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Lessons from Innovation Economics for Digital Platform Policy

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Abstract

This paper relates to current concerns about the high concentration of digital platform markets and the effects of large companies such as Amazon, Facebook, Google, and Microsoft, on innovation. Several stakeholders and analysts assert that digital platforms have become so dominant that they slow the speed of innovation and that regulatory and antitrust intervention is needed to protect the public interest. Despite the strong claims, few systematic studies have examined the positive and negative effects of digital platforms on innovation. This paper seeks to contribute to closing this gap by pursuing three overarching objectives. First, it develops a theoretical framework to deepen our understanding of the multi-faceted relations between digital platforms and innovation. Second, it discusses which empirical evidence could be used to examine the multitude of potential, positive and negative, impacts. Third, the paper discusses the implications of these largely conceptual arguments for the design of policies toward digital platforms. In contrast to traditional regulatory theory and practice, which often uses static economic optimization models, much of innovation economics emphasizes that incentives to introduce new processes, create new products, services, designs, and business models are strongest in out-of-equilibrium processes. However, there are conditions under which market power and the interests of large companies do not align well with the broader goals of vibrant innovation. The paper argues that the most promising instruments to address these issues affect the constitution of digital markets.

Keywords: Digital platforms, innovation economics, innovation ecosystems, market power, regulation, competition policy

JEL Codes: L86, L96

1. Introduction

Concerns about the growing market power of digital platforms, their ability to manipulate digital markets, and the pervasive appropriation of personal data have greatly increased the willingness of national policy makers to regulate digital platforms and the Internet. One widespread belief is that concentration of major digital markets has increased to a level where it is impeding innovation directly and indirectly (e.g., Morton et al., 2019). A related, but somewhat more narrowly construed, assertion is that the dominance of digital platforms biases the direction of innovation to projects that benefit shareholder interests while devoting less attention to innovations that serve the public interest more broadly (e.g., Mazzucato, 2018). Although there is supporting anecdotal and case study evidence for both claims and growing public concerns (e.g., Knight Foundation & Gallup, 2020), systematic work investigating these issues is only starting and more efforts are needed to critically examine these potentially concerning outcomes, the conditions under which they might materialize, and what might be done to mitigate them.

This paper seeks to contribute to these efforts by pursuing three overarching objectives. It, first, develops a theoretical framework within which an examination of the multi-faceted relations between digital platforms and innovation can be positioned. Development of this framework builds on recent insights from research in innovation economics and innovation management and some of our own prior work (e.g., Bauer, 2019; Bauer & Bohlin, 2020). Innovation economics has drawn on computer science, management and other disciplines to explore different types of innovation (e.g., modular, architectural, incremental, radical, independent, interdependent), and it has examined the coordination needs of business processes in complementary innovation ecosystems, such as the digital economy and in innovation ecosystems more generally (e.g., Baldwin & Clark, 2000; Bauer & Knieps, 2018; De Meyer & Williamson, 2020; Hobday, 1998; Parker, Van Alstyne, & Choudary, 2016; Teece, 1992).

Second, the paper discusses which empirical evidence could be used to examine the multitude of potential, positive and negative, impacts. Innovation research has a long tradition of examining either input measures, such as the share of research and development (R&D) in total expenses of firms or sectors, or output measures, such as patents, possibly weighed by citations to capture their importance. Given the unique forms in which value is generated and appropriated in platform value systems, these measures will need to be critically reassessed as well.

Third, it discussed the implications for the design of policies toward digital platforms. The current techlash discussion quickly reaches recommendations, such as breaking up tech companies, the imposition of strict neutrality obligations, and the reliance on common carriage-like regulatory models. We critically examine these proposed policy solutions and discuss their strengths and limitations. In contrast to traditional regulatory theory and practice, which often uses static economic optimization models, much of innovation economics emphasizes that incentives to introduce new processes, create new products, services, designs, and business models are strongest in out-of-equilibrium processes (e.g., Dosi & Nelson, 2010; Fransman, 2010, 2011). We make a first step in translating these findings to the discussion about the market power of digital platforms, its potential positive and negative consequences, and how to mitigate undesirable effects.

The remainder of the paper is organized as follows. Section two provides a succinct overview of the innovation economics literature with an emphasis on how market power and competition affect innovation activity. Section three applies these insights to digital platform markets to identify conditions under which the desirable innovation properties of digital ecosystems might be compromised. The fourth section starts and exploration of measures to assess these effects empirically. It provides a quick overview of traditional measures of innovation activity and their challenges when applied to digital innovation systems. one option to empirically assess the potential positive and negative repercussions of digital platforms on innovation. We then explore an alternative approach that looks at the role of venture capital activity and venture capital funding as a proxy to assess the effects of dominant digital platforms on innovation activity. The fifth section explores preliminary implications for public policy and the concluding section reiterates main points of the paper.

2. The economics of complementary innovation

Innovation is traditionally defined as a new production process, product or service, organization, marketing method, or design (OECD, 2010; Stoneman, 2010, 1995). More generally, innovation is conceptualized as a creation of novelty that contributes to sustainable, efficiency increases (Antonelli, 2011). Digital technology greatly expands the role of software in the design of new products and services. It is more plastic than mechanical technology, allowing a larger set of technological combinations to produce output, and accelerates the speed of change by reducing the cost of innovation. Applications and services often require the joint input of functions by complementary layers of the digital innovation system, typically devices, networks, logical functions, and application software.

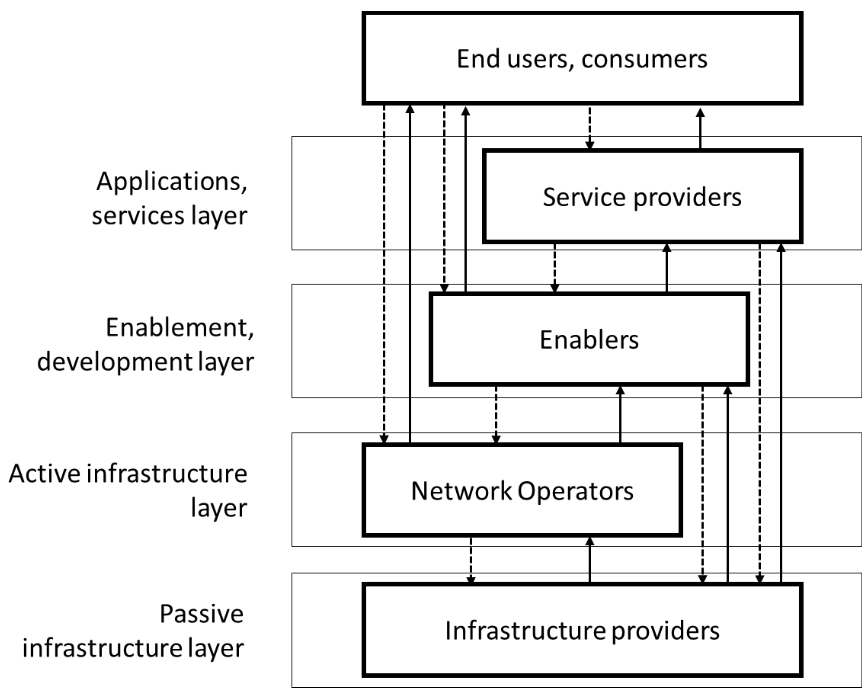
Innovation in these systems exhibits strong complementarities: innovation activities in one part of the interdependent system affect (i.e., increase or constrain) innovation activities in related parts. An early model of such innovation processes has been suggested by Bresnahan and Trajtenberg (1995). A vast research literature in strategic management and in management and information systems is recognizing the importance of complementarities (e.g., Cusumano, Gawer, & Yoffie, 2019; De Meyer & Williamson, 2020; Parker et al., 2016). Because of its dynamic nature, digital innovation often unfolds in the presence of fundamental uncertainty that necessitates that entrepreneurs and investors make decisions that are based on hunches and rough conjectures about the likely effects of a project on future firm values than on optimization of profits at the margin (Janeway, 2018). Evolutionary theories that emphasize the trial-and-error processes that lead to innovation offer a promising route to analyze innovation decision in these dynamic, uncertain conditions.

2.1 Value generation in platform markets

The term "platform" is widely used so that it may be helpful to conceptualize it clearly. From an engineering perspective, platforms are often seen as technical artefacts upon with products and services can be built. Intel semiconductors, the physical Internet, operating systems, and logical development environments such as Android or iOS would constitute prototypical platforms. From an economic perspective, the key attribute of platforms is that they facilitate transactions between affiliated parties that would otherwise not be feasible because the transaction costs in the marketplace are prohibitively high (Hagiu & Wright, 2015; Henten & Windekilde, 2016; Parker et al., 2016). A key function of platforms is to reduce the coordination costs and thus enable the realization of efficiency gains. Similarly, Cusumano et al. (2019, p. 13) explain that a key function of (industry) platforms is that "they bring together individuals and organizations so they can innovate or interact in ways not otherwise possible, with the potential for nonlinear increases in utility and value". That definition emphasizes the presence of multiple participants, the reduction of coordination costs, and the potential realization of network effects. Platforms are institutional innovations that allow the internalization of supply- and demand-side network effects in addition to the realization of economies of scale and scope. Cusumano et al. (2019, p. 18) differentiate *transaction platforms*, such as Airbnb, Uber, Alibaba, LinkedIn, and Salesforce Exchange, and *innovation platforms*, such as Amazon AWS, Apple iOS, Google Android, Steam, and ARM). Many companies pursue *hybrid* business models with a presence in both types of platforms. Our article focuses mainly on innovation platforms, even though many of the arguments can be generalized to transaction platforms.

Value generation in digital innovation platforms is typically organized in a multi-layered system in which functions from more than one of the layers need to be combined, often simultaneously, to enable an application or a service. A generic layered system of value generation is the Internet, upon which many of the digital platforms depend as one of the layers (see van Schewick, 2010). In specific innovation platforms, the layered structure may vary somewhat, depending on the industry segment. Authors have also used different approaches to distinguish layers (Fransman, 2010; Schultze & Whitt, 2016). Figure 1 is a simplified and abstract representation of the layered structure of a platform value system, using the example of 5G technology. Higher layers request functions from lower layers (represented by dotted arrows) but typically not vice versa. Higher layers receive services from lower layers (represented by solid arrows) but typically not vice versa.

Figure 1: Layers and interdependencies in a platform system



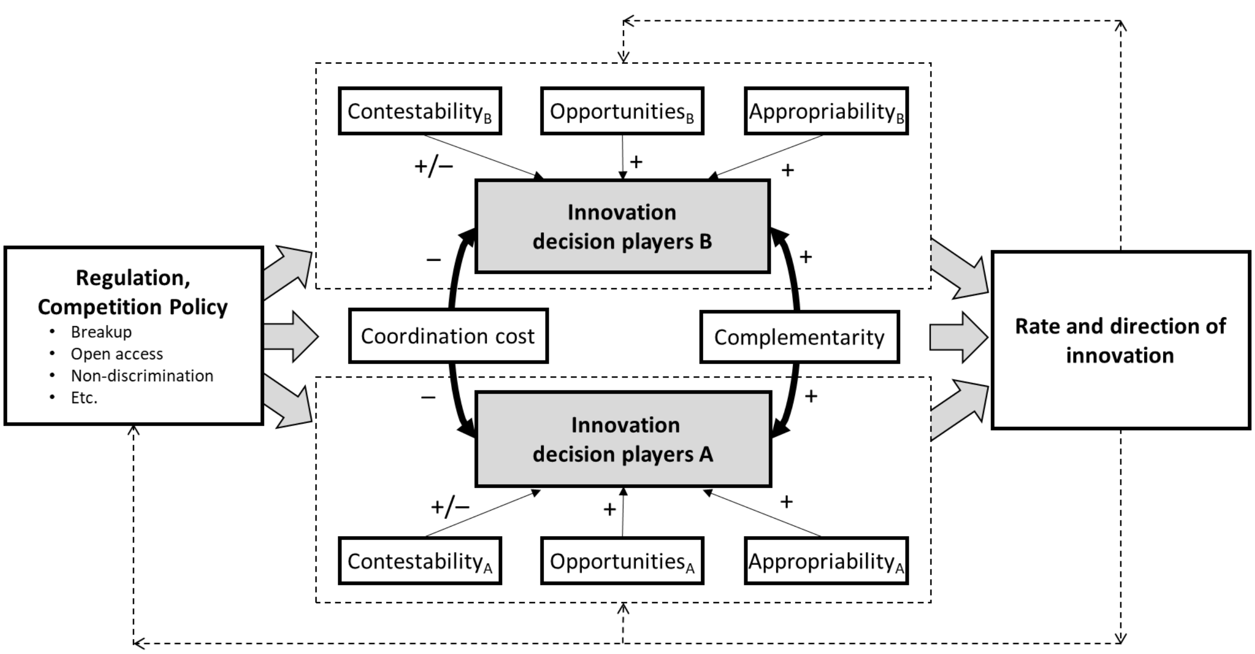
Source: Bauer and Bohlin (2020).

An important feature of the differentiation of functions at these layers and between stakeholders is the increased importance of interdependencies and feedback loops. Such feedbacks can be positive and negative, and each type may increase or decrease system performance. A form of a positive feedback loop that increases system performance are synergies between players. For example, if networked element providers design higher-performing components, network operators and application providers are enabled to enhance the quality of their services. At the same time, better services and applications create additional incentives for component manufacturers to improve components. An example of a negative feedback loop that increases system performance might be an algorithm that mitigates the spread of contagion. However, feedback loops work in both directions and may enhance or decrease overall performance. For example, if component manufacturers fail to upgrade their products, they constrain further improvements by players dependent on their services, possibly leading to overall deteriorating performance. One overarching challenge of platform governance and leadership is to orchestrate and align positive and negative feedbacks in ways that optimize performance of the entire system.

2.2. An evolutionary approach to innovation

Through an evolutionary lens, digital innovation is conceptualized as a succession of experimentation (typically a recombination of knowledge), real-time feedback on what works and does not work, the selection of a successful innovation in the market place or by other means (e.g., policy), and its scaling beyond an experimental stage (Antonelli & Patrucco, 2016; Brynjolfsson & McAfee, 2011; Nelson & Winter, 1982).

Figure 2: Factors driving innovation in platform systems



In this general framework, it is possible to identify common forces that shape innovation in digital platform markets (see Figure 2). At the firm level, innovation responds to conditions faced by individual players in their market segment. Particularly important are the competitive conditions, the technological and economic opportunities, and the conditions for the appropriation of innovation rents. In addition, interactions with players in complementary activities and how efficiently they can be coordinated influence innovation. From these interactions, the rate and direction of innovation at the sector level emerge.

Figure 2 offers a stylized depiction of the factors that influence the rate and direction of investment and innovation in this multi-layer, complementary system. To simplify, the multitude of layers is collapsed into only two (A and B), say network infrastructure including network services and enabling functions as well as applications and services, are distinguished. However, the model may be generalized to *n* layers. In each of the related layers, innovation decisions by players on that layer are propelled by the contestability of the market, the opportunities for innovation, and the appropriability conditions of extra profits by innovators. If the innovation activities in these layers are complementary, the interdependencies between players on the interrelated layers will also influence innovation activity. Two factors are at work that typically affect innovation activity in opposite directions, the strength of complementarities and the costs of coordinating the actions of players needed to realize them. Regulation influences this system directly and indirectly. It targets the decisions of selected players directly (e.g., by regulating prices of dominant providers, by separating business activities of platforms and applications) with the goal to improve performance of the system. In addition, these direct interventions have indirect effects on innovation by mediating the relations between innovation drivers (especially contestability, opportunities, appropriability, and coordination costs) and outcomes (the rate and direction of innovation) (see Bauer, 2019, for more details).

Economic theory suggests that a positive relation exists between innovation opportunities and innovation activity. Similarly, improved appropriability of extra profits by innovators, other things being equal, also increases innovation activity. The relationship between contestability and innovation activity is most likely an inverted, U-shaped relationship, even though the shape and strength of this relationship varies across sectors. Firms that are operating in a contestable market will seek to defend their market against emerging competitors. Likewise, in response to and to pre-empt competitive threats, they will seek to capture other existing markets or develop new ones. These incentives to innovate will be highest in workably contested markets. They will be low, but not necessarily absent, in uncontested or only weakly contested markets (e.g., monopolies or tight oligopolies). Innovation incentives will likely also be low in ultra-contested markets because any innovation can easily be imitated by competitors. Only in the rare case in which firms seek to escape intense contestability by pursuing a course of radical innovation may such markets exhibit strong innovation activity (Aghion, Bloom, Blundell, Griffith, & Howitt, 2005). More recent research has identified exceptions to this model, but the cases seem relatively special and seem to be contingent on certain production technology assumptions (Gilbert, Riis, & Riis, 2018; Hashmi, 2013). There is a lack of research of this relationship for digital platform markets and our paper attempts to make a first step to help clarify these relations for digital platform markets.

2.3 Interdependence, complementarity, and coordination costs

Recent contributions to research on innovation ecosystems suggest that interdependencies between players and systemic relations are exceedingly relevant in the digital economy (De Meyer & Williamson, 2020; Fransman, 2018; Iansiti & Levien, 2004). Two types of effects are particularly influential for the course and direction of innovation: complementarities and coordination costs. Complementarities link the innovation activities of each layer by influencing innovation opportunities of players at related layers. A higher (lower) rate of innovation in one layer will have positive (negative) spill-over effects on innovation on players in related layers. Thus, the factors that influence innovation on one layer will, indirectly, also affect innovation on the related layers (and vice versa). For example, more rapid innovation in network technology, manifested in a higher variety and quality of network services, will broaden the innovation opportunities of players in related layers. Similarly, a broader range of applications and services will likely increase innovation opportunities, appropriability, and possibly contestability at the network layer, thus providing additional stimulus for innovation at the network layer.[1] This effect may work in reverse so that weak innovation activity on one layer may constrain innovation activity at a related layer. An early model of such innovation complementarities was formulated by Bresnahan and Trajtenberg (1995) in their discussion of general-purpose technologies (GPT).[2]

Coordination costs include transaction costs among players and possibly the costs of adaptation of technology developed by one player to the requirements of the larger ecosystem. Because coordination

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[1] There is a counter argument to this logic. Because innovation sometimes is a solution to seemingly insurmountable constraints, there might be scenarios in which constraints beget additional innovation efforts. However, these effects are probably rarer than the potential, negative effects of constraining regulation on the rate and direction of innovation.

[2] It is too early to tell whether some platforms will be a GPT, but the general model developed by Bresnahan and Trajtenberg can be adapted to complementary innovation processes, which are widespread in platforms.

costs reduce the expected benefits of an innovation for profitability or firm value, they link innovation activities at interdependent layers in a negative feedback loop. Other things being equal, higher coordination costs reduce innovation activity, whereas lower coordination costs increase them. Coordination costs are not unique to the digital economy, but they are particularly relevant, given the increased differentiation of the value system. They have resulted in numerous market and non-market arrangements that facilitate coordination and reduce these costs. Such arrangements include contracts between businesses, standards and protocols, Internet exchanges, and digital platform companies, such as Apple and Amazon, which integrate an innovation ecosystem. Spulber (2019) distinguishes market-making costs from market-transacting costs. Both types matter in platform markets: the former during the early stages of innovation and the latter in more mature stages. Market-making costs will occur in negotiating and contracting for rights of way, network quality of service tiers, the development of application programming interfaces (APIs), and so forth. Market transaction costs will exist if, for example, after the initial, market setup application service providers (ASPs) need to negotiate with multiple platforms to launch their services on all of them. Adaptation costs may arise if an application/service needs to be adapted to run on different network protocols or if ASPs need to meet varying quality criteria required by different platforms for their affiliated partners.

There are reasons to believe that such coordination costs may be pervasive in platform markets, at least during the early phases of development and for certain innovations that require coordination among systems of systems (e.g., vertically integrated value systems in health care and automated vehicles). Private actors will succeed in coordinating their actions if the interaction is a common interest or a pure coordination game. They may not be able to find solutions in mixed interest games, in which one party can gain at the expense of another (Friedman, 1994).[3] Similarly, decentralized actors may not find solutions if the coordination costs are prohibitively high or some of the benefits have public good character.[4] It is possible that new types of systems integrators will emerge that coordinate across many complementary stakeholders. This has been discussed actively in 5G markets (e.g., Devlic et al., 2017) where such system integrators are envisioned as coordinating the resources for network slicing, and in other network markets where new operator platforms are expected to coordinate stakeholders (e.g., Knieps, in press). It is possible that a social learning process is involved so that it will become easier to

[3] An example of a mixed interest game is the interaction between a vertically integrated mobile network operator and single layer over-the-top (OTT) players.
[4] An example of high or even prohibitive transaction costs may be the need to negotiate rights of way (ROWs) with numerous municipalities and owners of buildings.

imitate a solution once one is found. Furthermore, it is possible that the architecture of a system can be modularized over time, so that decentralized coordination can replace more centralized approaches (if the core players relinquish their role). Regulation and public policy may be able to reduce coordination costs and help internalize benefits to levels at which a project will generate net benefits.

3. Innovation in digital platforms

3.1 The coexistence of multiple innovation types

The reasoning thus far shows the dynamic, most likely non-linear, character of the platform innovation system and its drivers. To fully appreciate the roles of platforms on innovation, it is important to recognize that platform ecosystems do not constitute one homogenous, innovation system. Given the versatility of digital technology, it is likely that multiple innovation processes (or "innovation technologies") will co-exist. The multiplicity of innovation types and processes, each with unique attributes, has been recognized in other industries (Breschi, Malerba, & Orsenigo, 2000; Malerba & Orsenigo, 1996). In platform markets, the most important innovation attributes are the magnitude and risk of innovations, the degree of their interdependence with related innovations, and their scope (Bauer, 2019). Some constellations of these dimensions will likely occur more frequently than others (e.g., modular innovations, architectural innovations, systemic innovations), creating a unique topology of the innovation opportunity space.

Based on the magnitude of change and risk involved, innovations fall on a spectrum that ranges from incremental to discontinuous. Incremental innovations affect only a limited number of attributes of a product or service. In contrast, discontinuous innovations (sometimes referred to as "radical" innovations) change many attributes simultaneously. Consequently, they are often riskier than incremental innovations. Entrepreneurs will pursue each type, if they have a reasonable expectation of appropriating a profit or increasing the valuation of the firm that is commensurate with the level of risk. Based on the extent to which novelty in one part of a system is influenced by novelty in other parts (Hobday, 1998), innovations fall on a spectrum from independent to tightly interdependent. This is a particularly important aspect of innovation in platform markets because innovations often have systemic character that require the coordination among multiple players. For example, cyber-physical systems that are part of smart cities are nested systems of systems.

Based on their scope, innovations may range from modular to architectural. Modular innovations affect only one element of a system and can be carried out by one player. Improvements of individual modules stimulate additional innovations in related modules, initiating a virtuous cycle of innovation that percolates through the system. These improvements require agreement on an overall architecture and interfaces between modules but do not require explicit coordination among innovators. However, modularity has limits, and the elevation of a system to a higher performance trajectory may require the restructuring of the architecture of the system once the opportunities for modular improvements have been exhausted (Yoo, 2016). Such architectural innovations require different types of coordination among the relevant players to redesign the overall structure of the system. Many envisioned platform innovations, for example, those supporting autonomous vehicles or advanced health applications, will likely require such architectural efforts.

These innovation types coexist in many platform systems, yet they thrive under different conditions. Platform governance as well as market and regulatory design will influence whether and at which intensity these types of innovation will be explored. For example, an open network architecture and standardized connectivity platforms facilitate modular, incremental, weakly interdependent innovations. In contrast, a framework that allows the differentiation of platforms, creation of toll gates to collect fees, the differentiation of prices, and contractual arrangements will be better aligned with the requirements of architectural, discontinuous, tightly interdependent innovations. As will be discussed in more detail in section five, traditional conditions for regulatory intervention, such as the prevalence of market power and dominance, remain relevant but the threshold for intervention may be different than in traditional markets. For example, non-myopic MNOs will recognize innovation complementarities and set prices and service qualities for network services accordingly, even if they are dominant market players. This is particularly true during the early market development stage. Regulatory intervention during that phase may weaken incentives to exploit innovation opportunities that require exploratory business models.

At the same time, the interdependencies in the value system may give rise to systemic forms of market power and market deficiencies that provide new rationales for regulation. For example, under certain conditions, mandated reference offers for interconnection or interoperability requirements may significantly reduce coordination costs and expand innovation opportunities for players on higher layers. Such interventions would be welfare-enhancing if their total benefits outweighed their total social costs. However, it may be difficult to establish with confidence ex ante whether this condition is met. One of the challenges for forward-looking platform policy, therefore, is the creation of an investment and innovation climate that supports the coexistence of these multiple types of innovations. Any market design must therefore create conditions that allow enough flexibility to pursue multiple types of innovation.

3.2 Platform power and innovation

For the sake of this section, we assume that platforms are positioned on layer A in Figure 2 above. Innovation decisions by the platform affect the rate and direction of innovation on layer A. They also affect innovation by players on layer B that offer complementary services. Innovation performance of digital platforms can be assessed in multiple ways. It could be measured across all digital platforms, the ecosystem of digital platforms, that are, broadly defined, offering digital economy services. Innovation performance could also be measured more narrowly by looking at one platform ecosystem. We will initially focus more narrowly on the latter aspects.

Platforms build technology systems and tools that complementors use to create additional value. The speed and direction of platform innovation will be influenced by the level of contestability of the platform market, the technological and market opportunities to innovate, and the appropriability of innovation premiums. Although platform markets are principally contestable (see Google's notorious claim that "competition is only one click away"), the dominant platforms have built systems that are not easy to replicate. The sources of competitive advantage vary across platforms. For example, the large number of users and their social graphs as well as the direct and indirect network effects the company was able to build are formidable barriers to entry into Facebook's market. The strong position in the search market has allowed Google to improve its search engine more rapidly than its competitors. Amazon benefits from the vast range of products and the product search services it can offer to its users. All these and other platform players can derive revenues from multiple direct and indirect sources, with Facebook and Google occupying strong positions in the online targeted advertising markets.

These multifaceted and multi-layered business ecosystems are extremely difficult to challenge by competitors. At the same time, their dominant position must not be taken for granted. To sustain and further grow their strong market position, these companies commit significant resources to research and development and to explore potential new directions for service provision. Like Bell Labs during the time of the AT&T monopoly, the research organizations generate valuable outcomes (Gertner, 2013).

However, two concerns arise and are difficult to confirm or disprove: that the innovation opportunities pursued by platforms are not diverse enough and that the platforms may withhold innovations from the marketplace and/or complementors. Historical experiences in telecommunications provide examples of both scenarios (e.g., Temin & Galambos, 1987). The first concern relates to the relatively small number of platforms. In an evolutionary view, innovation is an exploration of "adjacent possibilities", a combination and recombination of existing and new knowledge. Since it is not known in advance which innovation experiments will succeed, the vibrancy of innovation typically increases with the number of alternative directions that are being explored. Given the limited number of platforms and their awareness of their strategic interdependence, the high concentration in platform markets may result in a sub-optimally low diversity of innovation experiments. However, it is extremely difficult to verify that conjecture because we do not know which potential innovations were not pursued or missed.

The second set of concerns relates to how platforms relate to players on complementary layers. Recent research on innovation ecosystems emphasizes that platforms have the potential, but do not automatically, improve the innovation activity in the entire interrelated ecosystem (e.g., Fransman, 2018; Parker et al., 2018; Cusumano et al., 2019; De Meyer & Williamson, 2020). Williamson and De Meyer (2012, p. 33) emphasize six critical areas that platform management will need to address to build highly preforming ecosystems: (1) pinpointing the added value, (2) structuring differentiated partner roles, (3) stimulating complementary partner investments, (4) reducing transaction costs, (5) enabling flexibility and co-learning, and (6) engineering value capture mechanisms. There are many ways in which platforms can fail to find a good balance between these areas. For example, in pursuit of profitability and growth in firm value, especially in market where the platform holds a dominant position, management may be inclined to design a value capture mechanisms that extracts a high share of the value generated by ecosystem partners and thus reduce incentives for complementors to innovate.

Well-designed, platforms are institutional solutions that unlock new forms of value co-creation. They allow to reduce coordination costs in ecosystems of related players. Since coordination costs are inversely related to innovation activity in complementary innovation processes, platforms that succeed in mitigating such costs will, other things being equal, stimulate innovation among complementors. Innovation by complementors is further enhanced it platforms design their systems to strengthen synergies between the platform and affiliated partners, for example, by offering transparent business and technical conditions for business partners or by offering additional development tools. Similarly, platforms provide business opportunities for complementors that they might otherwise not have, such as access to a large user base, again increasing innovation incentives. Platforms can design rules of affiliation in ways that create competition among complementors in ways that boost innovation. Finally, they could design financial transactions with complementors in ways that offer a level of appropriability that optimizes innovation among complementors. Another important way in which platforms can affect the appropriability conditions of complementary innovators is by contributing to the capitalization of projects via venture capital financing, an aspect that we will examine in more detail empirically.

As the research on platform management points out, these are complicated management decisions and in each of these cases, the right balance between platform interests, complementor interests, and the health and vibrancy of the entire ecosystem needs to be found. It is possible to approximate such a balance in a process of trial and error. However, it is also possible that management acts myopically and biases the entire governance structure in ways that serve short-term platform interests at the expense of the entire innovation ecosystem. Management could err on the side of creating overly restrictive technical access conditions (reducing the extent of realizable complementarities), it could claim an excessive revenue share, or it could make coordination complicated by offering fewer standardized features. Innovation research has provided evidence that there is an inverse U-shaped relationship between the intensity of competition and innovation activity (e.g., Aghion et al., 2005). More recent research has narrowed the conditions under which this non-linear relationship is likely to hold (e.g., Gilbert et al., 2018; Hashmi, 2013) but there is also additional supportive evidence from network industries and telecommunications (Katz & Callorda, 2018). Given the unique system of positive and negative feedbacks in platform ecosystems, it seems likely that such non-linearities characterize the relationships between platforms and complementors. Perceptive management would not need to know the shape of the entire non-linear relationship to find the optimal balance. If it knows the gradient of changes, for example, that easier access might increase or decrease overall innovation efforts, it could approximate an optimal balance via trial and error. Enlightened management that understands the logic of innovation ecosystems will indeed pursue such strategies but for external observers it may not be possible to establish whether a myopic or an enlightened management strategy is being played.

There are additional concerns that are raised by dominant platforms. One is that they will defend their established markets using strategies that will quench innovation. An aggressive strategy of mergers and acquisitions pursued by dominant platform is one observation that nourish such fears. Another one is alarm about “kill zones” for start-ups that are created by the unlikely success of directly competing against a big and resourceful digital platform. Such reasoning might undermine adoption by customers and reduce interest by venture capitalists, who stay away from funding such start-ups (Kamepalli, Rajan, & Zingales, 2020). Another strategy is that dominant platforms may use their strong presence in advertising markets to starve potential competitors from developing a sustainable revenue stream (Prado, 2020).

Overall, theoretical considerations reveal strong potential positive and negative effects of platforms on innovation activity in the broader platform ecosystem. It is possible that different platform governance approaches will result in different overall net effects and different patterns of support and impediment for innovation. More empirical research that allows assessing these effects in a nuanced way is desirable. We will turn to one possible approach in the next section by examining venture capital activity and platform involvement in start-ups.

4. An empirical assessment of platform effects on innovation

Venture capital is defined as "equity or equity-linked investments in young, privately held companies, where the investor is a financial intermediary who is typically active as a director, an advisor, or even a manager of the firm" (Kortum & Lerner, 1998, p. 3). The research literature provides evidence of a close relationship between innovation and venture capital. A positive, causal association between venture capital activity and patenting activity has been found in several studies (Da Rin & Penas, 2007; Faria & Barbosa, 2014; Kortum & Lerner, Winter 2000). Recent studies have also supported the key role played by venture capital in enabling small and medium-sized start-ups, innovation, and growth (Imarhiagbe, Saridakis, & Smallbone, 2019).

Informational asymmetries and uncertainties are frequently associated with start-up activity. As in any risk-seeking financial activity, however, venture capitalists (VCs) presumably want to make informed and rational investment decisions that optimize expected profits. Giving a plethora of start-up firms from various industry sectors, venture capitalists' investment decisions are reportedly more related to factors like time to scrutinize firms and expertise on their industry niche than cash availability (Gompers & Lerner, 2001; Sørensen, 2007).

To mitigate search costs and time, as well as the risks associated with venture investing, VCs frequently syndicate with other VCs (Hochberg, Ljungqvist, & Lu, 2010). There is empirical evidence showing that, to limit the risk that bad deals get funded, even experienced venture capitalists value a "second opinion" of other VCs with a similar level of expertise (Lerner, Autumn 1994). Digital platforms are among the leading providers of venture investment. For example, measured by the number of deals, Google was the fourth-biggest venture investor from 2015-2019 and the eight-largest investor from 2010-2019, contributing to 345 deals and 545 deals, respectively. Among deals with a funding value above the median of $7.5 million, Google's leading position is even stronger, with the company ranking seventh and third. Other digital platform companies also have been active in venture investments. Since 2010, Microsoft participated in 113 deals above $7.5 million and Apple in 62 deals.

The reputation, wide and diverse market presence, investments in R&D, and reportedly intense venture capital activity during the last ten years begs the question of whether they significantly affect other VCs' investment decisions. Do platforms' venture-capital investments in specific industry sectors drive other venture capitalists to invest in startups in the same niches? Does the presence of a platform in a deal attract more funding to a deal? Does the presence of a platform in a deal attract more venture capitalists to that deal? To investigate such questions and so provide empirical evidence of the impact of platform venture decisions on overall venture capital activity, a proxy for innovation, we examine available data of venture-capital activity from 2010 to 2019.

Our analysis is based on data collected by CB Insights.[5], This database contains approximately twenty-four thousand venture capital deals that took place between 2010 to 2019 whose value exceeded $7.5 million[6]. This data set represents 40% of the total number of venture capital deals in this period and 92% of the total value of $1.1 trillion funded by venture capitalists during the same period. We are limited to a subset of data due to use conditions imposed by CB Insights. Whereas the focus on the upper half of the number of deals limits our analysis, it has the benefit of avoiding including very small deals in the estimation. The table below contains selective descriptive statistics about the dataset.

[5] https://www.cbinsights.com

[6] Median of the value funded per deal, calculated among all venture capital deals from 2010 to 2019.

Table 1 - Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
amount	24,428	39.14538	142.59	7.5	14000
n_new_invest	24,428	3.868266	2.691216	1	92
platform_part	24,428	.0285738	.1666087	0	1
usa	24,428	.6063124	.488577	0	1
china	24,428	.1379564	.3448613	0	1
other_c	24,428	.2557311	.4362803	0	1
internet	24,428	.4326183	.495449	0	1
mobtel	24,428	.1356231	.3423949	0	1
healthcare	24,428	.1850336	.3883327	0	1
software	24,428	.0537089	.2254469	0	1
other	24,428	.1930162	.3946737	0	1
phi	24,428	5.688963	6.13285	0	93
y2010	24,428	.0458081	.2090729	0	1
y2011	24,428	.0612412	.2397771	0	1
y2012	24,428	.0569429	.2317381	0	1
y2013	24,428	.0642296	.2451665	0	1
y2014	24,428	.0900606	.2862744	0	1
y2015	24,428	.1117979	.3151241	0	1
y2016	24,428	.1063124	.3082434	0	1
y2017	24,428	.1312019	.3376279	0	1
y2018	24,428	.1639103	.3702017	0	1
y2019	24,428	.1684952	.3743131	0	1

In Table 1, *amount* accounts for the total amount of funding invested in each venture capital deal (in US$ million); *n_new_invest* shows the number of venture capitalists that syndicate in each deal; *platform_part* accounts for the participation of Google, Facebook, Apple, Microsoft and/or Amazon among the investors in a deal; *usa* accounts for the presence of the startup's headquarter (HQ) in the United States, the home-country of many venture-capitalists, assuming a value of 1 if the HQ is located in the United States and 0 else; *china* accounts for the presence of the startup's HQ in China, assuming a value of 1 if the HQ is located in China and 0 else; *other_c* accounts for the presence of the startup's headquarter in any other country but the United States and China; *internet* tells if the startup plays in the Internet economic sector, the most popular niche sector among startups and venture capitalists in the past decade; *mobtel* accounts for the mobile telecommunications sector; *healthcare* accounts for the healthcare sector; *software* accounts for the non-internet and non-mobile-telecommunications software sector; other accounts for any other industry sector; *phi* represents the number of firms that already had private equity of each startup before each deal; and, finally, the *year* dummies show the distribution of such deals throughout the last ten years.

Table 1 reveals that only 2.86% of the VC deals in the last 10 years had a presence of the big techs. Surprisingly, the distributions of the number of deals by industry sector made by platforms and by other venture-capitalists are quite similar, as it can be seen in the graphs below. Such similarities suggest a relationship between the decisions made by the five digital platforms and the other venture capitalists worthy to be explored further.

Figure 3: Deals per industry sector

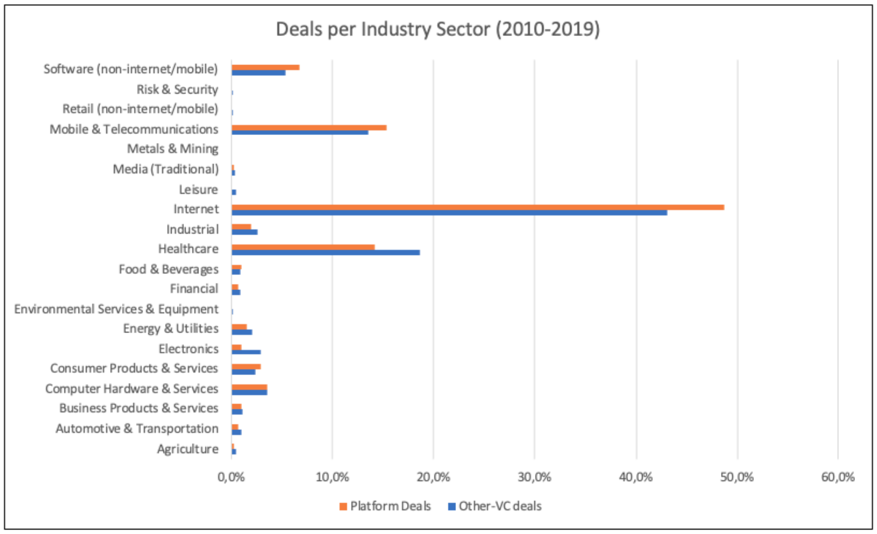


Figure 4: Deals per industry sector

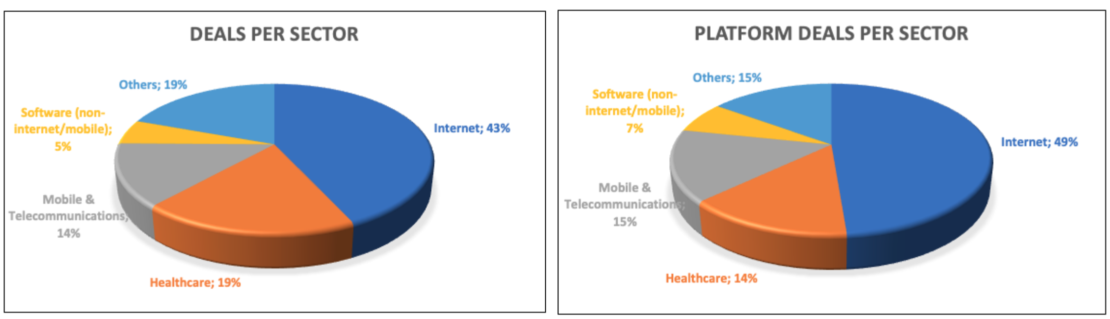
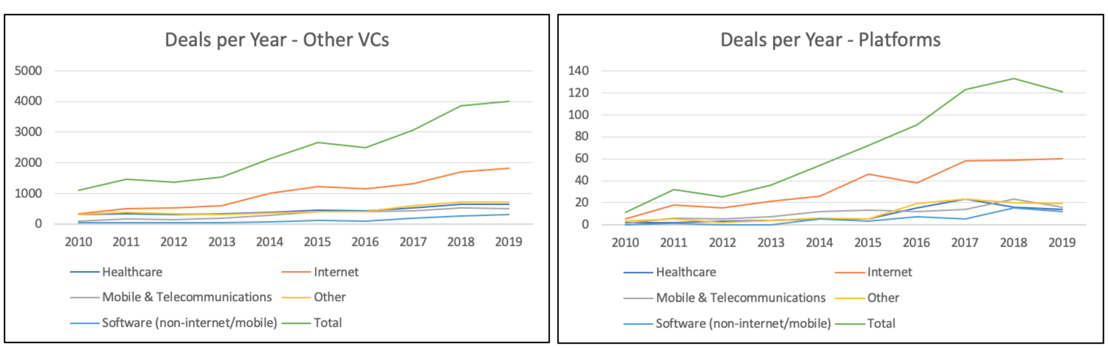


Figure 5: Deals per industry sector per year



To do so, we made use of econometric analysis to examine these patterns of investment and the role of digital platforms. First, we examine the patterns of quarterly deals per sector to understand whether venture-capital investments by digital platforms in specific industry sectors drive other venture capitalists to invest in startups in those sectors. Second, we analyze the patterns of funding and the composition of investors per deal to explore if the presence of a platform in a deal attracts more funding to the deal and more investors to syndicate in the deal.

4.1 Analysis of quarterly venture capital deals per sector

To empirically investigate whether the venture-capital investments of digital platforms in specific industry sectors drive other venture capitalists to invest in startups in these sectors, we modeled the factors influencing the quarterly number of venture capital deals by relevant sector from 2010 to 2019 (see Figures 4 and 5). We were particularly interested whether the number of deals in which venture capitalists other than the digital platforms participated could be explained as a function of deals realized by the five digital platforms, after controlling for other sectoral and time factors. The tables bellow present summary statistics of the variables, their correlation matrix, as well as the results of the ordinary least squares (OLS) regressions, performed using six different model specifications (labeled one to six).

The first model includes dummy variables to control for the main sectors and also a constant to capture the effect of the internet sector, given that it is highly colinear with the number of deals made by platforms (*n_deals_plat*), as can be seen in Table 3. The second model builds on model one and includes dummy variables for years, to isolate unobserved effects, such as economic cycles, on the number of venture capital deals per sector. The third model repeats the first model but considers a one-quarter-lagged variable of the number of deals made by platforms (*lag_n_deals_plat*), to investigate the existence of a stronger relationship between the sector's choices made by the platforms in the past quarter when compared to the same quarter, as suggested by the correlation matrix below. Finally, models four to six builds on the first three models but swap the positions of the key variables of interest by regressing the number of deals per sector made by platforms (*n_deals_plat*) as a function of the number of deals made by other VCs (*n_deals_vc*) and its one-quarter-lagged variable as well (*lag_n_deals_vc*). The objective of including these three last models is to investigate the direction of the relationship between the variables *n_deals_vc* and *n_deals_plat*.

Table 2: Analysis of deals per quarter per sector - descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
n_deals_vc	686	34.59184	70.48091	1	518
n_deals_plat	686	1.017493	2.670682	0	23
internet	686	.058309	.2344979	0	1
mobtel	686	.058309	.2344979	0	1
healthcare	686	.058309	.2344979	0	1
software	686	.058309	.2344979	0	1
other	686	.7667638	.4231999	0	1

Table 3: Analysis of deals per quarter per sector - correlation matrix

	n_deal~c	lag_n_~c	n_deal~t	lag_n_~t	internet	mobtel	health~e	software	other
n_deals_vc	1.0000								
lag_n_deal_vc	0.9865	1.0000							
n_deals_plat	0.8794	0.8607	1.0000						
lag_n_deals_plat	0.8879	0.8784	0.7925	1.0000					
internet	0.7866	0.7788	0.7208	0.7037	1.0000				
mobtel	0.1562	0.1563	0.1562	0.1537	-0.0666	1.0000			
healthcare	0.2627	0.2652	0.1086	0.1102	-0.0666	-0.0666	1.0000		
software	-0.0187	-0.0210	0.0109	0.0089	-0.0666	-0.0666	-0.0666	1.0000	
other	-0.6633	-0.6590	-0.5569	-0.5458	-0.4473	-0.4473	-0.4473	-0.4473	1.0000

Table 4: Analysis of deals per quarter per sector – results

Variable	Model_1	Model_2	Model_3	Model_4	Model_5	Model_6
n_deals_vc	(DV)	(DV)	(DV)	.03585287***	.03443506***	
n_deals_plat	13.84573***	12.703131***		(DV)	(DV)	(DV)
lag_n_deals_vc						.03229329***
lag_n_deals_plat			14.266537***			
mobtel	-93.414051***	-100.18395***	-95.13409***	.36538615	.11663147	-.54069329
healthcare	-55.816186***	-63.15738***	-58.370047***	-1.2344007***	-1.439664***	-2.0223126***
software	-120.79931***	-129.31167***	-122.69839***	.57925038	.26173194	-.5282207
other	-129.81228***	-139.95975***	-131.70243***	.39956633	.04362379	-.8520944
y2010		(omitted)			(omitted)	
y2011		1.5376685			.17837083	
y2012		1.3951111			.11743851	
y2013		1.8082255			.19697404	
y2014		7.2141076			.16582916	
y2015		11.218948**			.17054485	
y2016		6.0302712			.52490025*	
y2017		8.1426078			.68808854**	
y2018		16.539551***			.43838949*	
y2019		20.225386***			.22145685	
_cons	135.78444***	138.25673***	137.9994***	-.51220109	-.42007912	.77445849
Adj_r2	.88317955	.88972132	.89969412	.78931883	.79180016	.75618778
N	686	686	625	686	686	625

legend: * p<0.05; ** p<0.01; *** p<0.001

The results presented in Table 4 confirm the strong correlation between the sector choices made by the digital platforms and by other venture capitalists, with stable coefficients among the first three regression models and high adjusted R-squared. It is possible to notice that the addition of dummy variables for the years (Model 2) does not present a meaningful increase to the results of Model 1. A careful analysis of the correlation matrix presented in Table 3 also suggests that the platforms' sector choices in the past would explain slightly better the sector choices made by other venture capitalists. Indeed, as per the results of the regressed Model 3, we found a highly significant relationship between the variables *n_deal_vc* and *lag_n_deal_plat*, and a slightly higher adjusted R-squared when compared with Model 1.

The results presented so far support the hypothesis of a strong correlation between the sector choices made by venture capitalists and digital platforms, even though venture investments made by the big five digital platforms considered represent less than 3% of the total number of deals between 2010 and 2019. However, the analysis would benefit from additional empirical evidence to corroborate a causal relationship between the choices made by both groups. While the results discussed so far suggest that venture capitalists are attracted to invest in startups playing in industry sectors which recently received venture investments from digital platforms, the data also suggests that the venture investments of digital platforms are driven by the sector choices made by the myriad of other venture capitalists.

Aiming at providing first empirical evidence to support a directional correlation between the sector choices made by the two groups of investors, Model 4 regressed the number of deals per sector made by platforms (*n_deals_plat*) as a function of the number of deals made by other VCs (*n_deals_vc*) and other controlling variables. The results found suggest a weaker explanatory performance when compared with Model 1 results, with an adjusted R-squared of 0.79 and 0.88, respectively. The addition of dummy variables for the years (Model 5) does not present meaningful performance increase with respect to Model 4's results, as also seen when we compared Models 1 and 2. Finally, Model 6 includes a one-quarter-lagged variable of the number of deals made by other VCs (lag_*n_deals_vc*), resulting in the model with weaker explanatory power among all the six models.

Such findings thus support the hypothesis of a great influence of platforms' venture capital decisions on the overall venture capital activity in the past decade and show the great influence of such platforms on innovation patterns. Thus, a key finding of the six models is a pattern of asymmetric interdependence of venture investments made by digital platforms and other venture capitalists, what suggests a stronger effect of platforms' venture investment decisions on other VCs than the opposite direction.

4.2 Analysis of funding and investors per deal

In order to empirically investigate whether the presence of a platform in a deal attracts more funding to the deal and/or more investors, we modeled the total amount of funding per deal and number of investors syndicated per deal from 2010 to 2019 as a function of the presence of a digital platform among the investors, as well as some controlling variables. The tables bellow present summary statistics of the variables, their correlation matrix, as well as the results of the OLS regressions performed using four different models labeled from seven to ten.

The seventh model regresses the log-transformed number of new investor per deal (*log_new_invest*) with respect to the presence of a platform among the investors (*platform_part*), the base-country of the startup targeted by the deal (*usa*, *china* or *other_c*), and the number of previous investors who compound the private equity of the startup (*phi*). Model 8 repeats the variables of model six and includes controlling dummy variables for years, to isolate the effect of economic cycles on the number of investors per deal. Model 9 regresses the log-transformed amount of funding provided in each deal with respect to the log-transformed number of new investor per deal (*log_new_invest*), the presence of a platform among the investors (*platform_part*), the base-country of the startup

Table 5: Analysis of funding and investors per deal - descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
amount	24,428	39.14538	142.59	7.5	14000
log_amount	24,428	3.060435	.8619405	2.014903	9.546813
n_new_invest	24,428	3.868266	2.691216	1	92
log_new_invest	24,428	1.13493	.6799042	0	4.521789
platform_part	24,428	.0285738	.1666087	0	1
usa	24,428	.6063124	.488577	0	1
china	24,428	.1379564	.3448613	0	1
other_c	24,428	.2557311	.4362803	0	1
phi	24,428	5.688963	6.13285	0	93
y2010	24,428	.0458081	.2090729	0	1
y2011	24,428	.0612412	.2397771	0	1
y2012	24,428	.0569429	.2317381	0	1
y2013	24,428	.0642296	.2451665	0	1
y2014	24,428	.0900606	.2862744	0	1
y2015	24,428	.1117979	.3151241	0	1
y2016	24,428	.1063124	.3082434	0	1
y2017	24,428	.1312019	.3376279	0	1
y2018	24,428	.1639103	.3702017	0	1
y2019	24,428	.1684952	.3743131	0	1

Table 6: Analysis of funding and investors per deal - correlation matrix

	log_am~t	log_ne~t	have_p~m	usa	china	other_c	phi
log_amount	1.0000						
log_new_invest	0.1696	1.0000					
platform_part	0.0856	0.1241	1.0000				
usa	-0.0707	0.0957	0.0940	1.0000			
china	0.1739	-0.1377	-0.0641	-0.4941	1.0000		
other_c	-0.0555	-0.0007	-0.0558	-0.7390	-0.2206	1.0000	
phi	0.2449	0.0929	0.0899	0.1219	-0.0940	-0.0622	1.0000

Table 7: Analysis of funding and investors per deal - results

Variable	Model_7	Model_8	Model_9	Model_10
log_new_invest	(DV)	(DV)	.22403086***	.21091706***
log_amount			(DV)	(DV)
platform_part	.44549368***	.42995312***	.29816706***	.26706226***
usa	1.1231437***	1.0533895***	2.5232697***	2.3797083***
china	.86801058***	.77767761***	3.0742872***	2.8805416***
other_c	1.0858402***	.99946538***	2.5348388***	2.3462598***
phi	.00769802***	.00814841***	.03434918***	.03577949***
y2010		.00849334		-.03934741
y2011		.02116171		.01438672
y2012		(omitted)		(omitted)
y2013		-.02189036		-.03076356
y2014		.03059237		.08252205**
y2015		.08142264***		.18312318***
y2016		.08323891***		.13410646***
y2017		.09413119***		.17082399***
y2018		.11777276***		.2949979***
y2019		.1310697***		.35372989***
Adj_r2	.74588155	.74708942	.93624989	.93782375
N	24428	24428	24428	24428

legend: * p<0.05; ** p<0.01; *** p<0.001

targeted by the deal (*usa*, *china* or *other_c*), and the number of previous investors who compound the private equity of the startup (*phi*). Finally, Model 10 repeats the variables of Model 9 and includes controlling dummy variables for the years.

While the correlation matrix presented in Table 6 shows a weak correlation between the presence of a digital platform in the deal and the amount of funding raised or the number of investors which syndicated in each deal, the regression results presented in Table 7 denote a statically significant relationship between these variables. The regression of Models 7 and 8 resulted in stable coefficients for the variable *platform_part* and satisfactory adjusted R-squared, which suggests the relevance of the designed models to explore the phenomenon studied. More importantly, the results of such regression models suggest that the presence of at least one of the five big digital platforms among the investors in a venture capture deal increases the number investors in approx. 45%. Such a strong impact supports the hypothesis that venture investment decisions made by the big digital platforms significantly affect other VCs' investment decisions and innovation.

Similarly, Models 9 and 10 shown stable and highly statistically significant coefficients for the variable *platform_part*, as well as high adjusted R-squared, showing the relevance of the models to explain the amount of funding provided in each venture capital deal. The results of such regression models also suggest that the presence of digital platforms increases in approx. 30% the funding amount per deal, adding one more empirical evidence supporting the hypothesis that venture investment decisions made by the big digital platforms significantly affects other VCs' investment decisions and, consequently, the innovation patterns.

4.3 Limitations and next steps

The approach outlined in this section contributes empirical research examining the influence of digital platforms on innovation. Our work focuses on whether digital platforms driving funding and investors to the industry sectors and startups in which they have chosen to invest. These decisions primarily affect two of the five drivers of complementary innovation, appropriability and opportunities. The number of venture capital deals about $7.5 million has been increasing year over year in in most sectors during the past decade. The data shows a strong asymmetric interdependence between investments by digital platforms and other venture capitalists and a clear pattern of parallel development. This could be interpreted as evidence of platforms exerting influence over the direction of innovation. However, the data does not allow the conclusion that digital platforms reduce innovation in the subset of ventures we studied. At the same time, given that our data does not include deals below $7.5 million we cannot tell whether, overall, digital platforms boost or quench innovation activity. Such a broader assessment would also require systematic information on ventures that were not funded at all.

Some authors have suggested the existence of kill zones, that is industry segments in which the presence and strategic interests of digital platforms discourage venture investments from other venture capitalists (Hylton, 2019; Kamepalli et al., 2020). our analysis at the sector level does not support such a claim. Instead, it shows a positive impact of the venture investments made by digital platforms in aggregated industry sectors on the appetite of other VCs to also invest in startups of such sectors. These results corroborate other research that found positive impacts of platforms acquisitions and venture capital investments on innovation (e.g., Foerderer, Kude, Mithas, & Heinzl, 2018). However, our present analysis could not fully assess this claim. We are building a more comprehensive dataset to expand our analysis. An expanded dataset would also allow to identify if the pace of venture investment has slowed in specific industry niches due to an increase or a decrease of platform investment and acquisition activity.

Having found a strong and asymmetric correlation between venture investments made by digital platforms and other VCs, next steps in this research agenda include (i) a further unpacking of the relationships between venture capitalists and digital platforms investment decisions, examining additional factors that influence the decision-making process followed by venture capitalist before a deal; (ii) a framework to examine in more detail the existence of kill zones created by digital platforms investment and acquisitions; and (iii) efforts to assess the net economic impact of the multiple positive and negative influences of digital platforms on innovation.

5. Preliminary policy implications

The preceding sections have reviewed the recent literature in innovation economics and management that highlights the conditions under which innovation ecosystems work well. We also examined empirical evidence from venture capital markets to assess whether there is evidence that platforms systematically bias the innovation systems they orchestrate. Our conceptual analysis suggests platforms have many ways to enhance innovation performance that this is typically aligned with self-interest. This is corroborated by empirical observations that show that some ecosystem leaders succeed in orchestrating the entire system of interrelated players in ways that enhances innovation activity while enabling participants to build sustainable business models. However, this conclusion does not necessarily hold in all cases. It might be a risky strategy to rely on the ability of platform management to act non-myopically. Moreover, the problem of aligning innovation activities that emerge from the platform ecosystem with social goals will not necessarily be addressed in such an approach. In these conditions, what would appropriate policy measures be? Is it reasonable to assume that government agencies would have the savvy and knowledge necessary to address these challenges? Would case-by-case approaches best be suited to address the policy challenges?

Providing answers to these questions will require more empirical and theoretical work. However, we believe that our analyses allow sketching a first set of policy implications. One challenge is the coexistence of multiple innovation types in platform ecosystems. If all or most innovations could be architected as modular engineering and business problems, a policy of structural separation or even breakup of dominant platforms may not have a strong negative effect on innovation activity in the overall system. In this scenario, coordination tasks could be effectively addressed by the modular architecture and the complementarities could be realized in decentralized entrepreneurial processes. However, if this is not the case, and non-modular innovations are important, as they seem to be in critical areas of digital infrastructure and services, such interventions may have considerable costs by impacting innovation negatively. Moreover, even though there is considerable concern about the strong market position of digital platforms, there is equal resistance in the population for government intervention and regulation (Knight Foundation & Gallup, 2020). This suggests that the space of policy options will also be limited by political considerations. What, then, is to be done, given that the concerns about platform dominance are also real?

Several of the options that are currently being discussed (Crémer, de Montjoye, & Schweitzer, 2019; Khan, 2016; Morton et al., 2019) have been applied previously in U.S. telecommunications or are being used in other countries. These include breaking up large digital platforms, structural separation between platform infrastructure along horizontal layers, functional separation between platform functions and complementary activities, neutrality obligations, and general interoperability requirements. Moreover, the question arises whether these instruments should be used ex post, that is after an abuse has occurred, as is typical for competition policy interventions, or ex ante, as was the mode of regulation over long periods. Each of these instruments has strengths and weaknesses and none is likely able to address the full range of issues. Similarly, traditional ex post and ex ante methods have known strengths and weaknesses.

A breakup into smaller companies raises the complicated question of what logical units would be. The AT&T breakup is often seen as a successful example of that model, but it could also be considered an intervention that put American telecommunications on a decade long detour to reconfigure networks and services. If an appropriate separation model could be found, it would allow preserving some of the vertical synergies in digital platform markets. Given strong direct and indirect network effects as well as economies of scale and scope, it might be only a question of time before similar forms of market concentration reoccur. Structural separation would reduce the set of options available to realize vertical synergies. It would constrain the platform to interact with other players via contracts and service agreements, possibly with additional requirements such as non-discrimination and openness of interfaces and business conditions. While this would likely create a more open system and reduce the transaction costs of some stakeholders, such an approach will also make it more difficult to achieve the differentiation of service quality and business arrangements that are vital for advanced information services.

Functional separation is less intrusive than breakup and structural separation. Like the other instruments, not all design issues are straightforward. It might seem compelling to establish that a platform should not also participate in markets in which it offers platform services to competitors (e.g., Amazon should not be present in retail markets served by third-party vendors). But participation is not the main concern, it is forms of discrimination that could be used by the platform, such as keeping lower inventory of third-party vendors to increase delivery times, which might incent some customers to switch to alternatives offered directly by the platform. Similarly, network neutrality or interoperability requirements seem to be appealing policy prescriptions, but they overlook the need in advanced networks to differentiate services and prices.

In contrast to these traditional tools, innovation economics and the management of innovation literature redirect the focus of regulatory and other digital policies away from specific detailed interventions to the design of the rules governing digital markets. It cautions against structural regulatory interventions such as breaking up platforms, which would only be appropriate in cases of gross abuse of platform power. Even then, they would need to be compared to potential downsides of such measures. Regulatory of legislative rules that provide safeguards against discriminatory behavior while allowing differentiation and entrepreneurial experiments would most likely be the most appropriate solution in the current innovation environment. Innovation economics also provides a strong argument in favor of institutional and organizational diversity. Most likely, the full innovation potential of next generations of digital technology will be best explored in a contest between a multitude of private, public, and non-profit players. Securing public interest innovation goals will also require new forms of engagement of local communities, public sector agencies, and the research community. Most likely, such a framework could best be implemented at the legislative level combined with ex post regulation. This would allow players maximum flexibility to conduct innovation experiments while safeguarding the entire ecosystem against manipulation by the dominant players.

6. Conclusion

Recent research in innovation economics and the management of innovation suggests that digital platforms can have both positive and negative effects on innovation. For example, because they can facilitate coordination among affiliated market players that might otherwise not be able to connect or reach critical masses of customers, they enhance the innovation opportunities space. Moreover, their enormous capitalization and financial resources allows them to pursue innovation projects with a high risk/high reward profile. Under certain conditions, other players are enabled by these platform innovations to develop complementary innovations. However, platform management may not act in such benign ways. Dominance of platforms in data and advertising markets may, over time, reduce the overall innovation activity in the sector. Platforms also influence the direction of innovation. Their most concerning effect might be to bias innovation experiments by start-up companies in a direction that will increase their chances to affiliate with or sell out to platform players.

The paper complements the existing research in three ways. It develops a conceptual framework of innovation drivers in digital platform systems, modeling them as one form of complementary innovation process. This revealed that in addition to the key drivers of contestability, appropriability, and technological/business opportunities, the strength of complementarities between players in different parts of the innovation system and the costs of coordinating them influence the rate and direction of innovation. The paper, next, examines the role of platforms in these innovation ecosystems. They can, directly and indirectly, exert considerable influence over the factors that drive innovation decisions by individual participants, thus affecting the innovation performance of the entire system. In principle, non-myopic platform management will recognize these interdependencies and complementarities and develop, often in a trial and error process, governance principles that optimize innovation performance for the entire ecosystem. However, if the strengths and shape of these interdependencies are misunderstood or platform management does not fully realize the benefits of growing the entire ecosystem, platforms may deliberately or inadvertently inhibit innovation or bias it in directions that mainly benefit the platform.

Considerable empirical work will be necessary to disentangle these issues and provide robust evidence on these matters. One challenge may be that there are few platform ecosystems and that their diversity and different approaches force the analyst to base insights on case studies of few platforms rather than large numbers of platforms. As a first step, this paper analyzed the role and effects of platforms on venture capital activity for projects attracting funding of $7.5 million or more. This represents the upper half of the distribution by value of venture capital projects contained in the CB Insights database. The evidence reveals that the number venture capital deals has been increasing year over year in in most sectors during the past decade. It shows a strong asymmetric interdependence and parallel development of venture investments by digital platforms and other venture capital. For deals above $7.5 million, our analysis at the sector level does not find evidence of a “kill zone”. Instead, it shows a positive impact of the venture investments made by digital platforms in aggregated industry sectors on the appetite of other venture capitalists to also invest in startups of such sectors. However, one must keep in mind that our analysis does not capture projects below $7.5 million and that we do not have any systematic evidence of unrealized projects. Thus, although our data does not find evidence that the presence of digital platforms reduces innovation, a conclusive assessment will need additional research.

Finally, the paper seeks to distill insights from the theoretical and empirical discussion for regulation and competition policy. Innovation economics and the management of innovation literature redirect the focus of regulatory and other digital policies away from specific detailed interventions to the design of the rules governing digital markets. It cautions against structural regulatory interventions such as breaking up platforms, which would only be appropriate in cases of gross abuse of platform power. Even then, they would need to be compared to potential downsides of such measures. Regulatory of legislative rules that provide safeguards against discriminatory behavior while allowing differentiation and entrepreneurial experiments would most likely be the most appropriate solution in the current innovation environment. Innovation economics also provides a strong argument in favor of institutional and organizational diversity. Most likely, the full innovation potential of next generations of digital technology will be best explored in a contest between a multitude of private, public, and non-profit players. Securing public interest innovation goals will also require new forms of engagement of local communities, public sector agencies, and the research community.

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