



Platform capitalism: The intermediation and capitalisation of digital economic circulation

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Abstract

A new form of digital economic circulation has emerged, wherein ideas, knowledge, labour and use rights for otherwise idle assets move between geographically distributed but connected and interactive online communities. Such circulation is apparent across a number of digital economic ecologies, including social media, online marketplaces, crowdsourcing, crowdfunding and other manifestations of the so-called 'sharing economy'. Prevailing accounts deploy concepts such as 'co-production', 'prosumption' and 'peer-to-peer' to explain digital economic circulation as networked exchange relations characterised by their disintermediated, collaborative and democratising qualities. Building from the neologism of platform capitalism, we place 'the platform' – understood as a distinct mode of socio-technical intermediary and business arrangement that is incorporated into wider processes of capitalisation – at the centre of the critical analysis of digital economic circulation. To create multi-sided markets and coordinate network effects, platforms enrol users through a participatory economic culture and mobilise code and data analytics to compose immanent infrastructures. Platform intermediation is also nested in the *ex-post* construction of a replicable business model. Prioritising rapid up-scaling and extracting revenues from circulations and associated data trails, the model performs the structure of venture capital investment which capitalises on the potential of platforms to realise monopoly rents.

Keywords

Digital economy, platform business model, intermediation, capitalisation, venture capital

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Introduction: White Label

At a small-scale academic-practitioner conference held in London in the middle of 2015 devoted to the United Kingdom's rapidly growing crowdfunding economy, a debate took hold about the recent proliferation of crowdfunding platforms. Discussion amongst conference participants stressed that this economy had initially been dependent upon the emergence of pioneering platforms that were created by the ingenuity of their founders in bringing together financial and technological expertise. Zopa, for instance, opened for business in 2005 and quickly emerged as a global leader in peer-to-peer (P2P) unsecured lending to household borrowers. The first-ever equity crowdfunding platform, Crowd Cube, was launched in the UK in 2011, the same year as Abundance Generation, the first platform to arrange the issue of fixed-interest bonds. The crux of the conference debate came to centre on how to interpret the large number of crowdfunding platforms presently operating in the UK. Growth has been rapid and continues apace: by 2016, over 40 platforms were members of the UK Crowdfunding Association,¹ while a further eight were members of the Peer-to-Peer Finance Association.²

The prevailing view expressed at the conference was that, although there would likely be bankruptcies which could cause a 'correction' to the pace of growth, an increasing number of platforms with relatively distinct market niches was an indicator of the continuing expansion of the crowdfunding economy and of the UK's position as a world leader in this sector. Albeit from a low base, crowdfunding in the UK expanded much faster than the rest of the financial sector in recent years. By 2015, the volume of funds raised through crowdfunding reached £3.2 billion, compared to £666 million in 2013 and £1.74 billion in 2014, an increase of over 300% in two years. It has been estimated that crowdfunding accounted for over 3% of gross lending to UK small- and medium-sized enterprises (SMEs) in 2015, and was responsible for the equivalent of 14% of new bank loans to small businesses (Zhang et al., 2016).

One practitioner in the conference audience intervened in the debate, drawing attention to White Label Crowdfunding, a company that offers an 'off-the-shelf' platform building tool for would-be crowdfunding enterprises. White Label promote themselves as providers of "market-leading technology and support", enabling firms to "enter the alternative finance market quickly".³ As the examples on White Label's website attest, the design, build and maintenance of a crowdfunding platform is an expert service that the company has provided to a number of new market entrants. Most are start-up firms, but Invest and Borrow, for example, is a crowdfunding spin-off by the pay-day-lender, Wonga. By drawing attention to White Label, the conference delegate wanted to illustrate that a crowdfunding platform could be assembled with relative ease and at much reduced cost than was once the case. Indeed, the platforms assembled by White Label and other similar platform builders (e.g. Sharetribe, Near Me) are an amalgam of widely available generic plug-and-play extensions for core platform competencies, such as electronic payments and content management, as well as bespoke code (Choudary, 2015). The proliferation of crowdfunding platforms in the UK is, therefore, not merely an indicator of the on-going expansion of the crowdfunding economy. Rather, it is also constituent of the maturity and ubiquity of multi-sided platforms as enterprises and socio-technical systems in an emergent digital economy which includes, but stretches well beyond, crowdfunding.

This fieldwork vignette takes us to the problematic that we address here. Whether emphasising pioneering crowdfunding platforms or drawing attention to the consolidation of the platform business model, the conference debate foregrounded multi-sided platforms in the emergence and expansion of the new digital economy. Yet, this platform-focused interpretation jars disconcertingly with received understandings of the novel form of digital economic

circulation of which crowdfunding is but part. Emerging over the last decade and now apparent across a number of digital economic ecologies – including social media, online marketplaces, crowdfunding, crowdsourcing, and the sharing economy more broadly – such circulations carry ideas, knowledge, labour and use rights for otherwise idle assets between geographically distributed but connected and interactive online communities. Prevailing explanations cast digital economic circulations as horizontal, networked exchange relations between users which are new and different because of their disintermediated, collaborative, and even democratising qualities. Deploying concepts such as ‘co-production’ (e.g. Prahalad and Ramaswamy, 2004; Thomke, 2003), ‘prosumption’ (e.g. Ritzer and Jurgensen, 2010), ‘productive publics’ (Arvidsson and Peitersen, 2013), and ‘peer-to-peer’ (Oram, 2001), established accounts are problematic, in short, because they render platforms largely invisible in the understandings that they offer of the digital economy.

In this article, by contrast, we want to develop an analysis provoked by ‘platform capitalism’, a neologism that can be traced to a critique of the sharing economy offered by the German blogger, Sascha Lobo (2014). Under the rubric of platform capitalism, we aim to place ‘the platform’ at the centre of critical understandings of digital economic circulation. For us, platform capitalism is a useful signifier for naming an analytical focus on ‘the platform’ which, following José van Dijck (2013), can be thought of as a discrete and dynamic arrangement defined by a particular combination of socio-technical and capitalist business practices. Over time, we would hope that the neologism of platform capitalism will provoke further research dedicated to detailing how this particular coming together of socio-technical and business practices manifests itself in concrete terms for specific enterprises. Here, however, we take the first steps toward centring critical understandings of digital economic circulation on the platform by opening up key conceptual and analytical concerns. By building on but departing from van Dijck’s (2013) prescient work on social media platforms, we argue that the generative force of the platform in digital economic circulation turns, in different ways, on *practices of intermediation* and *processes of capitalisation*.

Although the platforms operating in each domain of digital circulation are somewhat different – we will offer a typology below – they nonetheless share a distinctive logic and set of socio-technical practices of intermediation. Integral to framing ‘marketisation’ and, in particular, to structuring ‘market encounters’ in digital space (Çalışkan and Callon, 2010: 14–16), platform intermediation is distinctive because it attempts both to make the ‘connections’ of multi-sided markets and to coordinate the network effects of ‘connectivity’ (van Dijck, 2013). The business of intermediating digital circulation is also increasingly the enactment of a unique platform business model. Performing the structure of the venture capital investment which also backs it, the platform business model prescribes a novel enterprise form that is crucial to the valuation and ‘capitalisation’ processes which leverage debt against future revenue prospects from digital economic circulation (see Doganova and Muniesa, 2015; Leyshon and Thrift, 2007).

Our intervention differs from previous critical research that, confronting the problematic understanding of digital economic circulations as networked exchange relations, also relates the new digital economy to capitalism. We do not contribute here to the debate over the capitalist/post-capitalist character of digital economic circulation that typically collapses into ‘the users-versus-owners standoff’ (van Dijck, 2013: 18; see, for example, Kostakis and Bauwens, 2014; Mason, 2015). Nor do we begin by placing the new digital economy in the context of the apparent contradictions, limits, and transformations of the capitalist mode of production, or insist that the cutting edge of value creation is based upon the ‘enclosure’ of ‘the commons’ and the exploitation of ‘immaterial’ and ‘affective labour’ (e.g. Boutang, 2012;

Greene and Joseph, 2015; Hardt and Negri, 2009; Terranova, 2004). For us, such considerations of property relations and value are folded into an explicit concern with the practical accomplishment of 'the platform' as a distinct mode of socio-technical intermediary and business arrangement that is incorporated into wider processes of capitalisation. We acknowledge that, despite the rhetoric around the 'disruption' of intensified market competition, platforms conduct digital turf wars. We will highlight, however, that the 'winner takes all' objective of platforms (Kenney and Zysman, 2016) is grounded in an intermediary logic and business model that hinges on cornering market-making and the coordination of network effects in particular niche domains of digital circulation. Similarly, we recognise that value capture from connectivity by platforms relies upon harnessing the affordances and fragilities of immaterial labour (Friedman, 2014; Hill, 2015; Leyshon et al., 2016). However, we want to stress the future-facing processes of valuation and capitalisation (see Helgesson and Muniesa, 2013; Muniesa, 2012), and we will show how, for the present at least, such processes are also highly significant to sustaining the platform.

Our method throughout the paper is to interrogate the burgeoning coverage of digital economy platforms in the media and popular literature, especially the 'how to' and 'secrets of my success' guides offered by pioneers who provide personal accounts of their own platform start-ups (e.g. Chase, 2015; Stephany, 2015). We also engage with the dedicated body of expert academic-practitioner business knowledge that coalesces around the *ex-post* rationalisation of the new digital economy as a 'platform economy' (e.g. Choudary, 2015; Parker et al., 2016; Kenney and Zysman, 2016; Zysman and Kenney, 2014). The following section elaborates upon the distinctive intermediary logic of the platform, which is to make multi-sided markets and coordinate network effects, and provides a typology of the domains of circulation and corresponding platform types that can be categorised under the rubric of platform capitalism. The third section elucidates the socio-technical practices of platform intermediation which proceed by enrolling users through a participatory economic culture, and by mobilising an array of codes and data analytics to construct the infrastructures which are immanent to digital economic circulation. Section four considers how platform intermediation is now nested in a business model that targets scale economies and seeks to extract rents from circulations and associated data trails. The business model is also shown to perform the structure of venture capital investment funds that capitalise on the potential of platforms to realise monopoly rents. In conclusion, we highlight the issues of platform capitalism that require the most urgent attention: the role of platforms in the degradation of work, and the sustainability of platforms that are now highly valued and heavily capitalised as a consequence of venture capital investment.

The intermediary logic of the platform

For Sascha Lobo and likeminded critics, the neologism of 'platform capitalism' is a necessary counterweight to a narrative building around the sharing economy which depicts it as diverse and redistributive, made possible by new kinds of networked exchange. Summarising Lobo's position, fellow blogger Sebastian Olma (2014) argues that the platform has emerged as "a generic 'ecosystem' able to link potential customers to anything and anyone, from private individuals to multinational corporations" (Section 3, Paragraph 1). This means that "[e]very one can become a supplier for all sorts of products and services at the click of a button", which "is the real innovation that companies of the platform capitalism variety have introduced" (ibid.). Rene Ridgway (2015) broadens this definition when she suggests that, in

donation and rewards crowdfunding, it is platform capitalism that ‘conditions’ how networks come together. Meanwhile, Kostakis and Bauwens (2014) suggest that the digital economy is characterised by a tension between two organisational modes of control over online infrastructures: first, what they call “distributed capitalism”, in which “infrastructure is primarily distributed with the promise to make everyone a small capitalist” (p. 71), and second, what they call “netarchical capitalism”, where infrastructure is “in the hands of centralized privately owned platforms” (p. 71). These various observations about platform capitalism all point towards the intermediary logic of the connective ecologies and infrastructures of the platform.

The underlying intermediary logic of the platform is that it solves coordination problems in market exchange by extending the distance-shrinking networking capacities of the internet first identified during the 1990s (e.g. Evans and Wurster, 1999; Liebowitz, 2002). In particular, the advent of the internet created new opportunities to solve the problem of two-sided or multi-sided markets, where economic agents need to find each other to transact. Evans (2011) provides four exemplars of intermediation within two- or multi-sided markets. A traditional example is a physical place-based exchange, like a stock or commodities exchange, which hosts buyers and sellers (for a fee). Other exemplars include advertising-supported media, which provide content of various kinds to attract audiences that are delivered to advertisers (who are charged for access); and transaction systems such as credit and debit cards, that act as a form of payment between buyer and vendor (with an interchange fee charged to vendors). Evans’ fourth exemplar – software platforms – explains in part why the intermediation of multi-sided exchange in digital space is increasingly regarded as the preserve of the platform. Here code, in the form of an operating system, becomes the medium for connecting disparate actors (for example, through its Windows platform, Microsoft co-ordinates a three-sided market that connects computer users, applications developers and hardware manufacturers). In contrast, Microsoft’s main rival, Apple, runs a two-sided market which connects users and application developers through its iOS platform, but maintains a monopoly over the manufacture of its hardware. The smartphone industry similarly divides into two-sided (e.g. Apple iPhone) and multi-sided platforms (e.g. Google Android), while in the computer game industry two-sided console platforms (e.g. Sony Playstation, Nintendo, Microsoft, Sega) match game developers with users.⁴

Emerging from these software-based industries and refracted through neo-classical assumptions about market exchange, platform intermediation has rapidly expanded since the mid-2000s to encompass a wider set of multi-sided markets. Table 1 below provides a typology of the primary domains and platform types that can be categorised as comprising the new digital economic circulations of platform capitalism, and identifies examples of the main platforms that we have in our analytical sights. What our typology recognises, moreover, is that the intermediary logic shared by all platform types is distinctive in crucial respects: it goes beyond the making of multi-sided markets through software code to also include the creation and coordination of network effects. Platform intermediation thus frames the “market encounters” of marketisation processes in ways that are significantly different to the typical mediation of market exchange (Çalışkan and Callon, 2010: 14-16). What is distinctive is not so much the role of the platform as a “non-human mediator” of market encounters that mobilises the distance-shrinking network powers of the internet (Çalışkan and Callon, 2010: 15), but that platform intermediation targets the ostensible opportunities offered by network effects and the so-called ‘co-creation’ of value between users. In van Dijck’s (2013) succinct terms, platforms are not simply in the business of intermediating *connections*, but of actively curating *connectivity*.

Table 1. Platform capitalism: Domains of circulation and platform types. *Source:* Authors' own.

Domain of circulation	Platform type	Principal platforms
Online exchange markets	Marketplace for sale of products and services through physical distribution, downloads, and streaming, normally at a discount to those charged by traditional incumbents. Includes multi-sided platforms typically with closed APIs, and two-sided vendor platforms with open APIs for developer innovation.	- Amazon - Apple - Spotify, - eBay - Alibaba - AmazonMarketplace - Craigslist - Taobao - Rakuten, etc.
Social media and user-generated content	Host for user communities to post content. Multi-sided and open APIs for developer innovation.	- Facebook - YouTube (Google) - Flickr - Twitter, etc.
Sharing economy	Marketplace for hire of assets and services that would be underused or not even recognised as such, normally at a discount to those charged by traditional incumbents. Multi-sided with typically closed APIs.	- Uber - Airbnb - Sidecar - RelayRides - JustPark, etc.
Crowdsourcing	Marketplace for transactional and contractual work, freelance and informal labour, and know-how. Multi-sided, open APIs.	- TaskRabbit - Upwork - Amazon Mechanical Turk, etc.
Crowdfunding and P2P lending	Marketplace for donation, pledging, lending or investing money, rates of interest normally higher than traditional financial service incumbents. Multi-sided, closed APIs.	- Kickstarter - Indiegogo - Lending Club - Prosper, etc.

An appreciation of the distinct intermediary logic of the platform thus leads us to include social media within our typology, as one of the most prominent domains of the new form of digital economic circulation. This is because, since the mid-2000s in particular, the type of platform operating in this field has been at the forefront of the intermediation of networked connectivity, relying on the input and creativity of their interactive users – from posting updates to uploading new content – in order to generate audiences that can be sold to advertisers as consumers (van Dijck, 2013; Mangold and Faulds, 2009). Indeed, social media platforms have been particularly successful at not only attracting large audiences but, by subjecting their data to close analytical scrutiny, offering advertisers and their clients more forensic and targeted consumer marketing campaigns.

It is the distinctive intermediary platform logic that also leads us to exclude from our typology those websites that attract consumers through aggregator interfaces which provide price-based comparisons (e.g. Money Supermarket), or user-generated reviews (e.g. Trip Advisor). Price-comparison and review-based websites are fee-earning digital economy intermediaries but, unlike platforms, they do not seek to facilitate and capture value from the interactions and circulations of Web 2.0. Our demarcation of domains of circulation and platform types also excludes what might be described as ‘mainstream’ e-commerce which arrived with much fanfare during the ‘new economy’ or ‘dot-com’ boom of the late 1990s

(Feng et al., 2001; Thrift, 2001; Zook, 2005). There are important continuities from e-commerce into platform capitalism, including an intermediary logic, the catalytic role of venture capital in funding new start-ups, and the urgent need to quickly 'scale-up' operations to make a business viable (see below and, for e-commerce, Daniels, et al., 2007). But, for the most part, the web sites and mobile apps of e-commerce typically intermediate exchange in two-sided markets – either business-to-consumer (B2C) or business-to-business (B2B) – and provide an additional 'channel' (alongside 'bricks and mortar' retail outlets and telesales) through which established firms market their products and services.

Digital economies are highly dynamic, however, and some e-commerce firms have extended their operations to become platforms that intermediate network effects. In order to do so, a critical decision for e-commerce firms is whether to open up their application program interface (API), which specifies how software components in its systems should interact. Firms that have open APIs enable software developers to build applications that can be added to the platform. This model of interaction was successfully developed in the open source software community of the 1990s (von Hippel, 2005; Weber, 2004), and is a way of fast-tracking innovation by drawing on a distributed community of knowledge. The incentive for developers is to write applications that are attractive to users, and that might generate extra revenue for platforms for which developers are rewarded with commissions. For example, it was the adoption of this approach that, following the dot-com boom, gradually transformed Amazon from an e-commerce retailer that mainly challenged incumbent bookshops into a platform-intermediated, wide-spectrum online marketplace (Simon, 2011). By opening up its API, a host of new applications and revenue streams were attached to the platform. For example, individuals with their own web sites were encouraged to become Amazon associates, taking commission when users are directed to Amazon to make a purchase. It also developed a multi-sided marketplace where both individuals and retailers can offer their own products for sale, with Amazon taking a commission on all sales.

Participatory culture and infrastructural intermediation

The distinctive intermediary logic of the platform materialises through a particular configuration of socio-technical practices. For one of the leading gurus of the platform economy, Paul Choudary (2015: loc 868), for example, platform intermediation combines three distinct operational "layers" which will vary in "thickness" and importance according to market context and competitive strategy. These layers are: first, a network or community layer, which consists of platform participants and the relationships between them; second, an infrastructure layer, which is made up of software tools, rules and services; and third, a data layer, which allows the platform to attempt to match supply with demand. The webpages and marketing pitches of platforms are crucial to the first of these 'layers', and typically produce a participatory economic culture that plays to the broader and deeper cultural rhetoric about the inclusive and democratising qualities of the internet (van Dijck, 2013: 9-10). To a greater-or-lesser extent, different platform types attempt to enrol participants who are figured not as 'consumers' but as 'users' who 'co-create value'. In Choudary's (2015: 43) terms, "*platforms must invest in behavior design*", eliciting "new behaviors that had never existed in the past" and ensuring that "users stick around of their own accord" (emphasis in original). Put differently, and in the more critical terms of Lovink and Tkacz (2015: 14), the intermediation of networked economic connectivity features the summoning-up of the popular passions and interests of what they call the "platformed masses".

For UK equity crowdfunding platforms, for example, what they offer is a prospect that is explicitly entrepreneurial – “a chance to be part of the next big thing”, a “revolutionary opportunity” which “enables anyone to invest in British businesses alongside professional investors and VCs” (venture capitalists).⁵ Reward and donation modes of crowdfunding will not typically involve venture capitalists or invoke venture capitalism. Nonetheless, the funding campaigns run by various kinds of artists or innovation-based companies attempt to draw those who donate money into the entrepreneurial trajectories of their projects, both by providing regular updates on progress (often by vlogs and ‘microfilms’ in ways that mimic other social media platforms) and by offering early access to the product, service or creative output.

Meanwhile, sharing economy platforms like Uber and Airbnb offer users the prospect of gaining access to services – taxis, short-term rented accommodation, and so on – that are generally cheaper and possess different qualities and features to those offered by traditional providers. Users enrolled in the sharing economy thus appear as a networked consumer-entrepreneur, a kind of digital amalgam of the canny consumer of exchange markets and the entrepreneurial owner of an asset portfolio. In particular, sharing economy platforms promise a “seemingly flatter and more participatory model, whereby customers engage directly with each other” (Morozov, 2015: n.p.), an appeal to ostensible disintermediation that is also found on the webpages of platforms that specialise in the P2P lending mode of crowdfunding. Moreover, thanks to the always-on and mobile connectivity provided by smartphones, it seems that users in the sharing economy “can suddenly do things that previously required an array of institutions” (ibid.). Buyers and sellers also meet as ostensible near equivalents in such transactions; whereas in the past such exchanges were characterised by information asymmetries, platforms such as Uber and Airbnb provide information on the reputation of buyers and sellers that can inform both sides in deciding whether an exchange should take place.

Tarleton Gillespie’s (2010) account of the diverse etymological origins of the term ‘platform’ provides for a particularly insightful vantage point from which to consider their positioning as enablers of the ‘co-creation of value’. They are “platforms of opportunity” which are ostensibly “flat, featureless and open to all”, and capable of “lifting us all up, evenly” (Gillespie, 2010: 347, 350, 352). Gillespie finds the origins of ‘platform’ to be simultaneously computational (as in a software code, discussed above), architectural (as in a raised surface), figurative (as a grounding for an action), and political (as in a political position or base). The conflation of these different meanings results in what Gillespie calls a “discursive positioning” of the platform which brings together:

... terms and ideas that are specific enough to mean something, and vague enough to work across multiple venues for multiple audiences. To call one’s online service a platform is not a meaningless claim, nor is it a simple one. (Gillespie, 2010: 349)

The use of the term platform has computational and coding roots, but the other architectural, figurative, and political understandings are bundled in and create “broad connotations” that platforms are “open, neutral, egalitarian and progressive” (p. 352). This appeal to openness and participation means “it should come as no surprise ... that the term would ... gain traction around user-generated content, streaming media, blogging and social computing” (p. 351). And, we would add, it is equally no surprise that the category of ‘platform’ has largely replaced ‘domain’ and become ubiquitous across digital economic spaces that are typically held to be marked by the creative and collaborative character of networked exchange.

While the presentation and marketing of platforms positions them as the enablers of a participatory digital economic culture amongst users, the ‘how to’ and ‘secrets of my success’ guides offered by the pioneers of platform start-ups tell a different story that begins to highlight the other principal ‘layers’ of this discrete mode of socio-technical intermediary practice. For ZipCar co-founder Robin Chase (2015: 18), for example, the emergence of the sharing economy – or what she terms Peers Inc – is broadened out into “a revolution ... taking place inside capitalism as we reimagine the role of consumers, producers, and even ownership”. And, as digital economic networks become the “new paradigm” to replace “industrial capitalism” (pp. 18-19), the role of platforms (or ‘the Inc.’) is cast as crucial:

It is the Inc. that has the ability to make long-term and large investments, marshal teams with many kinds of expertise, extract economies of scale, and apply standard forms of interaction and quality. The unique role of the Inc. is to do what peers cannot – to create platforms for participation and to put the assets ... into the hands of the smaller, autonomous peers who participate. (Chase, 2015: 36-7)

What Chase argues, in effect, is that as they seek to facilitate the creative energies of *network economicus*, platforms are indispensable because they *are* the network.

As sociological and geographical research into Web 2.0 culture underscores, networked associations and interactions are necessarily dependent upon software code which must continuously operate to produce digital spaces (Kitchin and Dodge, 2011), not to mention the physical hardware of computers, tablets, and mobile devices and labyrinths of fibre optic cables, wireless networks, cloudservers, and so on (Kinsley, 2014). It follows that digital economic circulations are not merely everyday encounters enabled with and between software (Thrift, 2005), but are actually constituted through and by what can be accordingly conceived of in various socio-technical and material terms as ‘infrastructures’ (Beer, 2013), ‘architectures’ (Collins, 2010) and ‘ecosystems’ (van Dijck, 2013). The constant running of the partially concealed software code and applications of platforms are, to borrow from David Beer (2013), the ‘infrastructures of participation’ in the digital economy.

The platform can be said, then, to mobilise the infrastructures of participation that are immanent to the new digital economic circulation. Digital economic circulation is afforded through platforms that undertake coding based on data and metadata; deploy algorithms for processing relations between data points; use protocols to script interactions; and configure interfaces which are both visible features (e.g. buttons, scroll bars) and defaults, as well as the invisible links between data, software and hardware (open or closed to application programming) (van Dijck, 2013: 29-32). Contrary to the meanings that might be implied by the metaphor of ‘infrastructure’, however, platforms are not utilities or conduits that simply channel circulations. Platforms actively induce, produce and programme circulations. As Beer (2013) notes in relation to the infrastructures of Web 2.0, platforms realise and act upon data (through archiving and algorithms, for example) in ways that feed-back, structure, delimit and even determine the circulations of popular culture.

For us, the neologism of ‘platform capitalism’ foregrounds the holding together of the infrastructural and intermediary qualities of the platform. Platforms are particular comings together of code and commerce: when infrastructures of participation and connectivity are designed and data is realised and acted upon, this is the intermediation of digital economic circulation in action. As van Dijck (2013) puts it when she ‘disassembles’ the principal social media platforms, platforms are, at once, techno-cultural constructs and socioeconomic structures. Acting to make market networks as what we might call infrastructural intermediaries, platforms necessarily ‘standardise’ the circulations in which they specialise, whether these be ideas, knowledge, labour, or use rights for otherwise idle assets (see

Çalışkan and Callon, 2010: 7-8). While this involves legal and contractual devices, it is also a matter of conventions of inclusion/exclusion and differentiation through categorisation. For example, in the sharing economy, both Uber and Lyft require their independently contracted drivers to undergo background checks in order to inculcate trust among passengers using the service. Airbnb, meanwhile, deploys categories for room type, amenities, and charges to enable users to connect with the assets that best suit their needs, whims, and wallets. Due diligence is deployed by equity crowdfunding platforms to screen out projects on grounds of their integrity and feasibility. Similarly, Funding Circle, a leading P2P lending platform in the UK, demarcates the business loans that it offers to would-be investors according to its own risk-weighted categories ranked A+ to E (Langley, 2016). Such standardisations, inclusions/exclusions, and differentiations are especially significant to stabilising participants' expectations, and are the underpinnings of pricing processes that platforms also programme and organise.

The infrastructural intermediation of digital economic circulation also features a further device that is especially significant to making multi-sided markets and coordinating network effects; namely, the judgment and evaluation systems of platforms that solicit user reviews and rankings, often by counter-parties (e.g. Uber drivers and riders can rate each other, as can Airbnb's hosts and guests). As Morozov (2015) observes, for some free-market enthusiasts, reputational devices contribute to making the sharing economy a near perfect market, where participants have access to almost fully disclosed information on the other parties: "if you are a nasty customer or an ill-mannered driver, everybody else will soon discover this, and specific laws to police your behaviour are rendered unnecessary" (n.p.). In popular parlance, punishment by the crowd takes the form of 'public shaming' (Ronson, 2015). For Arvidsson and Peitersen (2013: xvi-xvii), meanwhile, digital economies become "reputation economies", where "reputation functions as a kind of capital" and measure of value for participants that, "at an abstract level", "could constitute the foundation for the institutional architecture of an ethical economy (much like the institutions of industrial capitalism were based on the idea of value derived from labor time)".⁶ Leaving aside Arvidsson and Peitersen's broader claims, what is important is how platforms build ostensibly stabilising reputation economies into the infrastructures of digital economic circulation. Ideas, knowledge, labour and use rights for otherwise idle assets in circulation are thus qualified in a manner that appears thoroughly consistent with the figurative positioning of the platform as an enabler of participatory economic culture.

The platform business model and venture capital

The intermediary logic and socio-technical practices of the platform have developed somewhat fitfully. As van Dijck observes of social media platforms from the late-1990s and early-2000s,

... most Web 2.0 platforms started out as indeterminate services for the exchange of communicative or creative content among friends. These services also emanated from community-bound initiatives – a group of college students, photo aficionados, video enthusiasts – who adopted a specific niche of online interaction and developed a mediated routine practice. (van Dijck, 2013: 6)

Given this indeterminacy – and although there are notable exceptions, such as Amazon – it is of little surprise that platforms have been slow to translate the logic and socio-technical practice of intermediation into a viable business strategy (Lacy, 2008). However, an emergent business model is now providing an *ex post* rationalisation of the platform as enterprise and,

in effect, of a decade or so of investment by venture capital funds and other institutions that has backed 'the rise of the platform economy' (Kenney and Zysman, 2016).

Expressed through a burgeoning body of consultancy knowledge and the 'how to' and 'secrets of my success' guides of early platform pioneers, the business model is crucial to a platform-centred understanding of digital economic circulation in two principal respects. First, and most obviously, it inscribes strategic business logics and meanings on the contingent developments and innovative 'tinkering' of platform intermediation (see Mokyr, 2002). Contemporary platforms now enact experiments across the various domains of circulation outlined in the first main section of this article but, according to the business model, the success of all platform types turns, in the first instance, on significant investment in the technology and know-how necessary for the design and operation of an infrastructure which has to 'scale' as a matter of priority (i.e. rapidly and consistently add users). In this respect, there are clear parallels between the platform business model and B2C and B2B e-commerce business models. Whereas e-commerce firms sought to quickly establish and protect their shares of new online marketplaces, for a platform to scale requires the delineation and domination of a multi-sided market network niche. In Bonchek and Choudary's (2013) terms, for example, it is 'connection', 'attraction' and 'flow' that determine the success or otherwise of a platform's scaling strategy. *Connection*, which refers to the ease by which others can connect to the platform 'to share and transact', will for some platforms mean making its API freely available, while for others it will be the ease with which users can add and store content or exchange, share, borrow, invest, and so on. The more straightforward the process of connection, the more *attraction* the platform will generate as a market network for users. Finally, connection and attraction ensure that the 'co-creation of value' between users will *flow* through the platform. This process has also been described as a 'flywheel' that, when in motion, seems to gather its own momentum to generate direct and indirect network effects (Evans and Gawer, 2016). For instance, when YouTube became rapidly established during the latter half of 2005 as the go-to video content-hosting platform, it quickly outstripped Google Video which was launched contemporaneously. YouTube featured an interface that was extremely popular with users because digital content could be uploaded in almost any format, whereas Google Vision required potential users to first download software that would standardise the format of their uploads. The ease and flexibility of the act of uploading ensured that the YouTube platform filled up with content, which in turn attracted audiences, and then advertisers. Google purchased YouTube in October 2006 at a cost of \$1.65 billion (BBC News Online, 2006).

Enacting experiments with a platform business model that targets up-scaling has become progressively easier over time. As the earlier example of White Label Crowdfunding highlighted, infrastructural investment no longer has to be largely in-house, but can be purchased 'off-the-shelf' from specialist providers and software companies. Core competencies and labour requirements can also now be accessed more easily. For instance, crowdsourcing platforms such as Skillshare allow 'everyday creators' to become 'teachers' who offer 'classes' in the form of short films or vlogs. Such classes cover a wide range of business, design, and technology matters that are relevant to building a platform enterprise, and are made available for a subscription fee which is shared between Skillshare and the 'teacher'.⁷

Moreover, while levels of investment clearly vary across platform types and the specific expansionary plans of particular platforms – Amazon, for example, spends an immense amount of money investing in its logistical and computational capacities – the platform business model holds that the marginal cost of up-scaling a platform is relatively trivial, especially when compared with the kind of investment in vertical integration, resources, and

intellectual property that is necessary to produce economies of scale in both 'old' and 'new economies'. For Chase (2015: 73-5), for example, the growth potential of platforms can "defy the laws of physics" because expansion is based on the "unlocking" and "leveraging" of the co-creation of value by networked peers. Framed and produced by the distinct intermediary logic of platforms, assets, knowledge, and labour in circulation are non-proprietary and decentralised, but they are nonetheless amenable to aggregation and exploitation. As Choudary (2015: 38) succinctly summarises, "the network effect is the new driver for scale". It appears that the key for the platform is to intermediate the ever-expanding value created by user interactions across their market network. This is because continually increasing numbers of users – understood as producers and creators of value and generators of data, and not as consumers – is crucial to a platform's capacity to cultivate and capture value, and to do so over time and on an ever-greater scale.

The business model is also crucial to a platform-centred understanding of digital economic circulation in a second and further respect: the model provides for a relatively coherent and powerful framing of the valuation and capitalisation of the platform. As Fabian Muniesa (2016) points out, since the first decades of the twentieth-century, processes of business valuation have increasingly come to measure a business as "an asset", wherein "what a business is worth equals its capacity to generate a stream of revenues for the investor or investors that provide it with funding" (p. 196). Emerging from management schools during the 1970s and growing in popularity since the 1990s, business models further such valuation processes because they extol and specify the "asset-becoming" prospects of a form of enterprise that is new or different in one way or another (Doganova and Muniesa, 2015: 120). As it valorises the platform as capitalist business arrangement, then, the platform model is a proposition that more-or-less precisely articulates for investors how particular platform-assets "will yield income that can both act as collateral and as sources of profit in their own right" (Leyshon and Thrift, 2007: 100). The platform thus becomes a legitimate object of capitalisation, that is, an enterprise that is able to access debt from investors because its revenue prospects suggest that it can realise a return on capital.

According to the platform business model, achieving scale and coordinating network effects opens out into the enactment of two principal and somewhat overlapping "revenue models" (Chase, 2015: 121). The first is the preserve of 'constrained' or 'closed' platform types which typically operate in the sharing economy and the various crowdfunding ecologies. The infrastructures of these platforms facilitate "relatively uniform collaboration (and products and services)" (p. 105), and users are required by the platform to pay fees or charges. In this regard, as noted above, infrastructures feature the coding and design of effective user interfaces and webpage layouts that do not merely list goods, services, assets, work opportunities and the like, but which structure particular standardisations, qualifications and categorisations that can multiply transactions and the fees earned on those transactions.

The second revenue model is more diverse and dynamic in nature. It does not feature intermediary fees or charges, and is summarised in critical terms by Lovink and Tkacz (2015: 15) as the "service/data-profile/advertising complex". For Chase (2015), the second approach to revenue generation is the most significant for relatively 'unconstrained' platform types, especially social media platforms and those that intermediate online market exchange with open APIs. Some user-generated platforms initially sought to develop subscription revenues, but a number of related revenue streams have become particularly significant as data analytics have improved. By combining data analysis with automated customisation techniques, platforms earn revenues from targeted advertisements and recommendations appearing as banners or running in sidebars. Facebook, for instance, generates its largest

revenue stream by delivering its users to advertisers (Zysman and Kenney, 2014). Google, meanwhile, earned \$47 billion in 2015 from an advertising market for internet search platforms that alone is worth \$86 billion in total (Gallagher, 2016). And, for the Google-owned YouTube platform, the generation of advertising revenues is accelerated by the promotion of a new strata of social media celebrities who produce digital video content that can attract millions of followers. Moreover, as some commentators suggest (e.g. Foster, 2014; Zuboff, 2016), the harvesting and analysis of aggregated real-time data on the activities and movements of platform users may be in the process of becoming the primary source of revenue across the platform business model.

Understood in more critical terms, the revenues prescribed by the platform business model amount to the extraction of 'rent' from circulations and associated data trails. As Lazzarato (2015) argues, 'rent' can be understood as an 'apparatus' that is distinct from profit and taxation, and which combines constitutive knowledge processes of valorisation with a mode of appropriating value from property that has been long emphasised by Marxist political economists (e.g. Harvey, 1976). Re-thought in such terms, the enactment of the recently articulated platform business model has the effect of positioning platform intermediaries as the "'rentiers' of the network" (O'Dwyer, 2015: 234). The first platform revenue model – sitting comfortably with well-established intermediary practices that also accumulate fees and charges (e.g. in the financial sector, see Christophers, 2015) – is 'direct rent'; platforms intermediate by extracting rent (charging vendors, borrowers, those with assets to share, etc.) for transacting via their infrastructures. For the second revenue stream, meanwhile, rent extraction is 'indirect', and sits much less comfortably with revenues derived from land and other property. The extraction of rent via automated targeted advertising and data harvesting and analytics is "a payment in attention, information, or affiliation, which in turn can be sold to advertising companies and market researchers who require access to users, their content, and their networks" (O'Dwyer, 2015: 234-35). Both direct and indirect rent are rationalised and justified by a business model that – stressing the know-how, skills, and investment necessary to building a successful platform – extols the benefits of up-scaled networks for all users.

Furthermore, what is also especially notable about the platform business model is that it performs the structure of the venture capital funds that are the major source of investment in platforms. The most established platforms that survived and evolved out of the bursting of the dot-com bubble are now fully integrated into the mainstream, corporate landscape of the US stock market: Apple and Facebook, for example, are in the top 10 (by index market capitalisation weight) of the S&P 500, the leading US equity index.⁸ Younger platforms have also recently achieved stock market listings: in September 2014, for instance, the Chinese platform intermediary, Alibaba, achieved a \$25 billion Initial Public Offering (IPO) in the US that was the largest ever by valuation (Chen et al., 2014). Indeed, Evans and Gawer (2016: 10) argue that by 2015 there were as many as 176 platform companies with a market capitalisation of at least \$1 billion. But, across the domains of digital economic circulation where US-based platforms feature strongly and continue to set the pace, many platforms remain privately owned, largely by San Francisco Bay-based venture capital funds, private equity and other similar institutions.⁹ This has been made possible in recent years by increasing volumes of capital being channelled into venture capital funds that, at the same time, have directed their attention to platforms and other software firms. For example, \$58.8 billion of investments flowed through US venture capital funds in 2015, the second highest annual total since 1995 (i.e. the beginning of the new economy boom). And, in terms of distribution, investment flowed disproportionately into the software sector, over and above the biotechnology and media and entertainment sectors (NVCA, 2016).

The performance of the structure of venture capital funds by the platform business model reflects the prevalence of the knowledge and valuations of venture capital firms in technological innovation by new enterprises. As Matthew Zook (2005: 52) shows, since the 1960s, venture capitalists have established a powerful position as both investors and “knowledge brokers” in cutting-edge technology firms. However, the platform business model does not perform a set script on digital innovation prescribed by venture capitalists. Indeed, the various ‘how to’ texts which outline the platform business model tend to pay only very limited attention to raising finance and attracting investors (see Chase, 2015). In this instance, the performative power of venture capital is better seen as an example of what Clarke (2012) classifies as ‘generic performativity’, wherein the platform business model continuously performs the common structural categories (not a specific theory) of venture capital funds in two main ways.

First, the platform business model performs the temporal structure of venture capital funds. Funds are typically 10-year fixed-term independent partnerships composed of so-called ‘limited partners’; that is, those who invest in the fund, including wealthy individuals and institutional investors (pension funds, insurance companies, endowments, banks and cash-rich corporations). Funds are managed by ‘general partners’ who receive annual fees of 2-3% of a fund’s value, plus a 20-30% share of eventual returns. Each fund’s portfolio will be assembled during its opening three years or so, as managers identify the start-ups they wish to support and hold back a portion of capital for subsequent rounds of investment to be triggered by agreed milestones (Mason, 2009). For a fund to achieve aggregate returns, the equity stakes in the start-ups that form the portfolio must be cashed-out within its 10-year term, although the target for such ‘liquidity events’ is usually three to five years. However, in order for liquidity events to take place – either via an IPO, acquisition, or sale of shares to another investor – start-ups are typically expected to have begun to demonstrate their capacity for revenue growth and thus cost-recovery to investors, an expectation that was largely suspended for the wave of tech company IPOs which characterised the dot-com boom (Feng et al., 2001). In terms of their temporal structure, then, venture capital funds are performed by the platform business model precisely because it elaborates upon the streams of revenue that can be realised by platforms which rapidly up-scale. To borrow from Feng et al.’s (2001: 501) account of the dot-com boom, the platform business model specifies the “variable form of the relation between [venture capital-backed] innovation and cost-recovery [for investors] in present-day capitalism”. As the business model makes rent extraction appear viable for platform intermediaries that quickly scale, so it performs the growth trajectory of start-up firms that is valorised by venture capital and which culminates in liquidity events.

Second, the platform business model also performs the portfolio structure of venture capital funds. Venture capital funds operate a high risk/high reward investment strategy. When capitalising on unproven start-up firms with a rapid growth potential in return for equity stakes, fund portfolios are expected to contain only a minority of investments that will ultimately pay-off. This is encapsulated in the so-called ‘2:6:2 rule’ governing venture capital funds: two investments will be losses, six will break-even, and only two will realise returns, but these ‘home runs’ will be of such an order of magnitude that the overall portfolio will generate returns that outperform equity markets over the same period (Mason, 2009). Thus, the parameters of venture capital fund portfolio structure are performed by a platform business model that explicitly coordinates network effects to generate revenues. The result, in our terms, are processes of valuation and capitalisation in which a platform’s attempts to extract rents from digital economic circulations conform to the oligopolistic and even monopolistic tendencies of platform intermediation: platforms target dominance of their own niche market

infrastructure, at the expense of others who are therefore destined to 'fail'. Platforms seek to extract rents from their network which are, in essence, monopoly rents.

Failure for start-ups in this context needs to be qualified, however, as success for venture capital may not only equate with achieving an IPO. Consider, for example, how publicly-quoted platforms seek to defend their dominant market share and expand in new directions by buying up smaller rivals, and how additional rounds of investment in privately-owned platforms is often for the dedicated purpose of strengthening their market position, such that platforms targeting monopoly rents are currently a very strong presence amongst so-called 'unicorns' (privately-owned firms valued at over \$1 billion) (Kenney and Zysman, 2016). For instance, following the 2005 purchase of YouTube noted above, publicly-quoted Google has since made in excess of fifteen acquisitions of firms that variously specialised in advertising technologies and interfaces, email security, video compression, and mobile phone platforms (see Rosoff, 2011). Thus, if platform start-ups achieve sufficient prominence and promise and are bought out by a more dominant platform seeking or defending a monopoly position, then this equates to a viable and successful strategy: it does not result in an IPO, but nonetheless performs the temporal structure of venture capital funds because it permits investors to cash out.

Concluding remarks

By singling-out the digital economic circulations of platform capitalism for attention, we do not wish to downplay the significance of e-commerce platforms, cloud computing, and software code more broadly in the organisation of contemporary socio-economic life (Thrift, 2005; Amoore, 2016). Such digital technologies can be said, for example, to be contributing to a transformation of both the processes and end products of manufacturing enterprises (Zysman and Kenney, 2014). Rather, by invoking the rubric of platform capitalism, our purpose in this article has been to draw critical attention to a novel form of digital economic circulation, and to a typically overlooked feature of this new 'new economy' that is hiding in plain sight: the platform.

When placing the platform at the centre of critical understandings of digital economic circulation, moreover, we have suggested that the platform is not merely a manifestation of wider transformations in the relations and structures of contemporary capitalism. For us, analytical attention should be given to the contingent configuration and consequences of the platform as a discrete mode of socio-technical intermediary and capitalist business arrangement. This led us to stress both the distinctive marketising intermediation of digital economic circulation by platforms, and the incorporation of platform-intermediated circulation into wider processes of capitalisation. To make multi-sided markets and coordinate network effects, platforms enrol users through a participatory economic culture and mobilise code and data analytics to compose immanent infrastructures. And, nested in an emergent platform business model that also performs the structure of venture capital fund investment and valorises potential for monopoly rents, platforms prioritise up-scaling and the direct and/or indirect extraction of rent from circulations and accompanying data trails.

Given that the platform is likely to become a durable feature of the global economic landscape for some time to come, we close by highlighting two features of platform capitalism that require more immediate attention. First, platforms have been subject to considerable critical comment for their perceived role in degrading conditions of work. For Friedman (2014), for example, platforms usher in a 'gig economy' which has been a feature of employment growth in the US economy since 2001, and is dominated by short-term or casual contacts. While this could be argued to be advantageous for those with highly valued skills and

competencies – such as, for example, software developers who are able to write code to create applications for platforms – it remains the case that, for many, what Calloway (2016) dubs ‘applotation’ is precarious employment at best, and is certainly not accompanied by the kinds of benefits (e.g. health insurance, pensions) which normally accompany permanent employment. Thus, crowdsourcing platforms like TaskRabbit and Handy enable people to bid for often-mundane jobs that the better remunerated do not have either the time or inclination to undertake for themselves. And, when bidding for work via platforms, individuals may find themselves in a race to the bottom and, if successful, will do so as self-employed contractors.

The degradation of conditions of work that may accompany the rise of the platform is perhaps best illustrated by the rise of the sharing economy platform Uber, which describes itself as a ‘transport connection company’ that unites ‘riders’ with (self-employed) ‘drivers’. As an intermediary, Uber takes its cut from the fares earned by drivers. Uber’s appearance in the taxi markets of cities has mainly been met with hostility from incumbent, licensed taxi companies who are subject to city-based regulations designed to calibrate demand with driver numbers and to protect health and safety. Uber’s approach to these regulations is typically to ignore all but those regulations that render specific activities illegal (McNeill, 2016), thereby increasing supply, threatening the livelihoods of career taxi drivers, and provoking protests and industrial action (Topham, 2016). However, for those previously excluded from licensed taxi driving on the basis of race or class (Chassany, 2016), the disruptive capacity of Uber may create employment opportunities that might not have previously existed.

Second, attention needs to be given most urgently to the ways in which, by performing the temporal and portfolio structure of venture capital funds, the platform business model has become closely implicated in the present cycle of the venture capital industry. As Feng et al. (2001: 498) argue, in “macro-economic terms”, “venture capital is not a system” composed of separate investment funds, “but a cycle”. After the best part of a decade in which aggregate venture capital disbursements in platform businesses has increased and accelerated, the platform business model is pivotal to the outcome of the current cycle of venture capital investment.

In mid-April 2016, for example, a lead story in *The Wall Street Journal* reported that, in the first quarter of the year, the major venture capital firms such as Accel Partners and Founders Fund had attracted £13 billion worth of investments from pension funds and endowments into new funds, the largest quarterly total since the height of the dot-com boom in 2000 (Winkler, 2016). While a portion of this investment is flowing to new start-ups, the article holds that growth is symptomatic of the willingness of venture capitalists and other private investors to continue to write ‘bigger checks’ in further rounds of funding for existing companies which are encouraged ‘to spend to battle for market supremacy’. It also suggests, moreover, that the cause of the ballooning investment requirements of unicorns and other privately-owned ‘tech start-ups’ is their ‘burn rate’ – i.e., their investment costs are much greater than present revenues. For such firms, this also makes an IPO unlikely, as there is little sign that stock market investors are willing to suspend their scrutiny of revenue growth and cost-recovery, as was the case during the wave of dot-com IPOs at the turn of the millennium. Indeed, in the first quarter of 2016, there were no tech-firm IPOs in the US – the first time that this has been the case during a four-month period since the depths of the global financial crisis in 2009 (Farrell, 2016).

With an increasing volume of venture capital being staked on the prospect that a limited number of platforms will eventually be ‘home runs’ – producing the monopolistic, oligopolistic, and oligopsonist market outcomes that are necessary for user and revenue growth and thus cost recovery for investors – it also becomes increasingly unlikely that the failures and

bankruptcies of platforms will simply produce a ‘correction’ to present market optimism. As concerns emerge about the valuation of specific privately-owned platforms – Uber, for example, was valued at a staggering \$50 billion for a round of capitalisation in July 2015, despite recorded annual revenues in 2014 of just \$400 million (MacMillan and Demos, 2015) – they encourage doubts and anxieties about the sustainability of the platform business model in general and its capacity to deliver revenues and returns on investment. There are concerns, for example, that the proliferation of heavily capitalised platforms which are all seeking to monopolise market niches is undermining both the willingness of firms to provide unconstrained platforms with advertising income and the extant strategies of fee-earning constrained platforms (Morozov, 2016). Not only is the business proposition of unconstrained platforms troubled – it is based on the capitalisation of revenues from the collection, analysis and sale of data to advertisers – but a round of destructive competition amongst constrained platforms becomes necessary to their prospects for revenue growth. What needs to be subjected to further and urgent scrutiny, then, is whether investors and fund managers will continue to write ‘bigger checks’ for platforms with high ‘burn rates’ and thereby continue to sustain the present landscape of platform capitalism.

Notes

1. <<http://www.ukcfa.org.uk/members/>>
2. <<http://p2pfa.info/p2pfa-members/>>
3. <<http://www.whitelabelcrowd.fund/>>
4. The computer game industry has generated its own field of research described as ‘platform studies’ (Apperley and Parikka, 2015). While this may hold useful pointers for subsequent studies of platform capitalism, it is not our focus here.
5. See, respectively, <https://www.seedrs.com/invest/why_invest_in_startups#invest/>, and <<http://www.crowdcube.com/pg/investing-your-money-1513/>>.
6. See, for example, the discussion on this subject in The Economist’s Free Exchange blog: <<http://www.economist.com/news/finance-and-economics/21705831-new-technologies-will-make-society-richer-cultivating-trust-believing-seeing/>>.
7. <<https://www.skillshare.com/teach?via=homepage/>>
8. <<http://us.spindices.com/indices/equity/sp-500/>>
9. On the global significance of US venture capital funds and their concentration in the San Francisco Bay area, see Evans and Gawer (2016), Zook (2005) and McNeill (2016).

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