaries are most structurally important, and what kind of globally networked geographies this produces. Hon and Millard (2018) show that European banks are quite hesitant to adopt public clouds, but such studies date fast in the world of platformizing finance. Besides the piecemeal and aggregate-level discussion of public cloud usage by European banks, more general mappings of financial technology usage by advanced producer services firms (Trincado-Munoz et al., 2023), and case-study work (Hendrikse et al., 2024), there is a dearth of empirical insight into how banks rely on public clouds. Relatedly, there is little insight into the evolving relation between finance and tech, and the geographies these relations are producing. With tech firms becoming more central to financial intermediation, this has implications for how world cities and financial centres connect to other spaces, giving us hints of shifting geographies of the WCN and, more narrowly, GFNs.

2.2. Locating Tech in existing macro-frameworks

Existing analytical frameworks studying the geographies of intersecting Fin and Tech mostly focus on FinTech ecosystems. Research has investigated relations between market entrants ('disruptors') and incumbents, typically focusing on a specific market segment, such as corporate bonds (Macartney et al., 2022), asset management (Haberly et al., 2019), or foregrounding a particular financial centre such as Brussels (Hendrikse et al., 2020), London (Sohns and Wójcik, 2020), or Singapore (Harris, 2021). These studies lay bare nuanced interdependencies between Fin and Tech, going against mainstream claims of disruption, yet they do not allow a more systematic analysis of how such interdependencies connect the world of finance and tech at a macro-geographical level.

Existing frameworks at the macro-level, in turn, fall short in encompassing the increasingly intimate connections between Fin and Tech. The long-standing tradition of charting WCNs (Taylor and Derudder, 2016) has focused on Advanced Producer Services (APS), which are crucial intermediaries in the coordination of global production and financial markets. While originally the focus was mostly on world cities as organizers of 'seamless service' to global production spaces, the field has become more amenable to the shifting role of world cities amid financialization (Bassens and Van Meeteren, 2015) giving rise to complementary methods to trace the growing intersections between world cities and offshore spaces (Van Meeteren and Bassens, 2016). Since its inception, world cities research was informed by the service industries literature from the 1980s, paying occasional attention to the role of ICT firms in world-city formation (Moulaert and Djellal, 1995), but it has never been a core focus. The more infrastructure-focused strand of world cities research provides insights into how geographies of critical infrastructure (internet) produce global urban hierarchies (Devriendt et al., 2010).

Meanwhile, a parallel analytical track focuses on intersections of GPNs with finance (Coe et al., 2014). This engendered a more encompassing GFNs perspective (Haberly and Wójcik, 2022), where the focal point are connections between the APS complex, financial centres, offshore jurisdictions, and world governments. The GFNs framework is attentive to how financial centres are 'sticky places' for APS actors and connect the space of production to the space of finance, thereby utilizing the offshore world to shield and maximize capital accumulation (Wójcik, 2013). While it was less clear in the original GFN framework, where *tech* is to be situated, Haberly and Wójcik (2022: 270) have problematized the reliance of GFNs on 'technical geographies' producing centrifugal forces that may 'unbundle' financial geographies. Such an expanded GFN framework calls attention to the growing reliance on data centers and back-office technology centers. Empirically, however, research has remained limited to such dynamics in the realm of digital asset management, leaving a broader mapping of the intersections between GFNs and digital technology spaces and networks uncharted. A more recent paper by Migozzi et al. (2023) studies the intersections between finance and digital technology yet approaches the matter through investment flows into FinTech. Their research shows growing entanglements between

financial centers and technology hubs, yet this analysis is limited to one market (India), while the focus on investments leaves the strong infrastructural dependence of finance on tech uncharted.

In GPN research, in turn, ICT was from the onset treated not as a separate category of analysis, since it was "seen as an inherent element of GPNs, underlying the development and maintenance of network connections" (Henderson, 2002: 447). Recently, scholars have sought to develop new analytical concepts to better grasp the impact of platformization on the institutional embeddedness of firms, how value is produced and distributed across firms, and how control over global production is organized (Foster and Graham, 2017). This approach led to the conceptualization of a Digital Value Network (DVN) as a 'digitally mediated nexus of platform operations that produce and distribute value between territories, on the basis of labour transactions' (Howson et al., 2022: 632). In this DVN approach, however, the conceptual and empirical connections to GFNs remain unexplored.

2.3. Conceptualizing Global Digital Technology Networks

Although tech geographies are increasingly entangled with GPNs and GFNs amid platformization, they have a sufficiently autonomous logic that warrants analytical isolation. As Figure 1 details, isolating those geographies may offer analytical clarity regarding how different functional networks intersect amid platform capitalism (Srnicek, 2016).

First, GFNs unveil how, by whom and where *financial intermediation* takes place, and how this reproduces a networked hierarchy of financial centres and APS intermediaries servicing GPNs. Second, GPNs unveil how, by whom and where coordination of global supply chains takes place, and how this creates value in geographically uneven ways. Thirdly, what we dub *Global Digital Technology Networks* (GDTNs) unveil distinct tech geographies – i.e. the latest platform layer built upon the stack of modern capitalism – supplying GPNs and GFNs with tech capabilities, and exerting command and control accordingly, whilst offshoring labour and profits, that do not necessarily overlay with either GFNs or GPNs. The main analytical focus of GDTNs is how tech firms take on intermediary APS-like roles within GFNs and GPNs, and extract rents from their command and control over platform capitalism's core infrastructural tools (Van Dijck et al., 2018), ranging from hardware capabilities e.g. hyperscale datacentres (cloud infrastructures) to software dominance e.g. (mobile) operating systems and exclusive app stores (Birch and Cochrane, 2022; Hendrikse et al., 2022), through which 'lesser' sectoral platforms are developed, marketed and run - including the digital applications making up platform finance. The fact that tech firms and the infrastructural power they hold is rivalling the power of lead firms in GPNs, as well of the lobby power of GFNs as they influence governments worldwide, adds weight to treat GDTNs as a distinct analytical category.

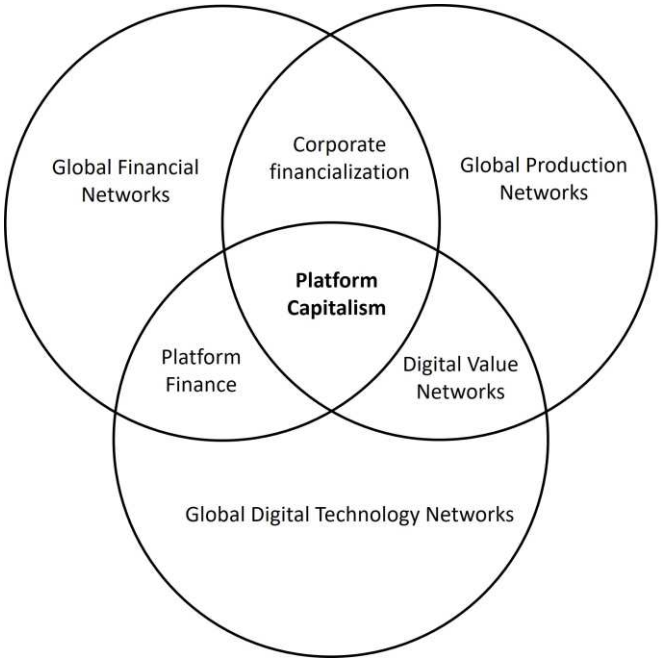


Figure 1. Intersections of global production, financial, and digital technology networks.

As Figure 1 details, the current form of globalized, financialized and platformizing capitalism blurs the sectoral boundaries between production, finance, and digital technology, but shows that such intersections can be geographically disentangled in three ways:

(i) Scrutinizing the intersections of GFNs and GPNs either to understand how industry acquires finance or, more critically, how such intersections drive processes of *corporate financialization* – this is a geography tied together by APS firms operating from world cities/financial centres, connecting industry to financial markets and offshore jurisdictions.

(ii) Scrutinizing the intersections of GDTNs and GPNs either to understand how production acquires technology or how these firms platformize their industrial operations through *corporate platformization*, for instance through the focus on the role of infomediaries in the early 21st century and currently under the banner of digital value networks as platform models infuse labour in production – this is a geography that connects tech valleys and their innovation facilities and corporate HQs to dispersed labour/firms across the globe, also anchoring that labour in platforms stored on a dispersed geography of data centres.

(iii) Scrutinizing the intersections GFN and GDTN, to understand *financial platformization*, but also how large tech companies use and rely on financial markets to augment the infrastructural sway (Klinge et al., 2023) – this is a geography that connects world cities /financial centres and offshore spaces to tech valleys and data centres.

Macro-level frameworks studying strategic insertion of places in the global economy would benefit from a more detailed analysis of how finance intersects with tech. To date, such mappings are rare and have mostly focused on issues of sector coalescence between what Van Meeteren et al. (2022) call Global Technology Space and the vanguard of the wider economy as embodied in start-ups. These authors offer a clear mapping of how a system of digital technologies that mark the current late phase of the fifth technological revolution (Perez, 2010) – Artificial Intelligence (AI), Mobile Technologies, Digital Platforms, and Cloud Computing – are adopted across the start-up economy. In their analysis of technological proximity across knowledge-intensive business services, they find a high likelihood of technological integration or convergence between FinTech, cryptocurrency and software, and cloud

computing. More recently, Trincado-Munoz et al. (2023) offer further empirical detail about the core role of AI, blockchain, cloud, (big) data analysis, and software in the digitization of finance. In the reminder of this paper, we seek to develop our systematic approach to integrate digital technology into GFNs.

The adoption of digital technology in finance is hence a plural rather than a singular process, meaning that the intersections between GFNs and GDTNs revolve around multiple types of firm-to-firm relations with potentially their own geographies. Yet, in our view it is key to note that there is a degree of infrastructural dependence between what are essentially software-oriented technologies seeking to analyze and store data (e.g., AI, blockchain, big data analysis) and the cloud as infrastructural hardware on which this increasingly crucial software runs. The cloud as a technology is something of an outlier as it is not only 'digital tech' but also a crucial *infrastructural layer* that has become a necessary resource for financial institutions to deploy platform finance (Hendrikse et al., 2022, cf. Van Dijck et al., 2018).

While recent years have seen a rise in data centre development in places with low energy costs, the geography of data centres remains notoriously concentrated and sticky as it is drawn to 'internet choke points' like internet exchanges that bridge different networks. One such place is Ashburn, Virginia (US), where Amazon, Google, and Microsoft (Farell and Newman, 2023: 28-38) co-locate. Such co-location allows the speeding up server communication yet also enable place-based infrastructural rents by those companies owning server capacity on that choke point. The potential infrastructural dependence on firms operating those 'chokepoints' is also what has given rise to financial worries concerning data sharing and new systemic risks, geopolitical concerns are rising accordingly (see Bratton 2015; Farrell and Newman 2023). More fundamentally Lehdonvirta (2022: 91, 211) refers to the rise of "cloud empires", giving way to "centrally planned free markets", with Big Tech increasingly encroaching state functions and statecraft. The growing power of Big Tech originates, for one, in the path-dependence of its users on the hyperscale of the cloud, further driving sectoral concentration:

> "Scale economies are particularly critical for cloud computing […] By hosting other organizations [and sectors] on their platforms, tech giants can detect emerging new promising business areas and use the information strategically for further expansion of their own business" (Lundvall and Rikap, 2021: 7)

But we may wonder how contemporary cloud empires also encroach on finance, where FinTech middlemen enable Fin and Tech interfacing. Some scholars argue that the growing deployment of platforms in finance cements a strong tie between two types of oligopolistic sectors:

> "Take an oligopolistic sector of tech giants, whose platforms are fused into the life of billions, and glue them via fintech infrastructure to an oligopolistic sector of financial giants, whose digital money is fused into the life of billions. Then glue both to everything else" (Scott, 2022: 12)

To end-users, it may seem that little is changing since they 'interface' with banks in simply novel way. But this does not undo the growing dependence on underlying cloud hardware and software by Big Techs and Fintech intermediaries that glue platform finance together. Such new dependencies also have a clear geopolitical dimension. Reverberating with EU developments (Bassens and Hendrikse, 2022), seeking to augment the bloc's "technological sovereignty" to counter its wholesale reliance on US Big Techs, geopolitics increasingly plays a role, as "regions without cloud computing empires of their own risk becoming a digital vassal to one of the geopolitical 'stacks'" (Lehdonvirta, quoted in Stevens 2022). As exemplified in the treatment of China's Huawei, to US policymakers Big Techs have become "strategic assets" whose global operations "may be deployed or destroyed" (Farrell and Newman 2019: 10) to advance the global reach of Silicon Valley's digital stack. More critically, some

are worried that platformization in general, and the rise of "cloud capital" in particular, is transforming financialized capitalism into an emergent technofeudalism (Varoufakis, 2023). In sum, broaching a much wider agenda of tracing intersections between GDTNs and other spaces of platform capitalism, we commence by more deeply analysing this third type of intersections, focusing on the growing dependence of incumbent finance and Big Tech.

3. Methodology: mapping the cloud interface between GFNs and GDTNs

Our paper zooms in on the adoption of public cloud infrastructure by commercial banks. To operationalise our analysis, we identify connections among banks, FinTech developers, and public cloud providers. We focus on the provision of public cloud infrastructure to banks by the leading public cloud providers. We identify these providers through an analysis of their relations with the top 100 largest banks globally by total assets according to Standard and Poor's (S&P) in 2022. According to the banks' websites and an internet search focusing on public-cloud adoption, 90 of these banks use public clouds as part of their ICT infrastructure, and the majority (71) of them rely on multiple cloud providers. Global market leaders Microsoft Azure and AWS are leading the pack, as both are used by 48 of the top 100 largest banks, followed by IBM (36), Google (34), and Oracle (22). In addition to US cloud providers, Chinese tech giants complete this list, with 15 banks using Huawei, followed by Tencent (10) and Alibaba (10). Our research is limited in scope and focuses only on the leading five public cloud providers in banking. This inevitably means that the role of smaller public cloud providers, in particular those from outside of the USA, simply goes under our radar. Yet, we are able to reliable map the major geographical trends.

Having identified the leading cloud providers, we turned to tracing connections among them and all banks that use their public cloud infrastructure, rather than limiting ourselves to the world's largest banks. We limited ourselves to the top five leading cloud providers: Microsoft, Amazon, IBM, Google, and Oracle. We exclude Huawei, Tencent, and Alibaba, who are less important outside of China and the data on press releases available to us is less comprehensive for these companies. We identified press releases in the LexisNexis database relating to the provision of public cloud services to commercial banks. We use search queries incorporating the name of each cloud provider and "bank" and "cloud" as keywords. We further restricted our search to newswires and press releases in English. This search yielded 360 press releases for Microsoft Azure, 355 for AWS, 203 for Google, 133 for IBM, and 104 for Oracle Cloud. We then reviewed these and filtered out duplicates, and press releases unrelated to cloud adoption. This reduced our dataset of press releases to 158 for Microsoft Azure, 112 for AWS, 66 for Google, 55 for IBM Cloud, and 32 for Oracle. We then reviewed these to identify key actors involved, namely a) cloud providers; b) FinTech software developers, and c) commercial banks. We obtain addresses of the operational headquarters using Bureau Van Dijk Orbis and corporate websites, to identify the geographical location – the metropolitan statistical area (MSA) of each actor.

We use this data to build a firm and a city network of public cloud services used by commercial banks. Our firm network allows us to show the variegated relationships among different actors, represented as nodes. There are 272 nodes in our firm network, which are divided into four categories: 5 cloud providers, 79 FinTech software developers, and 192 banks. Ties in our firm network are unweighted and directed from service provider to client. Nodes are scaled by the number of outgoing ties, meaning the number of clients that each node serves. We identify 367 ties in our firm network. There are 109 ties connecting cloud providers and banks, 100 ties among cloud providers and FinTech software developers, and 158 ties among FinTechs and banks.

We use information on head-office locations (MSAs) of the financial and tech actors in our firm network, to construct a city network, which allows us to analyse geographies of public cloud services to banks. We focus on headquarters for practical reasons, related to the impossibility to retrieve the actual geographical ties to scattered-yet interconnected data centres worldwide. More substantially,

our focus on headquarters is deliberate since these can be taken as proxies for networked power in the urban networks that support cloud services in nuanced ways. As such, our analysis is focused on where corporate control lies in the merging fields of finance and technology, and less on the material geographies of technological infrastructure undergirding that control, nor the actual 'flows' of data through the global cloud architecture.

Ties in our city network are weighted by the number of firm dyads with a service relationship for a given city-dyad and are produced by aggregating ties from our firm network. These ties remain directed from service provider to client. Nodes in our city network represent MSAs, which can host any of the actors in our firm network. Nodes are scaled by their network centrality, and we present results for outdegree centrality and betweenness. Outdegree centrality suggests relational power exerted by a corporation across the urban network. Betweenness serves as a measure to capture the importance of cities in bridging otherwise disconnected or less integrated parts of the network (Taylor and Derudder, 2016), or more specifically acting as switching points between GFNs and GDTNs in case of FinTech locations. Naturally, given that our city network aggregates data across actors in the firm network, some of the nuances relating to relationships among different actors are lost here. That said, directionality of ties and the use of different centrality measures allow us to identify (remote) command-and-control patterns in the geographies of public cloud services.

4. Geographies of cloud interfacing

Our empirical analysis dissects (i) the global market structure of public cloud services, (ii) firm networks that underpin the adoption of public cloud, and (iii) urban and country-level networks that reflect the geographies of public cloud adoption in banking. Our analysis allows us to answer three research questions. First, who are the key providers of public cloud infrastructure and associated FinTech software development services in banking? Second, how structurally important is the role of FinTech intermediaries in the platformizing banking sector? Third, how does the adoption of public clouds influence the networked importance of established and emerging financial and tech centres with potential geopolitical implications?

4.1 The cloud banking market

We begin with systematically tracing the adoption of public cloud by the world's largest 100 banks by total assets as of 2022. We find that 90 of those banks have adopted public cloud in tandem with private cloud, resulting in hybrid cloud strategy being most commonplace, while the remaining 10 only use private cloud. Most banks that use public cloud infrastructures (71/90) use multiple cloud providers to mitigate operational risks, and limit reliance on a single cloud provider.

Despite variegated cloud strategies, the cloud infrastructure that banks rely on is very concentrated (see Table 1), and consequently banks become (partially) reliant on the infrastructural core of Big Tech. For only eight US and Chinese cloud infrastructure providers dominate the global cloud market at the apex of banking. Despite the good representation of Chinese banks in the top 100, it is five US tech firms that are leading this list. It is not only the usual tech giants that lead the way here: although AWS, Microsoft, and to a lesser extent Google are market leaders, reflecting their leading status in delivering global cloud services, IBM and Oracle also play important roles.

Table 1. Leading public cloud providers to top 100 largest banks

Cloud provider	HQ location	Number of clients
Microsoft	Seattle, WA, USA	48
Amazon Web Services	Seattle, WA, USA	48
IBM	New York, NY, USA	36
Google	San Jose, CA, USA	34
Oracle	Austin, TX, USA	22
Huawei	Shenzhen, China	15
Tencent	Shenzhen, China	10
Alibaba	Hangzhou, China	10

Source: authors' analysis of banks' websites and press releases.

Reminiscent of growing geopolitical concerns, we see that the leading Western banks are exclusively reliant on US cloud providers. For the leading Chinese banks, who constitute 16 of 90 public cloud-adopting banks, cloud dependence is predominantly limited to Chinese providers (8), mixed across Chinese and US providers (6), or exclusively US-reliant (2). This shows that US tech firms have established a foothold in the Chinese banking sector, whilst Chinese cloud providers exhibit limited extraterritorial reach. This suggests that the global cloud market in banking is concentrated around a few American Big Techs. For European banks, such patterns are at odds with the strategic agenda toward technological sovereignty (Bassens and Hendrikse, 2022), and this also applies for countries like India, challenging its techno-cultural nationalism paradigm (Jain and Gabor, 2020).

4.2. Corporate cloud provision networks in banking

Having identified the leading public cloud providers among the world's 100 largest banks, we now turn to exploring the egocentric networks of five leading cloud providers with a global reach, namely Microsoft, Amazon, IBM, Google, and Oracle. In doing so we are able to explore their client networks comprehensively, rather than limiting ourselves to the world's largest banks. Figure 2 shows the resulting inter-firm network formed by combining egocentric networks for the aforementioned public cloud providers and features their ties with banks, which may be either direct or intermediated by FinTech software developers. In the former case a cloud provider supplies public cloud infrastructure directly to a bank, while in the latter case a FinTech developer builds software application for a bank, which runs in public cloud.

While the market shares revealed in this more comprehensive analysis are similar to those for the top 100 banks, it allows us to develop a more nuanced view of cloud banking. About 60% of the ties among cloud providers and banks are intermediated by FinTechs, suggesting that the use of public clouds by FinTech software developers to run their SaaS applications for banks is a major factor contributing to the rise of cloud banking. Despite the obvious point that corporate power in cloud provisioning networks is anchored in the core infrastructure owned by a handful of Big Techs, for it to function and be implemented in banking, FinTech software developers have become crucial intermediaries by acting as Big Tech satellites, or Big Fin-Big Tech lubricators. If we think of Big Fin and Big Tech as two distinct operating systems, FinTech software developers play the role of API (application programming interface), enabling the two to interface.

The cloud intermediation network (Figure 2) shows a lot of variation in the relative connectivity of FinTechs and compared to the heavily concentrated market for public cloud infrastructure, there are many FinTech software developers that only serve a small number of banks. There are, however, also larger FinTechs with more concentrated market shares, with Geneva-based Temenos (Switzerland) and the London-based Finastra (UK), respectively responsible for 14% and 11% of onward ties to client

banks. Both FinTechs are rather unknown outside of financial services sector, but nevertheless important and relatively large. Publicly-listed Temenos had a market capitalization of $8bn in early 2024[3]. The privately owned Finastra had an annual revenue of $1.9bn in 2023[4]. The networked importance of Temenos is also based on the fact that it acts as an intermediary for all five leading cloud providers, and as a potential one-stop multi-cloud shop for banks. Then follows a set of second-tier firms such as Suntec (Trivandrum, India), Tassat (New York, US), and Ethereum (Zug, Switzerland), the latter two illustrating that blockchain firms are important intermediaries in the implementation of cloud solutions for banks. Ethereum, for instance, offered smart contract solutions to a consortium of banks including Barclays, Credit Suisse, KBC, SIX, and UBS.

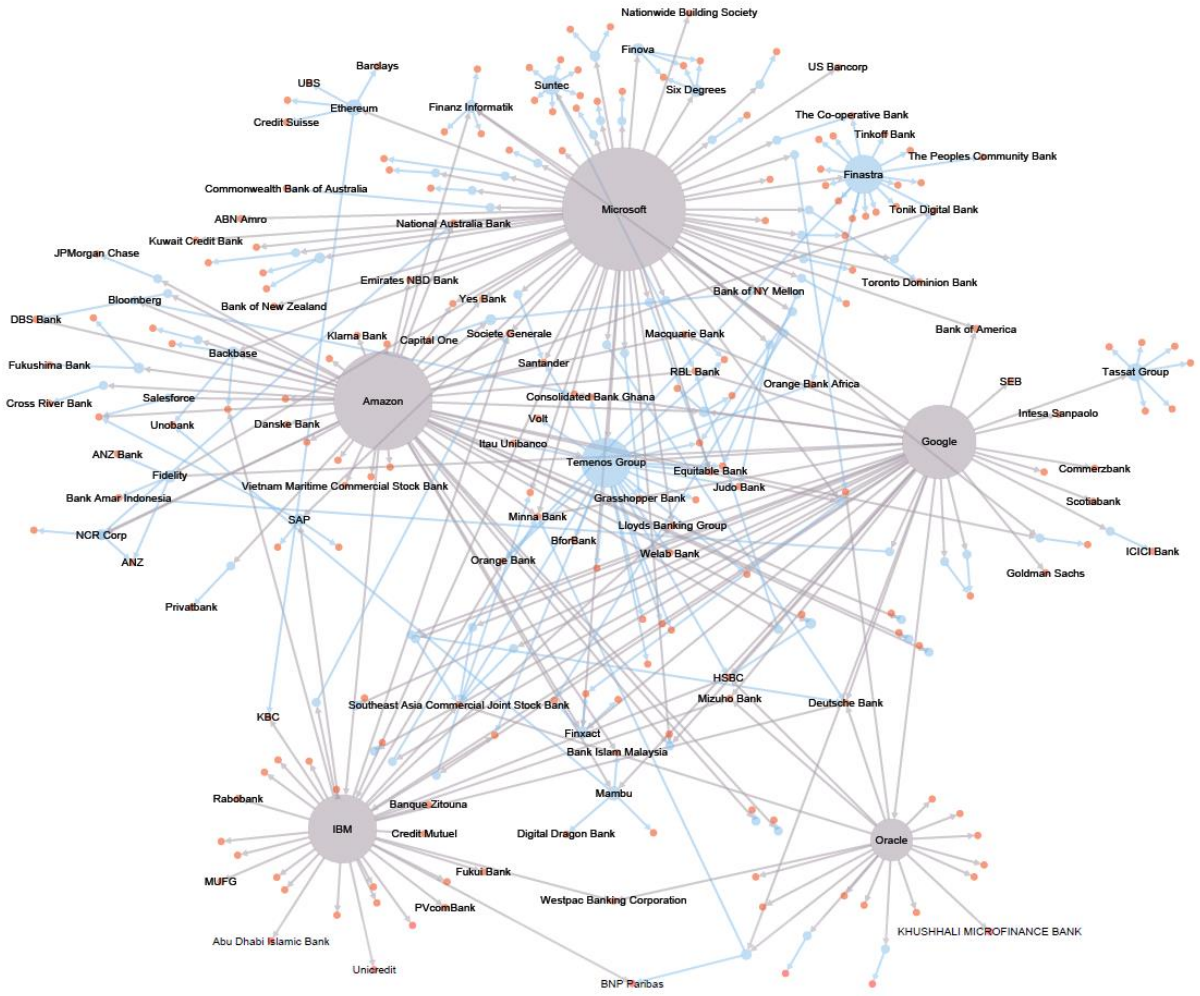
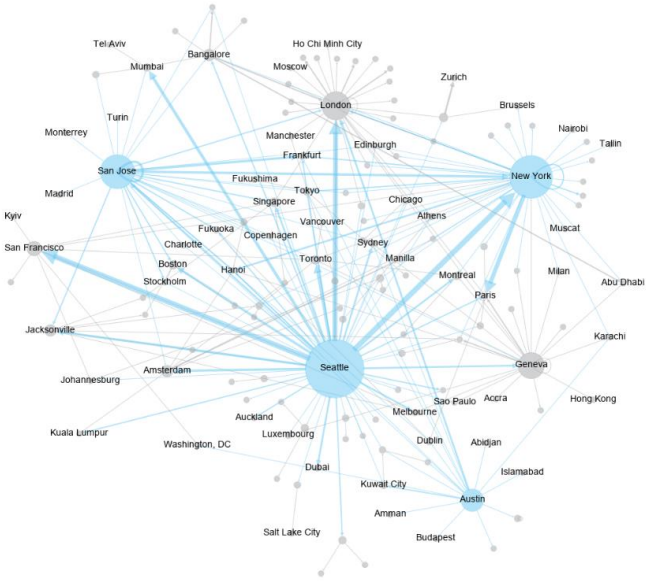


Figure 2. Corporate network of public cloud provision in banking.

Notes: The colour of nodes relates to the different categories of firms: public cloud providers (grey), FinTech software developers (blue), banks (orange). Nodes are scaled by the number of outgoing ties (outdegree centrality). Edge colour relates to the type of connections: cloud infrastructure provision to FinTech software developers (grey) and FinTech software developers to banks (blue). Edges are equally weighted.

Source: Authors' analysis of press releases sourced from LexisNexis database.

[3] https://www.bloomberg.com/quote/TEMN:SW
[4] https://www.finastra.com/about/corporate-information



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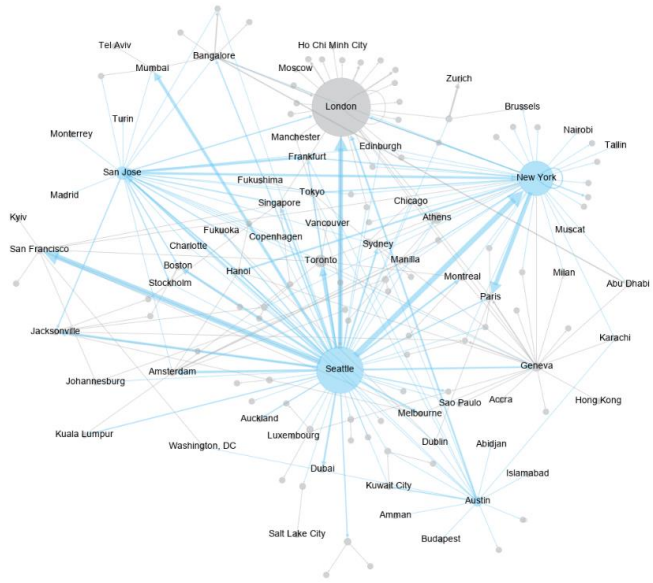


B

Figure 3. Urban network of public cloud provision in banking.

Notes: The colour of nodes relates to different types of cities: cities of headquarters of public cloud providers (blue), and other cities (grey). The colour of edges relates to the type of service links: provision of public cloud infrastructure (blue), FinTech cloud software development (grey). Edges are weighted by the number of firm-dyads connected for each city-dyad. Self-loops are excluded. Nodes are scaled by the number of outgoing ties (outdegree centrality) [A] or the extent they connected other nodes (betweenness centrality) [B].

Source: Authors' analysis of press releases sourced from LexisNexis database.

4.3. The networked urban geographies of cloud interfacing

We now examine the power relations in urban networks that entangle GFNs and GDTNs. Figure 3 respectively shows the urban HQ-centred networks that support the provision of cloud infrastructure and services to banks, with a focus on outdegree centrality (A) and betweenness (B).

When looking at outdegree centrality, headquarter cities of leading Big Techs are the key nodes in the urban networks of cloud provisioning. Seattle leads the pack, as it houses the two global market leaders in cloud services (AWS and Microsoft), followed by San Jose (Google) and Austin (Oracle). In this sense, the rising importance of the cloud suggests a shift in corporate power from financial centres toward American tech valleys. What is interesting, however, is that also New York as a leading financial centre acts as a powerful node by virtue of IBM. Other notable examples are financial centres London and Geneva. London has a thriving and diverse FinTech ecosystem, housing a leading player Finastra, while Geneva mostly reflects the strong influence of FinTech Temenos. Both financial centres are important cloud implementers for global banks, suggesting that both financial centres have seen the growth of tech capabilities with global influence.

Turning to betweenness, we can detect cities acting as switching points between GFNs and GDTNs. One would expect Geneva (Temenos) as main switching point here, yet betweenness points again to London. London does not host a large cloud provider in and of itself, but it is there that FinTech intermediaries like Finastra are implementing banking-as-a-service and banking-as-a-platform solutions for clients in London and across financial centres worldwide. New York has the second highest betweenness, but this is mostly due to IBM's contribution, rather than having a FinTech ecosystem comparable to that of London. That said, the financial dominance of New York and London is reconfirmed in the era of cloud banking, but each side of the dyad has a different modality of power in urban cloud networks.

Table 2 Leading city-to-city dyads undergirding cloud provision.

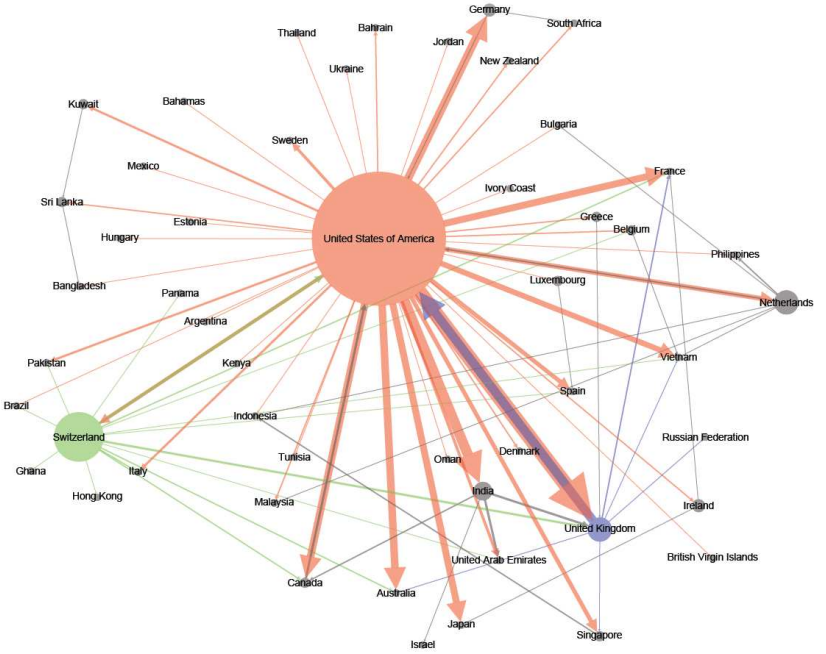
Dyad rank	Cloud infrastructure/service	Cloud adoption	Dyad strength
1	Seattle-Tacoma-Bellevue	New York - Newark - Jersey City	9
2	Seattle-Tacoma-Bellevue	San Francisco-Oakland-Berkeley	9
3	Seattle-Tacoma-Bellevue	London, United Kingdom	8
4	New York - Newark - Jersey City	Paris, France	7
5	Seattle-Tacoma-Bellevue	Mumbai, India	5
=	Seattle-Tacoma-Bellevue	Toronto	5
7	San Jose-Sunnyvale-Santa Clara	New York - Newark - Jersey City	4
=	San Jose-Sunnyvale-Santa Clara	Frankfurt am Main	4
=	San Jose-Sunnyvale-Santa Clara	San Jose-Sunnyvale-Santa Clara	4
=	Seattle-Tacoma-Bellevue	Amsterdam	4
=	Seattle-Tacoma-Bellevue	Jacksonville	4
=	Seattle-Tacoma-Bellevue	Boston-Cambridge Newtown	4
13	Austin-Round Rock-Georgetown	London	3
=	Bern	Zurich	3
=	Frankfurt am Main	Frankfurt am Main	3
=	New York - Newark - Jersey City	Hanoi	3
=	Seattle-Tacoma-Bellevue	Sydney	3
=	Seattle-Tacoma-Bellevue	Singapore	3
=	Seattle-Tacoma-Bellevue	Montreal	3
=	Seattle-Tacoma-Bellevue	Dubai	3
=	Seattle-Tacoma-Bellevue	Geneva	3
=	Seattle-Tacoma-Bellevue	Melbourne	3
=	Seattle-Tacoma-Bellevue	San Jose-Sunnyvale-Santa Clara	3

Notes: dyad strength is measured as number of cloud service ties.

Source: Authors' analysis of press releases sourced from LexisNexis database.

The nuanced positions of New York and London also become evident when looking into what city-to-city dyads dominate the network (Table 2). Interestingly, the strongest dyad in the global financial system, NYLON (Wójcik, 2013), does not feature among the leading ties in the urban cloud network. This seems to suggest that each of the leading financial centres operate to some degree in parallel cloud networks, with London's GFNs tied into American GDTNs, bypassing New York, while New York extends its GDTN into Europe and elsewhere.

Zooming out from the urban level to the scale of countries (see Figure 4)- a dimension becoming ever more salient for geopolitical reasons – the hegemonic reach of the US in GDTNS is even more striking than its centrality in the global financial system (compare with Haberly and Wójcik, 2022: 50 for instance). Data limitations do not allow to trace the extraterritorial reach of Chinese Big Tech's and its potential footprint across the Global South and elsewhere trailing its Digital Silk Road. Yet as our analysis of the top 100 banks showed before, the importance of Chinese tech firms at the apex of finance is rather limited. The connection to the UK as the main transatlantic partnership is also evident much to the parallel of the NYLON dyad in the global financial system, yet now articulated across other urban nodes. Finally, key financial (offshore) jurisdictions are absent from the GDTN country network: with the exception of Switzerland, other jurisdictions like Luxembourg, Singapore, Hong Kong have not taken on a central role. Such an observation does not undo the potential importance of these jurisdictions for the incorporation of Big Tech, the flow of data across the globe, yet it does stress that corporate control at the cloud interface is less dependent on these well-known (offshore) financial jurisdictions.



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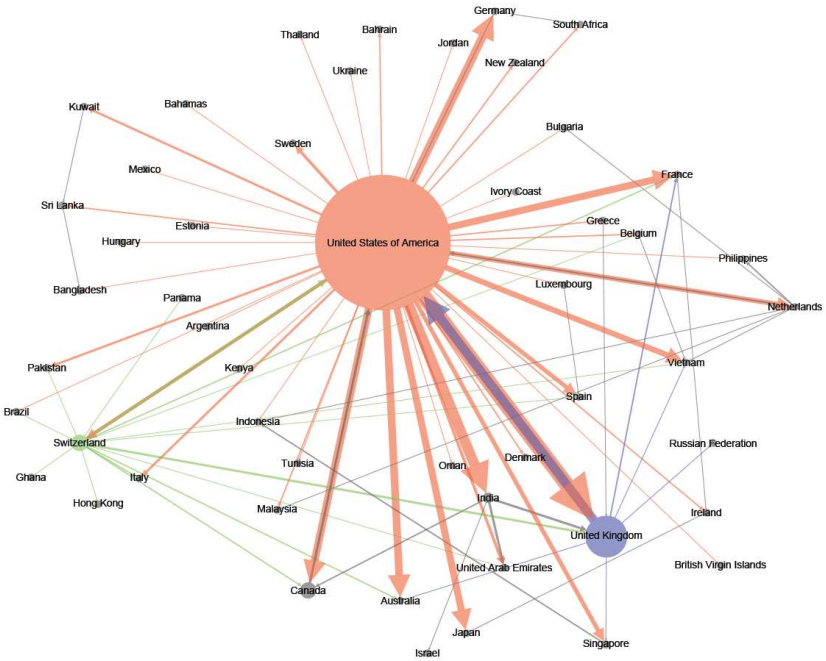

B

Figure 4. Country network of public cloud provision in banking.

Notes: The colour of nodes relates to different countries: United States of America (orange), United Kingdom (blue), Switzerland (green), all other countries (grey). The colour of edges is the same as their source node. Edges are weighted by the number of firm-dyads connected for each country-dyad. Self-loops are excluded. Nodes are scaled by the number of outgoing ties (outdegree centrality) [A] or the extent they connected other nodes (betweenness centrality) [B].

Source: Authors' analysis of press releases sourced from LexisNexis database.

5. Discussion

5.1 Setting the conditions for rent extraction by Big Tech from finance

What are the implications of our findings? First, we find that most banks have adopted public cloud services, deepening entanglements between GFNs and GDTNs. The platformization of banking indeed requires accessing public cloud services for reasons of cost cutting, cybersecurity, hyperscalability of applications, and so forth. In so doing, however, most banks make use of a hybrid cloud and/or multicloud approaches, which not only suggests that banks are careful with sharing their data, but also seek to refrain from wholesale reliance on Big Tech's infrastructural core, as observed elsewhere (Hendrikse et al., 2024). That said, our analysis confirms that cloud banking is chiefly concentrated around a handful of American Big Techs.

All this has important implications for how we see the locus of the global orchestration of value amid financialized globalization verging on platform capitalism. Traditionally, such acts of orchestration were attributed to what Sassen (2001[1991]) called the APS complex, consisting of mutually interdependent firms anchored in global cities. To date, finance has always been found to be the key actor in that complex, suggesting that we may better label it as a para-financial complex (Bassens et al., 2021; Cook et al., 2007), especially given its capacity to extract rents from the wider economy (Pazitka et al., 2022). Our findings show that finance, as the leading actor in that para-financial complex, is itself becoming (infra-)structurally dependent on a category of firms that are typically not considered to be part of that very complex: Big Tech. A platformizing para-financial complex thus installs the conditions for rent extraction by Big Tech firms found elsewhere (Birch and Cochrane, 2022), but now extending to the realm of financial intermediation (Hendrikse et al., 2024).

Much of the earlier concerns about Big Tech's financial inroads were focused on the degree to which they would start offering financial services themselves, fearing that the network effects and financial firepower these players could draw on would unlevel the playing field within financial sector (Bassens and Hendrikse, 2022). From our account, we find that the much more systemic forms of dependence are in the use of the Big Tech cloud. However, given increased regulatory scrutiny in key markets of Europe and Northern America, it would be unwarranted to assume that these cloud interdependencies equal an outright transfer of proprietary data prone to privacy regulations from banks to Big Techs. Storing those data in the cloud does not imply that Big Techs can automatically access, analyse, and utilize these data for their own purposes. How banks practically deal with this in contractual arrangements with their third-party cloud providers remains largely undocumented, but the forthcoming Digital Operational Resilience Act[5] in the EU stipulates that banks are responsible to diligently manage ICT-risk.

It hence becomes unlikely that banks pay with their data for the use of Big Tech cloud, unsettling the analogy with how platform users pay with personal data. But this does not imply that financial institution can indeed be in a situation, where actual monetary rents can be extracted. A highly concentrated and de facto oligopolistic cloud 'market' gives little alternatives and may produce forms of infrastructural 'lock-in' (FSB, 2019: 13) not unlike the kind of customer lock in once you have entered the ecosystem of firms like Apple (Hendrikse et al., 2018). In a market where platformization is the new deal, banks that operate in a competitive environment have little other option than to buy into these cloud services and accept the fees charged by Big Tech, it would appear. The implication would be that the practices of rent extraction by banks and other financial institutions from the wider economy are in part siphoned off to Big Tech and their shareholders.

5.2 Platformization as reintermediation

The interweaving of GFNs and GDTNs is in itself a mediated process. Put differently, the challenge of banking in the cloud relies on the core infrastructure of Big Tech, but is crucially enabled by a small set of impactful FinTech firms. We hence see a more nuanced image than the alleged disruption of

[5] https://www.digital-operational-resilience-act.com/

finance as a process of disintermediation and rather find a process of continued intermediation by incumbent banks enabled by the FinTech designed/implemented cloud banking services that run on Big Tech infrastructures. These FinTech firms mostly tie newer Big Tech's GDTNs together with GFNs, whereas older Tech firms (Oracle, IBM) that in many cases have a long history of catering to their banking clients are mostly doing business directly. This means that the challenge of enabling platformization has two paths, where it can imply engaging with older tech incumbents and trusted partners or relying on much younger FinTech firms that unlock the cloud infrastructure of Big Techs. FinTechs here are enablers of the wider merging of organizational/industrial fields of finance and technology.

Our findings clearly show how the challenge of platformization is not taken on by banks internally, yet relies on the critical insourcing of FinTech expertise. Regulators (Financial Stability Board, 2019: 12) are hence concerned that cloud banking may install knowledge asymmetries between financial institutions and tech firms, again increasing the systemic dependence on organisations not subject to banking regulation directly. While in-depth case studies would be needed to tease out this question, our press release data contains some clues about the labour and expertise needed to organize cloud migration. 60% of the cloud servicing ties are mediated by FinTech firms suggesting banks strongly rely on the expertise of FinTechs. 40% of the servicing ties remain unmediated and involve a direct servicing between Big Tech and the bank. This would suggest banks still need to curate their internal teams to (co-)develop or at least implement applications running in a public cloud. Whatever the case may be, there is nearly always a growing reliance on the actual expertise to run data infrastructure globally vested at the end of the line: a handful of Big Techs.

5.3 Expansion, intensification, and segmentation of GFNs

The entanglements of GDTNs and GFNs produce new centralities in an urban network that is knitted together by cloud banking services. When talking about the crucial sites of the global orchestration of value amid platformization, it becomes hard to ignore the expansion of GFNs to HQ cities of Tech firms. Whereas these cities and regions, and certainly Silicon Valley, have long gotten attention as global nodes in a regional world (Saxenian, 1990), this focus remained disjointed from the types of intermediation functions studies by world and global cities research and those studying GFNs. The platformization of finance, however, strongly cements those connections implying that orchestration clearly also becomes diluted and spatially unbundled to Tech HQs. Given the insights from the market structure, there is also the rise of a small set of cities that act as switching points or rather integrator of GDTNs and GFNs. It is the leading financial centres that have taken on that role and the mirror image of New York organized around IBM's actions, and London based on a wider FinTech ecosystem are two pathways by which that integration is organized geographically. Next to an extension of existing GFNs, the process of cloud adoption hence also relies on the rearticulated role of existing financial centres and hence a further intensification of their global primacy.

The nature of the process under study – cloud infrastructure dependence – suggests that we should qualify the traced GFN-GDTN entanglements in a different way than non-hierarchical networked processes of corporate globalization as studied in world and global cities research (Taylor and Derudder, 2016). For the reasons mentioned before, there is an emerging power imbalance between finance and technology firms that also plays out geographically. A situation of deep reliance on Big Tech infrastructure produces new obligatory passage points for global capital accumulation, as embodied in the HQ cities of Big Tech, or the here uncharted archipelagic geography of the actual data centres scattered across the globe. The question of where data is stored physically thereby becomes paramount since the location of data will potentially impact regulatory oversight into the abidance of data privacy and data protection laws. Further, financial regulators are concerned that getting hold of actual financial data for micro-prudential oversight may be encumbered, when data are not physically stored on the premises of the bank.

These and other geographical issues are shaping the contemporary geopolitical dimension of the charted interface of GFNs and GDTNs. Such geopolitical considerations are less of an issue per se for US banks that can rely on domestic Big Techs, even though data offshoring is also at play there, but ever more so for European banks, that seemingly by default are in the hands of American players, effectively placing them in the technological sphere of influence of the US. Despite Europe regulating data privacy and digital markets, it still has a long way to go to secure "technological sovereignty" over its financial data flows (Bassens and Hendrikse, 2022). For cloud interdependencies between European banks and American cloud providers can always be 'weaponized' (Farell and Newman, 2023) as has happened before when the privately run SWIFT (located in Brussels) was forced to give the US security services access to payments data as part of its strategy to combat terrorism financing post 9/11. Interestingly, moreover, our analysis also shows a great divide between China and the rest of the world, with US and European banks being extremely careful not to rely on their core infrastructure, and with only some piecemeal inroads by American players in the Chinese cloud market. In other words, the wider technological polarization that marks the present conjuncture (Farrel and Newman, 2019, 2023) clearly plays out within and between the world's competing cloud empires (Lehdonvirta, 2022). The implication is that GFN-GDTN entanglements are also producing new forms of segmentation.

6. Conclusions

It would be an understatement to say that the fields of regional studies and economic geography more widely has produced sharp analytical frameworks to understand how cities and regions are plugged into the global economy in distinct, variegated, and uneven ways. How such processes of regional integration are part and parcel of a wider geography of global uneven development has structured much of that shared agenda. But the ways in which this regional-global nexus has been approached, has become increasingly differentiated, much in line with the growing complexity of those very processes of regional-global integration in and of themselves. A rich tradition of GPN research building on cognate agendas (i.e. Global Value Chains and Global Commodity Chains) has centred on processes of production to analyze and explain uneven development (Coe and Yeung, 2015). Such frameworks hold significant explanatory power ever still.

The strength of any field lies, however, in its capacity to generate novel approaches that problematize existing frameworks, as well as finding ways to integrate, encompass, and augment them to enhance explanatory power. Over the past decades two processes have heightened the need for diversification. One such process is financialization, implying the growing power and influence of financial actors, narratives, metrics, and the like over economy and society. Regional studies has found productive ways to encompass such processes in existing frameworks. One path involved the integration of finance into GPNs (Coe et al., 2014), while giving shape to a blossoming agenda on the study of a distinct geography of GFNs (Haberly and Wójcik, 2022). Another path was situated in the world and global cities research tradition, where the original world city hypothesis was augmented to encompass the process of financialization (Bassens and van Meeteren, 2015). The result of such ventures has been the further institutionalization of financial geography as a distinct field that continues to seek the dialogue with economic geography, albeit not exclusively (Wójcik et al., 2023).

The second process entails digitization, and more specifically, the growing platformization of economy and society. There regional studies and economic geography has also found ways to integrate the growing relevance of such processes, for one by conceptualizing Digital Value Networks that primarily scrutinize the interface of the platform world and production (Howson et al., 2022). As with financialization, the field again shows great rigour and versatility in seeking ways to 'update' existing frameworks and engender novel ones that continue to speak to the original. But here, this paper argues, the work is not finished. Speaking from our background in studying financial geographies, and witnessing the growing platformization of finance, the paper identifies the need to further conceptualize the interface between the space constituted by GDTNs as they interface with the world

of finance. It has done so in an attempt to build conceptual bridges to inherited frameworks of GFNs (and world city networks more widely), GPNs, and DVNs. While this may invoke a level of conceptual 'dizziness', our point is that any serious attempt to critically unpack contemporary platform capitalism needs to have a clear view on what piece of the financialized and platformized global capitalism puzzle one is studying.

The paper has shown that GDTNs have much analytical purchase in distilling new patterns of regional interdependence across the global that have previously remained uncharted. The rising centrality of nodes that previously were taught to be crucial only in the realm of production – Silicon Valley first and foremost – suggest that our commonsensical maps of the world of finance are also being redrawn to encompass such tech valleys, as Big Tech is wielding significant infrastructural power in GFNs as well. The implication is not that the core dyad in GFNs – NYLON – is no longer the backbone of the global financial system, but – to stretch the metaphor – that this NYLON backbone is increasingly cast in a SILICONE mould. Amid platform finance, which has typically been seen as the leading actor in processes of financialization, appears to have become caught in the infrastructural webs of Big Tech, creating the structural conditions for rent extraction.

The current paper has given first evidence of that global finance and Big Tech interface in the hope that future studies may further scrutinize the underlying processes in more depth. This entails a more nuanced understanding of finance's infrastructural dependence on Big Tech, but also vice versa, of how Big Tech remains dependent on the expertise and money mobilized by the financial industry and the wider APS complex (Bassens et al., 2024). As for finance's dependence on Big Tech, we need more fine-grained understandings of where financial data is stored in a combination of actual data centres beyond the current HQ corporate control geographies. This is a highly demanding question, but we can observe a growing regulatory focus on data localization and data transfer between jurisdictions perhaps allowing a more precise localization of that infrastructural dependence. Further, we need more precision as to how cloud interfacing and other forms of tech dependence is embedded in financial firms. While HQ geographies give us a highly abstracted answer, the actual interfacing produces new divisions of labour across front and back offices (Santos, 2024). Future research should also investigate how commercial banks address the potential technological lock-in with their public cloud providers and whether the use of multi-cloud strategies can alleviate this concern.

Turning to the other side of the coin, future research needs to scrutinize the continued reliance of Big Tech on the financial industry and the wider APS complex. Amid financialization, Big Tech remains dependent on said complex to shape its offshore geographies and play the shareholder value game (Klinge et al., 2023). An emerging question here is to what extent offshore jurisdictions are also being transformed into data havens and the degree to which regulatory arbitrage as mediated by the APS complex also pertains to data offshoring strategies. Finally, with their rising infrastructural dominance the question of 'who owns Big Tech?' becomes an ever more pertinent and it is not unlikely that key financial centres remain crucial in gatekeeping investment and ownership into these infrastructural giants.

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