Association for Information Systems
AIS Electronic Library (AISeL)

2012 International Conference on Mobile Business

International Conference on Mobile Business (ICMB)

2012

PLATFORM COMPLEXITY: LESSONS FROM MOBILE WIRELESS

David Tilson
University of Rochester, david.tilson@simon.rochester.edu

Carsten Sorensen
London School of Economics and Political Science, c.sorensen@lse.ac.uk

Kalle Lyytinen
Case Western Reserve University, kjl13@case.edu

PLATFORM COMPLEXITY: LESSONS FROM MOBILE WIRELESS

Tilson, David, University of Rochester, Simon Graduate School of Business, Rochester NY USA, david.tilson@simon.rochester.edu

Sørensen, Carsten, London School of Economics and Political Science, Department of Management, London, UK, c.sorensen@lse.ac.uk

Lyytinen, Kalle, Case Western Reserve University, Weatherhead School of Management, kjl13@case.edu

Abstract

Platforms provide anchor-points for the coordination of a varied set of activities within their associated ecosystems. The understanding of platform complexity is therefore an important concern within both academia and industry as it defines the range of activities made possible by the platform and the related aspects of control. This paper argues that the abstractions applied in the current platform research remove some of the most important features that underlie the inherent complexity of digital platforms. This argument is forwarded through a small study of platform complexity in the mobile wireless industry. Our exploration highlights some of the phenomena that a comprehensive theory of digital platforms must encompass. We believe that advancement of a theoretical perspective that embraces the complexity of digital platforms is needed to fully capture the strategic and technological implications of emerging digital platforms.

Keywords: Digital platforms, mobile wireless industry, platform complexity

1. Introduction

In proposing a unified view of platforms Baldwin and Woodard (2009) argue that at a relatively high level of abstraction all platforms we know of, from credit cards and dating bars to Facebook, share several common features. The consensus is that a platform comprises *core* modules, which do not change quickly, coupled with *peripheral* modules that support variety. In principle such platforms support a wider diversity of products at lower cost. In the end such module reuse through platform based architectures leads to economies of scale due to sharing of fixed costs across products, as well as economies of scope through the increased flexibility to satisfy a broader range of customer needs. Furthermore, the industry-wide deployment of module interfaces results in these becoming standards which shape the dynamics of cooperation and competition (Baldwin & Clark, 2000).

In the academic literatures the term 'platform' has been applied to many things: products, systems, services and technologies as diverse as durable goods (e.g. airframes and jet engines, car underbodies and engines, printers, and power tool motors), computer operating systems, networking protocols, credit card systems, video game consoles, shopping malls, and dating sites. Mainframe computing and the rise of the personal computer have provided in-depth case studies that also reveal the relationship between modular architectures and organizational structures (Baldwin & Clark, 2000). Within the Information Systems field platforms play an increasingly important role. For example, Service Oriented Architecture (SOA) seeks to transform decades of legacy information systems into flexible platforms for the provision of novel services that support the coordination of varying business processes. The mobile wireless industry has been radically transformed though the creation of platforms based on the operating systems for smart phones and tablets. These mobile wireless platforms have, in conjunction with other industry platforms, transformed media- and computer industries. These significant developments speak of the importance of platforms as socio-technical re-configurations that can shape anything from high-level industry changes to the individual appropriation of technologies. Such changes are at the core of interests for the Information Systems field, but yet, paradoxically, have not here been at the center of academic attention (Tilson, Lyytinen, & Sorensen, 2010; Tilson, Lyytinen, & Sørensen, 2010; Yoo, 2010). The academic literature on platforms is almost exclusively from of the fields of new product development, strategy, and economics where the digital world is not conceived of differently from the world of atoms.

In this paper we pay attention to the particular differences in the types of platforms by exploring some of the complexities underlying digital platforms. We remain unconvinced that the same practical implications stated for platforms will apply equally across such a wide variety of phenomena, e.g. dating bars to mobile phone operating systems. Prior literature highlights that platforms are used within firms, along value chains, and across industries (Gawer, 2009a). This typology is our starting point, but we find that a theory of platforms willing to embrace real-world complexity would have to deal with aspects of control and the relationships between multiple platforms layered upon one another- not commonly found in the physical world. It should also deal with the differing natures of physical platforms and intangible ones, in addition to their dynamics, particularly digital platforms, as they change at different speeds across layers. The paper contributes to the debate on platform innovation by highlighting the need to explore their underlying complexity and by emphasizing that a classification of such complexity across platforms is a necessary next step to balance the need to render platforms a researchable unit of analysis while avoiding their over-simplification.

The manuscript is organized as follows. The next section reviews the dictionary definition of the term ‘platform’ to provide a starting point for our exploration. This is followed by a sampling of the literatures of that have dealt with the concept and an examination of the nature of platforms in the complex real-world setting of the mobile wireless industry (Ballon, Bouwman, & Yuan, 2011). We conclude by discussing some of the issues a comprehensive theory of platforms would have to deal with and reemphasizing the strategic importance of developing such perspectives as digital platforms multiply inside organizations and across industries.

2. The meanings of ‘platform’ in general usage

The Oxford English Dictionary (OED) has an extensive entry for *platform*[1] that includes 15 definitions each with several sub-usages. The terms *plate* or *plat* meaning flat or level, and *forme* meaning shape or arrangement of parts, stem from Middle French and have been imported into other languages meaning a flat, possibly raised, surface onto which something can be placed. Often the platform is not an end in itself but is used to support some objective. For example, a surface for building structures upon, for the mounting of a weapon, or as a base for drilling for oil. However, the recognized meanings of platform extend beyond the physical. It can be intangible, as in a company’s platform (plan) for growth, or a set of policies on which a politician appeals for support. More abstractly the term can be used metaphysically as a concept, idea, pattern, or model implying an intangible underpinning constructed to support another activity.

The OED definitions even extend to the computing domain by which a platform can be a standard system architecture, an operating system, and regarded as the base upon which software can be run. This explicitly introduces standardized arrangements of components (system architectures). In this metaphorical use hardware (e.g. a type of processor), software (e.g. an operating systems), and the ideas instantiated in both comprise the platform (e.g. Wintel). As with other uses of platform this “standard system architecture” is not an end in itself but the base upon which other layers of software support the fulfillment of human objectives (i.e. the “software applications”).

Summarizing, the term platform denotes types of foundations for building upon, either literally or figuratively. The “level arrangement” etymological origins of *platform* bring an emphasis on making further building as straightforward as possible and perhaps standardization in the making of such arrangements. However, the dictionary does not provide a typology of the information, digital, communications, and computer platforms central to the information systems and related disciplines.

3. Platforms Types and Characteristics

The term platform appeared in the product development literature from the early 1990s. A *platform product* (Wheelwright & Clark, 1992) was one that “meets the needs of a core group of customers but [is designed] for easy modification into derivatives through the addition, substitution, or removal of features.” The idea of platform product spurred research on *platform investments*, *platform technologies*, and *platform thinking*, as well as the development of advice for managers (Baldwin & Woodward, 2009). A typology recently proposed by Gawer (2009a) classifies platforms as: (a) internal platforms, (b) supply chain platforms, (c) industry platforms, or (d) multi-sided markets.

[1] http://www.oed.com/viewdictionaryentry/Entry/145374

(a) Platform products are a good example of the *internal platform* category where the approach is used within a single firm. The platform can be defined as "*a set of subsystems and interfaces that form a common structure from which a stream of derivative products can be efficiently developed and produced*" (Meyer & Lehnerd, 1997) and relies on modularity and an organizing logic represented by an architecture. Much of the literature on internal product platforms refers to physical products. In computing a defining example of an internal product platform is the modular design of the IBM System/360 family of computers defined in the 1960s that allowed customers to buy more powerful members of the family as their needs increased while retaining backward software compatibility. The explicit architecture also allowed IBM to assign the design of sub-systems to different groups. Thus it can be argued that the architecture shaped the structure of the organization as well at the product offerings (Baldwin & Clark, 2000).

(b) Outside the boundaries of a firm *supply chain platforms* share characteristics with internal platforms but with some modules designed and produced externally. In a scenario where a platform owner sets the architecture and assembles the final product this corresponds to simple outsourcing. The advice for platform owners carries over from the internal platform case with some additional complexity of coordinating a supply chain with price mechanisms rather than through hierarchical control. However, if specialist external firms gain knowledge of how to produce modules complying with the architecture they can directly compete with the platform owner. Thus firms incapable of creating their own platform architectures can extract value from those of others. The creation and enforcement of intellectual property rights, such as patents, can be used to ameliorate this. In the case of IBM's System 360, knowledge of the module interfaces became available outside IBM as key designers defected to other firms who then were able to produce compatible peripherals, such as tape drives and printers (Baldwin & Clark, 2000).

(c) The *industry platform* differs from the supply chain platform in that there is no explicitly managed supply chain but instead a loosely organized supply network or ecosystem in which several firms produce components that can be combined to form complete systems. There can still be a platform owner but the industry platform is distinguished from the supply chain platforms in that firms may not buy from one another and end-uses many not be known in advance (Gawer, 2009a). The architectures and instructions sets of Intel and ARM processors are examples of physical electronic platforms. Linux, Microsoft's Windows, Apple's iOS and other operating systems are examples of flexible software platforms. The IBM System/360 and the story of IBM outsourcing processor design to Intel and operating system design to Microsoft for its original personal computer provide empirical support for Gawer's suggestion that the development of industry platforms follows a trajectory from internal platform, supply-chain platform, to industry platform.

(d) In *multi-sided markets or -platforms* two or more groups of customers (firms or individuals) transact through the platform. The platform here acts as an intermediary between the activities and needs of different groups. Not all multi-sided markets are platforms in the sense of a stable modular core providing a foundation for a variety of offerings. For example, credit cards networks (cardholders and merchants), HMOs (patients and doctors), travel reservation services (travelers and airlines), and yellow pages (advertisers and consumers). Other multi-sided markets do count as platforms as they support innovative new products, technologies, or services. These types include operating systems (end-users and developers), video game consoles (gamers and game developers), and communication networks like the Internet. The category reflects the terminology used in industrial economics building on earlier network economics literature and tends to focus on the pricing mechanisms for coordinating these markets. For our purposes the multi-sided markets that are platforms in the sense we have been discussing can be thought of as industry platforms.

3.1 Platform Control and Openness

The essential difference between the industry- and supply-chain platform seems to be one of control. There is at least more complete control and the potential of a single vision of the end product or service in the supply-chain platform category. In the industry platform category the control becomes more distributed (unless there is natural monopoly). At the same time the level of control and which parts of an industry ecosystem are controlled vary from case to case and over time. What is controlled is also important: control of key platform assets or the relationship with the end customer form the the most important points of control (Ballon, 2009). For example, in the case of IBM's System/360 the loss of control of certain components and interfaces transformed a supply chain platform into an industry platform (Gawer, 2009a).

The industry platform has been a prominent phenomenon of interest for technology strategists. While considering the implications of a "platform strategy" Cusumano & Gawer (2008, p. 28) define an *industry platform* as "a foundation technology or service that is essential for a broader, interdependent ecosystem of businesses. The platform requires complementary innovations to be useful and vice versa. An industry platform, therefore, is no longer under the full control of the originator, even though it may contain certain proprietary elements." They offer prescriptions for firms hoping to establish industry platforms (Cusumano & Gawer, 2002; Gawer & Cusumano, 2008). The nature of their advice highlights that the process of building a platform at the industry level is an essentially sociotechnical process as platform leaders rely on the participation of, and on-going innovation by, complementors (e.g. the various parties needed to make VHS and music CDs viable, and more recently to keep the Apple iOS ecosystems flourishing). Core to platform building is effectively managing the tensions between using control of platform interfaces to extract value and retain ecological control versus opening the platform for others' innovations and successes (Ghazawneh & Henfridsson). This "balancing act of collaboration and competition that recognizes mutual dependency" may require the sacrifice of short-term interests in favor of the common good of the platform or ecosystem – say by agreeing to an architecture that allows others to extract value, making commitments not to enter complementary markets (Gawer & Henderson, 2007), or by offering tools and IPR for free.

Apple's iPod, iPhone, and iPad devices embody the iOS operating system and its potential for flexibility. The physicality of the devices is also relevant as they have been platforms for all sorts of complementary covers, chargers, sound systems, car interfaces, and so on. Not to be ignored is the complementary iTunes platform that provides a gateway for apps, e-books, music, movies, TV shows and other content for iOS devices. The contrast in the level of openness between iOS and Google's Android mobile operating systems and associated platforms bring the issue of control to the fore for industry platforms (Tilson, Sørensen, & Lyytinen, 2012) and the tensions between (a) retaining tight control of a platform to capture the lion's share of the value created, and (b) looser control to increase the overall platform value and benefiting from the innovations of complementary products, services, and technologies (Tilson, Lyytinen, & Sørensen, 2010). At the industry level at least technological platforms can be a product of not just a single strategic actor but one resulting from the interplay among several such actors. Furthermore, platform dynamics will be affected by decisions regarding platform openness and –control.

3.2 Platform Generativity

An important manifestation of control is the level of openness built into the platform. If the platform is not locked down by an owner's control of critical assets or intellectual property there is a possibility that it will be adapted, with the addition of new peripheral modules, to a few or a multitude of new and perhaps unimagined uses. This ability of a foundational technology to support multiple uses can be defined as, "*a system's capacity to produce unanticipated change through unfiltered contributions from broad and varied audiences*" (Zittrain, 2008, p. 70). However, there is more to generativity than just opening a platform to other's contributions. Some platforms have more potential than others depending on how they are composed. Zittrain for example, identifies 5 features that influence the level of platform generativity (p71):

1. Leverage – helps in performing some task
2. Adaptability – flexibility to be used in creative ways / ease of being built upon
3. Ease of mastery – easy for broad audience to adopt and adapt
4. Accessibility – can access tools (including expense and physical access)
5. Transferability – can share results and get an ecosystems of innovation and collaboration going

The combination of the personal computer with broadband Internet access exhibits these features and is a primary example of generativity flourishing on digital platforms. As we shall see below popular mobile operating systems are also highly generative.

4. Platforms in the Mobile Wireless Industry

The mobile industry is an ideal one in which to study different types of platforms and infrastructures. There are many different actors that both rely on, and provide, platforms to offer information, computing, entertainment, and communications services (Ballon, 2009). Indeed mobile operating systems have become pivotal platforms for creating service ecologies and a target for developing new services (Tilson, et al., 2012).

Mobile network operators deploy and operate the wide area cellular networks that are often referred to as 'wireless network infrastructure.' They consist of expensive physical equipment like antennas, land or rights to use high roofs, towers, radios, base station controllers, mobile switching centers, and Operation and Support Systems (OSS). This infrastructure meets the definition of a platform in that it provides the essential foundation upon which mobile communications services are offered. The particular instance of the platform represents an internal product (really service) platform. It allows a range of communications services to be offered: voice for 1G, adding texting and circuit-switched data for 2G, and packet-switched data for 2.5G onwards (Maitland, Bauer, & Westerveld, 2002; Peppard & Rylander, 2006). The industry's fairly clearly defined value chain in its voice centric 1G and early 2G eras transformed into a value network (Feng & Whalley, 2002; Sabat, 2002) as it transitioned to a more complex, data, and service centric third generation (Tilson & Lyytinen, 2006).

By including sophisticated enough billing and customer service elements the platform could be used offer a range of pricing and usage options. The use of a standardized air interface (e.g. GSM, CDMA, or UMTS) allowed many different types of handsets and some other devices (e.g. data only USB dongles, tablet computers, and e-books) to interoperate with the network. So, the physical platform with supporting software allows some variation in the product and service offerings network operators bring to market. However, at this layer it does not offer very much generativity. It is hardly *accessible* or *easy to master* for innovation by a broad audience due to both its technical complexity and the operator's ownership and control of the physical assets. The nature of the allocation of radio spectrum by governmental regulators also limits the possibility for innovation by other actors without the permission and cooperation of network operators – although WiFi is a successful exception.

Mobile networks rely directly on fixed telecommunications infrastructures for connections to telephone networks and data networks. This is essential both for the offering of primary services as well as for interconnecting geographically distributed sub-systems. The network also relies on the availability of electrical power usually delivered via a national power grid. The Internet, along with Web protocols, and the personal computer is a highly generative platform. The advent of powerful smartphones has extended the new possibilities to the mobile wireless industry. Thus, the Internet is another underlying platform upon which the mobile wireless platforms are built.

More abstractly the standardized air interfaces[2] and countless other standardized interfaces deeper in the infrastructure can be considered industry platforms. They provide the modularity for different producers to provide different parts of these complex systems. Platform leadership and -ownership is typically diffused with many types of actors involved in setting standards. Some actors may have more influence than others and may be able to capture more of the value through the licensing of IPR. Although built on deep understandings of natural phenomena and complex artifacts, these sorts of platforms while intangible are nevertheless more fundamental than the physical instances of wireless network infrastructures they underpin. The creation of intangible platforms (technical standards and architectures) is a major social undertaking common across the ICT related industries. Different processes and groups of actors can arrive at generative platforms (e.g. the Internet protocols) or more circumscribed ones (e.g. TV broadcast formats). The industry consortia and international standards bodies as well as their rules and procedures that facilitate the development of the necessary agreements represent an invisible social industry (or cross-industry) platform. Similarly, national and international agreements about the allocation of radio spectrum, professional bodies and educational institutions, and norms and laws regulating business operations and investments provide even more fundamental platforms that underpin multiple industries and other human activities.

This brief discussion makes it clear that some platforms in this industry context can be physical (e.g. radios, switches, and cables), while others can be essentially intangible, both in technical (architectures, interfaces, and protocols, designs) and social (e.g. regulations, processes, groupings) domains. It also reveals that the platform metaphor as a stable flat foundation for the creation of structures above is not quite sufficient. Platforms turn out to be recursive, building upon one another layer, upon layer. At least in what we have examined so far, the lower layers are more abstract and support a wider range of

[2] The 'air interface' incorporates the frequency assignments as well as modulation, coding, signaling and power-control schemes that allow the mobile devices to communicate with the mobile wireless infrastructure.

possibilities. This makes the idea of a core and peripheral module (Baldwin & Woodward, 2009) a relative one.

The other essential artifact of the wireless mobile industry is the mobile device. Most often this is a mobile phone handset although with the increasing popularity of smartphones it has also become a mobile computer and entertainment device. The wireless device is also built upon several platforms including the air interfaces and the various layers of the wireless network infrastructures just discussed. It is the wide adoption of the air interface and other standards that allow significant economies of scale as these intangible platforms are inscribed in the semiconductors and software. The key components in a typical mobile phone (covers about 80% of its cost) are: display, processor(s), storage, memory, camera, Radio (Cellular, Wifi, GPS, and Bluetooth) semiconductors, cellular and other IPR licenses, battery, PCBs and enclosure, keypad, and software (Dedrick, Kraemer, & Linden, 2011). Most smartphones use an ARM based microprocessor that is also a major cross-industry platform in its own right. The ARM core is a platform for numerous semiconductor manufacturers and its instruction set and software tools are platforms for developers working for device manufacturers and their partners. It is highly generative – at least for the professional audience it supports. The non-cellular wireless standards typically supported are also important platforms in their own right. As an example, the multi-billion dollar GPS system with its many satellites supports countless location, navigation, and precise timing needs around the world and across numerous industries. While many of the other key components of the device can be viewed a simply components from the perspective of the device manufacturers many of them are produced from their suppliers' product platforms.

The creation and evolution of service- and application platforms accessed on powerful smartphones represent a significant recent change to the mobile wireless industry. The earliest versions were run by network operators (e.g. DoCoMo in Japan) who had control of the service and billing relationships with the customer. More recently the Apple iPhone, built on the iOS mobile operating system and the iTunes platform for the distribution of content and applications, has become prominent. Here Apple has the primary relationship with customers as well as its own backend infrastructure that works across the networks of many mobile wireless network platforms in many countries. Apple's 'blue ocean strategy' brought a new platform that reset the rules of the game for even the most powerful mobile network operators. The operators previously exercised control of both the physical assets and the customer relationships but the new operating system centric platforms have changed the profile of their activities and competencies (Ghezzi, Balocco, & Rangone, 2010). Other mobile application platform models have also been tried including those developed by Microsoft (Windows Mobile and Windows Phone), Palm (standalone PDA and Treo phones), the T-Mobile Sidekick, and most recently the Android operating system developed at Google. The variety of models allows categorization based on the different patterns of control of key assets and customer relationships (Ballon, 2009; Gonçalves, Walravens, & Ballon, 2010). The various options and technologies have changed the governance models and flexibility for customers and network operators (de Reuver, Visser, Prieto, & Bouwman, 2010) as well as the industry structures in related industries (e.g. music, TV, movies, books) as architectures and locus of control change.

Despite exhibiting different patterns of features, Android and iOS are both highly generative platforms providing high leverage for the creation of applications. Android in addition provides leverage for device manufacturers. The two operating systems are highly adaptable but iOS may be less so as Apple reserves the option to censor applications it perceives as disruptive to its business model. Both types of mobile devices are easy to master for end users although the iOS based devices are usually considered to have an edge. The use of the Java programming language may make Android somewhat more accessible to developers than iOS's Objective C. The tight control and actively curated experience of the iTunes platform may make transferability very easy for most users but the increased openness to side loading apps or accessing them via alternative stores or peer-to-peer communities increases the accessibility for advanced users (Remneland-Wikhamn, Ljungberg, Bergquist, & Kuschel, 2011). Thus, mobile operating systems provide a clear example that there can be more than one way to establish an economically important platform technology.

5. Discussion

Theoretical perspectives are always tradeoffs of generality, accuracy, and simplicity (Weick, 1995). Many of the perspectives from the product development literature and technology strategy literatures have emphasized generality and simplicity (e.g. Gawer's internal/supply-chain/industry platform typology) while work on wireless platforms has focused on accuracy and simplicity (e.g. Ballon's typology based on what is controlled). Choosing these trade-offs is very understandable from a pragmatic point of view and the resulting books and papers are the more readable for it. Here, we use consideration of selected platform literatures and an examination of the mobile wireless industry to address the complexity of platforms, digital ones in particular. We have by no means come to an elegant theoretical perspective in this paper but have identified some of the characteristics, complexities, and relationships that theory builders willing to relax the trade-off around simplicity would have to take into account.

The first important point to come out of the examination of the mobile industry is that platforms do not generally stand alone. Rather both social and technical platforms build upon one another with the core of one platform being the periphery of another. This is handled by practitioners pragmatically by considering the affordances of other platforms as modules within the architectural models of platforms at their layers of concern. Researchers have also tended to do this but understanding the relationships between platforms could be insightful, particularly if we want to consider how they evolve. Control over physical assets, customer and complementor relationships, IPR, or 'terms and conditions' have been important in this but the relative importance of what is controlled changes over time with the evolution of the platforms and the relationships among them.

This brings us to another observation from the mobile wireless industry, and in particular for digital platforms: their dynamic nature. The industry has gone through several generations of its communications infrastructures and air interfaces. The service and applications platforms have seen several configurations with differing group of actors leveraging different types of control. At the time of writing the Android and iOS mobile operating systems were the most important service and application platforms in the industry. However, the history of such platforms has so far proven to be quite dynamic. It is possible a new platform, such as HTML 5, combined with a payment platform, could yet again change the rules of the game and the locus of control. Thus, the slow changing of the platform core versus the periphery is more intricate and interrelated than we might think as the different layers change at different rates.

A hierarchical model consisting of products and applications, comprised of components, which are in turn supported by (technical) infrastructure has been used to make sense of change in IT products

(Adomavicius, Bockstedt, Gupta, & Kauffmann, 2008). Interactions among elements at each level form the dynamic relationships of an ecosystem (e.g. the development of the cell phone spurred development of enhanced cellphone component technologies). A similar approach has examined the parallel development of business, application software, and ICT platform architectures (Aerts, Goossenaerts, Hammer, & Wortmann, 2004). Expanding the logic of this sort of perspective to take account of the layers of platforms could provide a way of tackling change across platforms and industries. It would probably be necessary to incorporate the social dimension, say by including the interplay between customer choice and product design hierarchies (Funk, 2007, 2008). This might offer a way breaking up the complex socio-technological world to help us examine platform dynamics.

There is also a distinct difference in the dynamics of platforms based on their tangibility. It makes intuitive sense that it is more challenging to change large physical capital-intensive platforms (e.g. electrical power infrastructures) that are constrained by the laws of physics than one purely instantiated in software (e.g. an application distribution platform). Nevertheless, the network effects of a widely adopted platform and difficulties of coordination can, in some contexts, make change just as challenging as evidenced by the difficult of moving to the IPv6 protocol before the lack of IP addresses become problematic (Hanseth, Monteiro, & Hatling, 1996).

Some platforms provide considerable generativity while others offer more limited affordances. This is partly explained by control exerted by a key actor on the platform, say through the ownership of assets. However, there are other considerations with some platforms being inherently more generative than others due to various features (Zittrain, 2008) and particularly the potential for flexibility inherent in digital platforms. For example, Applies iOS/iTunes platform has been updated and its terms and conditions changed in response to signals from its ecosystems. This has allowed Apple to change the affordances of the platform, i.e. what it will support, as well as to exert or relax controls. Characterizing and understanding the tensions between change and control in platforms may well provide the best hope of coming to a unified view of platforms that embraces complexity rather than abstracting it away (Tilson, Lyytinen, & Sørensen, 2010).

Developing platform theories will not only help us better understand industry dynamics. It is also becoming increasingly important as organizations seek to 'platformize' (e.g. using SOA) their internal IT capabilities that in turn rely on platforms developed by vendors, or integrate external platforms (e.g. cloud computing) with internal ones. Perhaps a viable research strategy for the further development of our understanding of platforms and their innovation must rely on drawing up harder analytical distinctions. For example, distinguishing between: 1) platforms anchored solidly within a manufacturing paradigm and relying significantly on the economies of scale of manufacturing processes through modularity; 2) platforms based on the tight coupling of physical- and digital elements, thereby characterized by a layered-modular architecture (Yoo, Henfridsson, & Lyytinen, 2010); and 3) digital platforms characterized by interrelated layers. It will also be critical for further platform studies to extend the understanding to include not only the technical elements making up the core technical platform artifacts. Rather, research must fully consider the inherent socio-technical complexity meshing social processes, socio-technical arrangements and the technical artifacts. Lastly, much of the traditional literature on platform innovation emphasize arrangements aimed at development and manufacture, whereas the context of digital platforms calls for an additional emphasis on the platform in use as this raises infrastructural issues concerning the role of the installed base.

References

Adomavicius, G., Bockstedt, J. C., Gupta, A., & Kauffmann, R. J. (2008). Making Sense of Technology Trends in the Information Technology Landscape: A Design Science Approach. *MIS Quarterly, 32*(4).

Aerts, A. T. M., Goossenaerts, J. B. M., Hammer, D. K., & Wortmann, J. C. (2004). Architectures in context: on the evolution of business application software, and ICT platform architectures. *Information & Management, 41*, 781-794.

Baldwin, C. Y., & Clark, K. B. (2000). *Design rules. Vol. 1, The power of modularity*. Cambridge, Ma.: MIT Press.

Baldwin, C. Y., & Woodward, C. J. (2009). The architecture of platforms: A unified view. In A. Gawer (Ed.), *Platforms, Markets and Innovation* (pp. 19-44). Cheltenham, UK: Edward Elgar Publishing.

Ballon, P. (2009). The Platformization of the European Mobile Industry. *Communications & Strategies, 75*(3rd Quarter), 1.

Ballon, P., Bouwman, H., & Yuan, Y. (2011). Introduction to special issue on Mobile Platforms. *Journal of Theoretical and Applied Electronic Commerce Research, 6*(2), v-vi.

Cusumano, M. A., & Gawer, A. (2002). The elements of platform leadership. *MIT Sloan Management Review, 43*(3), 51.

de Reuver, M., Visser, A., Prieto, G., & Bouwman, H. (2010). *Governance of flexible mobile service platforms*. Paper presented at the 14th International Conference on Intelligence in Next Generation Networks (ICIN).

Dedrick, J., Kraemer, K. L., & Linden, G. (2011). The distribution of value in the mobile phone supply chain. *Telecommunications Policy, 35*, 505-521.

Feng, L., & Whalley, J. (2002). Deconstruction of the telecommunications industry: from value chains to value networks. *TElecommunications Policy, 26*, 451-472.

Funk, J. L. (2007). Technological Change within Hierarchies: The Case of the Music Industry. *Economics of Innovation & New Technology, 16*(1), 1-16.

Funk, J. L. (2008). Systems, Components and Technological Discontinuities: The Case of the Semiconductor Industry. *Industry & Innovation, 15*(4), 411-433.

Funk, J. L. (2009). The co-evolution of technology and methods of standard setting: the case of the mobile phone industry. *Journal of Evolutionary Economics, 19*(1), 73-93.

Gawer, A. (2009a). Platform Dynamics and Strategies: From Products to Services. In A. Gawer (Ed.), *Platforms, Markets, and Innovation*. Cheltenham, UK: Edward Elgar Publishing.

Gawer, A. (2009b). *Platforms, Markets and Innovation*: Edward Elgar Pub.

Gawer, A., & Cusumano, M. A. (2002). *Platform Leadership: How Intel, Microsoft, and Cisco Drive Industry Innovation*. Boston, MA: Harvard Business School Press.

Gawer, A., & Cusumano, M. A. (2008). How Companies Become Platform Leaders. *MIT Sloan Management Review, 49*(2), 28.

Gawer, A., & Henderson, R. (2007). Platform Owner Entry and Innovation in Complementary Markets: Evidence from Intel. *Journal of Economics & Management Strategy, 16*(1), 1-34.

Ghazawneh, A., & Henfridsson, O. Balancing Platform Control and External Contribution in Third-Party Development: The Boundary Resources Model. *forthcoming in Information Systems Journal*.

Ghezzi, A., Balocco, R., & Rangone, A. (2010). *How a new distribution paradigm changes the core resources, competencies and capabilities endowment: the case of Mobile Applications Stores*. Paper presented at the Ninth International Conference on Mobile Business / 2010 Ninth Global Mobility Roundtable, Athens, Greece.

Gonçalves, V., Walravens, N., & Ballon, P. (2010). *How about an App Store? Enablers and Contrstraints in Platform Strategies for Mobile Network Operators*. Paper presented at the Ninth International Conference on Mobile Business / 2010 Ninth Global Mobility Roundtable, Athens, Greece.

Hanseth, O., Monteiro, E., & Hatling, M. (1996). Developing Infomration Infrastructure: The Tension between Standardization and Flexibility. *Science, Technology, & Human Values*, *21*(4), 407-426.

Maitland, C. F., Bauer, J. M., & Westerveld, R. (2002). The European Market for Mobile Data: Evolving Value Chains and Industry Structures. *Telecommunications Policy*, *26*(9-10), 485-504.

Meyer, M. H., & Lehnerd, A. P. (1997). *The Power of Product Platforms: Building Value and Cost leadership*. New York: Free Press.

Peppard, J., & Rylander, A. (2006). From Value Chain to Value Network: Insights for Mobile Operators. *European Management Journal*, *24*(2-3), 128-141.

Remneland-Wikhamn, B., Ljungberg, J. A. N., Bergquist, M., & Kuschel, J. (2011). Open Innovation, Generativity and the Supplier as Peer: The Case of iPhone and Android. *International Journal of Innovation Management, 15*(1), 205-230.

Sabat, H. K. (2002). The evolving mobile wireless value chain and market structure. *Telecommunications Policy, 26,* 505-535.

Tilson, D., & Lyytinen, K. (2006). The 3G Transition: Changes in the U.S. Wireless Industry. *Telecommunications Policy, 30*(10-11), 569-586.

Tilson, D., Lyytinen, K., & Sorensen, C. (2010). *Desperately seeking the Infrastructure in IS Reserach: Conceptualization of "Digital Convergence" as co-evolution of social and technical infrastructures*. Paper presented at the Hawaii International Conference on System Sciences, Kauai, HI.

Tilson, D., Lyytinen, K., & Sørensen, C. (2010). Digital Infrastructures: The Missing IS Research Agenda. *Information Systems Research, 21*(4), 748-759.

Tilson, D., Sørensen, C., & Lyytinen, K. (2012, January). *Change and Control Paradoxes in Mobile Infrastructure Innovation: Change and Control Paradoxes in Mobile Infrastructure Innovation.* Paper presented at the Hawaii International Conference on System Sciences

Weick, K. E. (1995). What theory is not, theorizing is. *Administrative Science Quarterly, 40*(3), 385-390.

Wheelwright, S. C., & Clark, K. B. (1992). Creating project plans to focus product development. *Harvard Business Review, 70*(2), 67-83.

Yoo, Y. (2010). Computing in Everyday Life: A Call for Research on Experiential Computing. *MIS Quarterly, 34*(2), 213-231.

Yoo, Y., Henfridsson, O., & Lyytinen, K. (2010). The New Organizing Logic of Digital Innovation: An Agenda for Information Systems Research. *Information Systems Research, 21*(4), 724-735.

Zittrain, J. (2008). *The Future of the Internet*. New Haven and London: Yale University Press.