Industry Platforms and Ecosystem Innovation

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Industry Platforms and Ecosystem Innovation

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Abstract

This article discusses how externally focused ?industry platforms? affect innovation. First, we define the term ?platform? and discuss why this concept is important. Second, we provide an overview of the relevant literature in order to clarify differences in the types of platforms and associated economic and strategic concepts. Third, we review the case of Intel and other examples to illustrate the range of technological, strategic, and business challenges that platform leaders and their competitors face as markets and technologies evolve. Finally, we identify practices associated with effective platform leadership and avenues for future research to deepen our understanding of this phenomenon.

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This article discusses how externally focused "industry platforms" affect innovation. First, we define the term "platform" and discuss why this concept is important. Second, we provide an overview of the relevant literature in order to clarify differences in the types of platforms and associated economic and strategic concepts. Third, we review the case of Intel and other examples to illustrate the range of technological, strategic, and business challenges that platform leaders and their competitors face as markets and technologies evolve. Finally, we identify practices associated with effective platform leadership and avenues for future research to deepen our understanding of this phenomenon.

Platform Definitions and Distinctions

What managers and researchers refer to as "platforms" exist in a variety of industries, especially in high-tech businesses driven by information technology. Microsoft, Apple, Google, Intel, Cisco, ARM, Qualcomm, EMC, and hundreds if not thousands of other firms, small and large, build hardware and software products as well as applications, and provide a variety of services, for computers, cell phones, and consumer electronics devices that in one form or another serve as industry platforms. All these firms and their partners participate in what we can call platform-based "ecosystem" innovation (Moore, 1996; Iansiti and Levien, 2004). Platforms are also often associated with "network effects": that is, the more users who adopt the platform, the more valuable the platform becomes to the owner and to the users because of growing access to the network of users and often a set of complementary innovations. As we will discuss later, moreover, there are increasing incentives for more firms and users to adopt the platform and join the ecosystem as more users and complementors join.[1]

Industry platforms and associated innovations, as well as platforms on top of or embedded within other platforms (such as microprocessors embedded within personal computers or smart phones that access the Internet, on top of which search engines such as Google and social media networks such as Facebook exist, and on top of which applications operate, etc.) have become increasingly pervasive in our everyday lives. Not surprisingly, several distinct academic literatures have studied this phenomenon. The term platform has become nearly ubiquitous, appearing in the new product development and operations

[1] We use the term "complementor" in the sense defined by Brandenburger and Nalebuff (1996), as a short-hand for "the developer of a complementary product" where two products are complements if greater sales of one increase demand for the other. Formally, A and B are complements if the valuation by consumers of A and B together is greater than the sum of the valuation of A alone and of B alone. $V_{a+b} = (1 + \delta)(V_a + V_b)$, $\delta > 0$.

management field (Meyer and Lehnerd, 1997; Cusumano and Nobeoka, 1998; Simpson *et al.*, 2005); in technology strategy (Gawer and Cusumano, 2002 and 2008, Eisenmann, Parker and Van Alstyne, 2006); and in industrial economics (Rochet and Tirole, 2003; Evans, 2003; Armstrong, 2006). But our analysis of a wide range of industry examples suggests that there are two predominant forms of platforms: internal or company-specific platforms, and external or industry-wide platforms.

In this paper, we define internal (company or product) platforms as a set of assets organized in a common structure from which a company can efficiently develop and produce a stream of derivative products (Meyer and Lehnerd, 1997; Muffato and Roveda, 2002). We define external (industry) platforms as products, services or technologies that are similar to the former but provide the foundation upon which outside firms (organized as a 'business ecosystem') can develop their own complementary products, technologies, or services (Gawer and Cusumano, 2002; Gawer, 2009a). These are high-level definitions, and it is instructive to see how researchers have treated the distinctions between these two types of platforms at a more detailed level.

Research on Internal and External Platforms[2]

Internal Platforms

The first popular usage of the term platform seems to have been in the context of new product development and incremental innovation around reusable components or technologies. We refer to these as internal platforms in that a firm, either working by itself or with suppliers, can build a family of related products or sets of new features by deploying these components. Wheelwright and Clark (1992), for example, describe how "product platforms" can meet the needs of different customers simply by modifying, adding, or subtracting different features. McGrath (1995), Meyer and Lehnerd (1997), Cusumano and Nobeoka (1998), Krishman and Gupta (2001), and Muffatto and Roveda, (2002) all define platforms as a set of subsystems and interfaces that form a common structure from which a company can efficiently develop and produce a family of automobile products or consumer electronics devices. Robertson and Ulrich (1998) propose an even broader definition, viewing platforms as the collection of assets (*i.e.*, components, processes, knowledge, people and relationships) that a set of products share. In the marketing literature, Sawhney (1998) even suggests that managers

[2] This section follows Gawer (2009a) ["Platform Dynamics and Strategies: from Products to Services"].

should move from "portfolio thinking" to "platform thinking," which he defines as understanding the common strands that tie the firm's offerings, markets, and processes together, and exploit these commonalities to create leveraged growth and variety.

These literatures have identified, with a large degree of consensus, several potential benefits of internal platforms: savings in fixed costs; efficiency gains in product development through the reuse of common parts and "modular" designs, in particular, the ability to produce a large number of derivative products with limited resources; and flexibility in product feature design. One key objective of platform-based new product development seems to be the ability to increase product variety and meet diverse customer requirements, business needs, and technical advancements while maintaining economies of scale and scope within manufacturing processes – an approach also associated with "mass customisation" (Pine, 1993).

The empirical evidence indicates that, in practice, companies have successfully used product platforms to control high production and inventory costs, as well as reduce time to market. Most of the early research is about durable goods, whose production processes involve manufacturing, such as in the automotive, aircraft, equipment manufacturing, and consumer electronics sectors. Companies frequently associated with module-based product development and families of products derived from common internal platforms include Sony, Hewlett-Packard, NDC (Nippon Denso), Boeing, Honda, Rolls Royce, and Black & Decker (Sanderson and Uzumeri, 1997; Feitzinger and Lee, 1997; Whitney, 1993; Lehnerd, 1987; Rothwell and Gardiner, 1990; Sabbagh, 1996; Reichtin and Kranz, 2003; Simpson et al., 2005).

Researchers have also identified a few fundamental design principles or 'design rules' that appear to operate in internal product platforms, in particular the stability of the system architecture, and the systematic or planned reuse of modular components (Baldwin and Clark, 2000; Baldwin and Woodward, 2009). We can see as well a fundamental trade-off couched in terms of functionality and performance: the optimization of any particular subsystem may result in the sub-optimization of the overall system (Meyer and Lehnerd, 1997). In this sense, internal platforms may promote only incremental innovation or constrain some types of innovation – a theme that we will return to later in this article.

We should also mention the concept of a "supply-chain platform," although we see this as a special case of internal platform, Here, a set of firms follow specific guidelines to supply intermediate products or components to the platform leader or the final product

assembler. The objective of these platforms is also to improve efficiency and reduce cost such as by the systematic reuse of modular components. Major potential benefits are that a firm with access to a platform supply chain can tap into external capabilities to find more innovative or less expensive components and technologies. At the same time, a firm may have less control over the components and technology, which can have its own negative consequences. Supply chain platforms are common in assembly industries, such as consumer electronics, computers, and automobiles (Tierney et al., 2000; Bremner et al., 2004; Szczesny, 2003; Sako, 2003, 2009; Zirpoli and Becker, 2008; Zirpoli and Caputo, 2002; Brusoni, 2005; Brusoni and Prencipe, 2006). We can also link this literature to other research on sharing modules across firms (Staudenmayer, Tripsas and Tucci, 2005), limits of modularity as a design strategy (Brusoni and Prencipe, 2001), and industry architecture or structure (Jacobides, Knudsen and Augier, 2006; Pisano and Teece, 2007). But the research suggests that a key distinction between supply chains and industry platforms is that, in the case of industry platforms, the firms developing the complementary innovations – such as applications for Windows or the Apple App Store – do not necessarily buy from or sell to each other. Nor are they usually part of the same supply chain or share patterns of cross-ownership, such as Toyota does with its major component suppliers.

External Platforms

We have defined external or industry platforms, the main subject of this paper, as products, services or technologies developed by one or more firms, and which serve as foundations upon which a larger number of firms can build further complementary innovations, in the form of specific products, related services or component technologies. There is a similarity to internal platforms in that industry platforms provide a foundation of common components or technologies, but they differ in that this foundation is "open" to outside firms. The degree of openness can vary on a number of dimensions – such as level of access to information on interfaces to link to the platform or utilize its capabilities, the type of rules governing use of the platform, or cost of access (as in patent or licensing fees). In general, despite different degrees of openness, various products and technologies serve as industry platforms: the Microsoft Windows and Linux operating systems; Intel and ARM microprocessors; Apple's iPod, iPhone, and iPad along with the iOS operating system and iTunes and the Apple App Store; Google's Internet search engine and Android operating system for smart phones, social networking sites such as Facebook, LinkedIn, and Twitter;

video-game consoles; and even the Internet itself. We can even view payment technologies, ranging from credit and debit cards to micropayment schemes, as platforms that enable financial transactions.

Early research on industry platforms and their innovation ecosystems generally focused on computing, telecommunications, and other information-technology intensive industries. For example, Bresnahan and Greenstein (1999), in their study of the computer industry, analyzed platforms as a bundle of standard components around which buyers and sellers coordinated their efforts. West (2003) defined a computer platform as an architecture of related standards that allowed modular substitution of complementary assets such as software and peripheral hardware. Iansiti and Levin (2004) called a 'keystone firm' the equivalent of what Gawer and Cusumano (2002, 2008) referred to as a platform leader, that is a firm that drives industrywide innovation for an evolving system of separately developed components. Gawer and Henderson (2007) described a product as a platform when it is one component or subsystem of an evolving technological system, when it is strongly functionally interdependent with most of the other components of this system, and when end-user demand is for the overall system, so that there is no demand for components when they are isolated from the overall system.

Taken together, these studies suggest several generalizations with regard to how industry platforms affect competitive dynamics as well as innovation at the ecosystem level. Positions of industrial leadership are often contested and lost when industry platforms emerge, as the balance of power between assemblers and component-makers changes. And, at the same time, industry platforms tend to facilitate and increase the degree of innovation on complementary products and services. The more innovation there is on complements, the more value it creates for the platform and its users via network effects, creating a cumulative advantage for existing platforms: As they grow, they become harder to dislodge by rivals or new entrants, the growing number of complements acting like a barrier to entry. The rise of industry platforms raises complex social welfare questions regarding the trade-offs between the social benefits of platform-compatible innovation, versus the potentially negative effects of preventing competition on overall systems.

The design principles or "design rules" of industry platforms also overlap somewhat with those for internal and supply-chain platforms. In particular, the stability of the platform architecture is still essential. However, there are important differences. In contrast to what happens for internal and supply-chain platforms, in industry platforms, the logic of design is

inverted. Instead of a firm being a "master designer" or assembler, here, we start with a core component that is part of an encompassing modular structure, and the final result of the assembly is either unknown *ex ante*, or incomplete. In fact, in industry platforms, the end-use of the end-product or service is not fully pre-determined. This creates unprecedented scope for innovation on complementary products, services and technologies. The situation simultaneously evokes the fundamental question of how incentives (for third-parties) to innovate can be embedded in the design of the platform. This leads to another design rule for industry platforms: The interfaces around the platform must be sufficiently "open" to allow outside firms to "plug in" complements as well as innovate on these complements and make money from their investments. This resonates well with research by Chesbrough (2003) and others (von Hippel, 2005) on open innovation. However, recent research on platforms, by highlighting the complex trade-offs between "open" and "closed" (Eisenmann, Parker and Van Alstyne, 2009; Greenstein, 2009; Schilling, 2009; Gawer and Cusumano, 2008), suggest that while opening up interfaces will increase complementors' incentives to innovate, it is important to preserve as proprietary some source of revenue and profit. It therefore adds a more subtle take on the literature on open innovation that had extolled the benefits of opening interfaces.

There are also specific strategic questions that arise in the context of industry platforms. For example, Gawer and Cusumano (2008) argue that not all products, services or technologies can become industry platforms. To perform this industry-wide role and convince other firms to adopt the platform as their own, the platform must (1) perform a *function* that is essential to a broader technological system, and (2) solve a *business* problem for many firms and users in the industry. While necessary, these conditions alone are not sufficient to help firms transform their products, technologies or services into industry platforms, nor indicate how platform leaders can stimulate complementary innovations by other firms, including some competitors, while simultaneously taking advantage of owning the platform.

One particular challenge for innovation dynamics is that platform leaders and competitors must navigate a complex strategic landscape where both competition and collaboration occur, sometimes among the same actors. For example, as a technology evolves, platform owners often face the opportunity to extend the scope of their platform and integrate into complementary markets. This creates disincentives for complementors to invest in innovation in these complementary markets. For example, Farrell and Katz (2000) identified the difficulty for platform owners to commit not to squeeze the profit margins of their

complementors. Gawer and Henderson (2007) show how Intel's careful selection of which complementary markets to enter (the connectors) while giving away corresponding intellectual property allowed the firm to push forward the platform/applications interface, thereby retaining control of the architecture, while renewing incentives for complementors to innovate "on top of" the newly extended platform. Another challenge is that, as technology is constantly evolving, the business decisions and the technology or design decisions have to be taken in a coherent manner. This is difficult to achieve since these decisions are often made by different teams within the organization. Hence, to make the whole greater than the sum of the parts, as in Gawer and Cusumano (2002), we can see the need in many complex systems industries for one firm or a small group of firms to act as a "platform leader".

Network Effects and Multi-Sided Markets

But perhaps the most critical distinguishing feature of an industry platform compared to an internal company platform or supply chain is the potential creation of network effects. As mentioned earlier, these are positive feedback loops that can grow at exponentially increasing rates as adoption of the platform and the complements rise. The network effects can be very powerful, especially when they are "direct" (sometimes called "same-side") between the platform and the user of the complementary innovation and reinforced by a technical compatibility or interface standard that makes using multiple platforms ("multi-homing") difficult or costly. For example, Windows applications or Apple iPhone applications only work on compatible devices. Or Facebook users can only view profiles of friends and family within their groups. The network effects can also be "indirect" or "cross-side," and sometimes these are very powerful as well. These occur when, for example, advertisers become attracted to the Google search engine because of the large number of users. Companies can also innovate in business models and find ways of charging different sides of the market to make money from their platform or from complements and different kinds of transactions or advertising (Eisenmann, Parker and Van Alstyne, 2006).

There may be some limits to these effects, however. Boudreau (forthcoming), in a study of ecosystems for mobile computing and communications platforms, has found that, while there is a positive feedback loop to the number of complementors, this positive impact does not perpetuate itself ad infinitum. Too many complementors at some point seem to discourage additional firms from making the investment to join the ecosystem.

In parallel with the strategy literature, some researchers in industrial organization economics have begun using the term platform to denote markets with two or more sides, and potentially with network effects that cross different sides. Such a "multi-sided market" provides goods or services to several distinct groups of customers, all of whom need each other in some way and rely on the platform to mediate their transactions (Evans, 2003; Rochet and Tirole, 2003 and 2006). While the concept of a multi-sided market can sometimes apply to supply-chain platforms as well as industry platforms, it does not entirely conform to either category. But there are important similarities between industry platforms and multi-sided markets. Among the similarities are the existence of indirect network effects that arise between two different sides of a market when customer groups must be affiliated with the platform in order to be able to interact or transact with one another (Armstrong, 2006; Caillaud and Jullien, 2003; Evans, 2003, Hagiu, 2006; Rochet and Tirole, 2003 and 2006). At the same time, though, not all multi-sided markets are industry platforms as we describe them in this paper. Double-sided markets where the role of the platform is purely to facilitate exchange or trade, without the possibility for other players to innovate on complementary markets, seem to belong to the supply-chain category. A multi-sided market that stimulates external innovation could be regarded as an industry platform. However, while all industry platforms function in this way, not all multi-sided markets do. For example, dating bars and web sites, a common example used in the literature, can certainly be seen as double-sided markets since they facilitate transactions between two distinct groups of customers. But there need not be a market for complementary innovations facilitated by the existence of the platform.

The emerging literature on double-sided markets (Rochet and Tirole, 2003 and 2006; Armstrong, 2006; Caillaud and Jullien, 2003; Evans, 2003) helps us understand the "chicken-and-egg problem" of how to encourage access to a platform for distinct groups of buyers or sellers. But, the literature also has some significant limitations from the perspective of platform research. For example, it takes for granted the existence of the markets that transact through the platform. With the notable exceptions of Parker and Van Alstyne (2005) and Hagiu (2007a and 2007b), this literature has delivered only limited insight into *why* such platforms come into existence in the first place: the drivers of platform emergence and evolution. Most papers focus on pricing as the key to encouraging access and adoption. In a welcome development, however, Evans (2009) focuses on start-up platform strategies, while

Hagiu (2007b), Eisenmann et al. (2009), and Boudreau and Hagiu (2009) focus on the importance of non-price mechanisms for the governance of platform ecosystems. They suggest, in accordance with Gawer and Cusumano (2002), that pricing alone cannot be the answer to the inevitable strategic questions of platform dynamics, such as how to share risks among members of an ecosystem. These papers take the double-sided (or multi-sided) literature to the next level and bridge the strategy and product design literature as well as the industrial organization economics literature.

Platform Leadership and the Case of Intel

Platform leaders find themselves in both a laudable and difficult strategic situation: They are central players in an ecosystem but highly dependent on innovations and investments from other firms. Far from remaining passively impacted by the decisions of others, however, the evidence suggests that platform leaders have a variety of strategic alternatives they can use to influence the direction of innovation in complementary products by third parties. Platform leaders, therefore, are organizations that manage to successfully establish their product, service, or technology, as an industry platform and rise to a position where they can influence the trajectory of the overall technological and business system of which the platform is a core element. When done properly, these firms can also derive an architectural advantage from their relatively central positions.

At the same time, platform leaders generally want to maintain or increase competition among complementors, thereby maintaining their bargaining power over complementors. Platform leadership is therefore always accompanied by some degree of architectural control (Schilling, 2009) as well as interdependence. The momentum created by the network effects between the platform and its complementary products or services, can often erect a barrier to entry for potential platform competitors.

It follows that establishing an industry platform requires more than technical efforts and astute decisions about design and architecture to facilitate complementary innovations. Platform leaders must also strive to establish a set of business relationships that are mutually beneficial for ecosystem participants and be able to articulate a set of mutually enhancing business models.[3]

[3] While platform leaders will often claim that establishing trust between themselves and complementors is essential to their success, recent research (Perrons, 2009) explores in detail the issue of trust in platform leadership and attempts to separate empirically whether the alignment platform leaders obtain from complementors is due to coercion or due to trust.

Gawer and Cusumano (2002, 2008) have studied several examples of industry platforms and the behaviour of leading companies in those markets. In particular, based on their study of Intel, with comparisons to Microsoft, Cisco, Palm, and NTT DoCoMo, they developed the concept of "platform leadership," along with its associated strategic activities and practices. Their 2002 study in particular describes in detail the key actions Intel took to rise from a simple component maker to supplier within a system architecture that it had not designed, and then to transform itself into a major source of influence over the evolution of the personal computer.

Beginning in the early 1980s, Intel (founded in 1968) has contributed an essential hardware component, the microprocessor, to personal computers, while Microsoft has contributed an essential software component, the operating system, as well as some key applications products such as Office. The PC market grew rapidly during the 1980s and industry leadership shifted from Apple (founded in 1976) to IBM and then to Intel and Microsoft (founded in 1975). But Intel executives, in the early 1990s, began to believe that it would be increasingly difficult to continue growing demand for PCs for at least two reasons: First was an increasingly obsolete PC architecture, which made it difficult to handle new graphical applications or communications functions (remote database access as well as fax and telephony, video conferencing, etc.). Second was the lack of technical leadership to advance the PC "system" – basic hardware and software as well as new applications and connections to peripherals such as printers, cameras, fax machines, scanners, and the like. It is well-known that, when Intel first developed microprocessors for personal computers, it was not the architect of the overall system. Intel entered the market merely as a component supplier to IBM, whose engineers had designed the overall platform. But the aging IBM PC architecture was becoming a problem for Intel in that the system architecture and limitations on available basic software and applications prevented its chips from reaching their maximum performance levels, especially compared to advances in the Macintosh computer (introduced in 1984) and various high-performance work stations using RISC (reduced instruction-set computing) architectures .

The problem was serious for Intel because what had become its primary business – designing and manufacturing microprocessors for personal computers — was an enormous growth opportunity that requires billions of dollars in investment for each microprocessor generation. Yet the systemic nature of the PC meant that the success of the platform involved many actors that Intel did not control. Many companies (in particular, all the suppliers for this

architecture) had a stake in the PC design. No single supplier of software or other components (chip sets, screens, keyboards, printers, operating systems or applications) could evolve the overall system by itself, let alone change it significantly.

Therefore, the first problem that Intel faced was that the architecture of the system was becoming obsolete or was less advanced and much more difficult to use than competing computer systems. The second problem was that there did not seem to emerge a leader capable of moving the platform technology forward in a way that was either satisfactory for users or for Intel. Intel executives, led by co-founder and Chairman Gordon Moore, and CEO Andy Grove, were also thinking ahead, to the trajectory of innovation in which they were planning to invest. They intended to develop and commercialise a whole stream of ever more powerful microprocessors frequently and regularly in subsequent years (this investment pattern, where microprocessor power increased on a predictable basis while prices fell came to be known as "Moore's Law"). A solution to the problem of the PC architecture, therefore, from Intel's perspective, had to accommodate management's future vision for the company.

In 1991, Intel executives established a laboratory within the company to address these fundamental technical and strategic challenges. This group would be called the Intel Architecture Lab – or IAL. Grove initiated the creation of IAL by asking Dr. Craig Kinnie, who had had already been involved in previous system-design effort within Intel, to tackle the problem that the PC platform was not moving ahead as fast as Intel would like. Kinnie went on to head the IAL for the next ten years and came to champion IAL's vision – both inside and outside Intel.

Grove wanted the Intel Architecture Lab to become the "architect of the open computer industry."[4] Kinnie recalled how "Dr. Grove concluded that … *we needed to provide leadership to the industry to cause the platform to evolve more quickly, to get new applications and new uses for the platform… Andy Grove essentially asked me* — his specific words — *to become the architect for the open computer industry, to help the industry figure out how to evolve the platform.* A narrow view of that would be to pretend that I was in a large company like IBM and that all these other companies worked for me and my boss, and that we could work together."[5]

[4] Author interview with Dr. Craig Kinnie, Director, Intel Architecture Lab, Intel Corporation, Hillsboro, Oregon, USA, 11 November 1997.
[5] Author interview with Dr. Craig Kinnie, *op. cit.*

During the mid-1990s, IAL's mission evolved so that IAL became "a catalyst for innovation in the industry."[6] Specifically, IAL became proactive in helping Intel with what company people called "Job 1" – selling more microprocessors, which were Intel's main revenue and profit generators. By driving or "orchestrating" innovation activities at other firms that complemented Intel microprocessors, IAL engineers tried to create new uses for computing devices and thus help generate demand for new computers – most of which would probably use Intel microprocessors.[7] By 1997, IAL's mission had become even broader: "to establish the technologies, standards and products necessary to grow demand for the extended PC through the creation of new computing experiences."[8] Accordingly, IAL became actively involved in driving architectural progress on the PC system, but also in stimulating and facilitating innovation on complementary products, and finally coordinating many firms' innovative work in the industry, attempting to push forward the development of new system capabilities. Table 1 is a list of representative IAL activities during 1997-1998 aimed at orchestrating industry-level innovation as well as developing open system interfaces to stimulate complementary products and services from third parties. Table A in the Appendix provides further details on the industry initiatives aimed at coordinating industry innovation.

Table 1: A list of Intel's platform leadership activities (1997-1998)

	Projects	**Type of Project**	**Did Intel share Intellectual Property for low royalties?**	**Did Intel engage in cross-industry coordination, or in other forms of facilitation of complementors' innovation?**
1	Networked Multimedia	Industry initiative	N first/Y later	Y
2	Manageability	Industry initiative	Y	Y
3	Big Pipes (Broadband)	Industry initiative	Y	Y
4	Security	Industry initiative	Y	Y
5	Anywhere-in-the-Home	Industry initiative	Y	Y
6	Advance-the-Platform	Industry initiative	Y	Y
7	PCI (Peripheral Component Interface)	System interface	Y	Y
8	AGP (Advanced Graphics	System interface	Y	Y

[6] Author interview with Dave Johnson, Director of the Media and Interconnect Technology Lab, Intel Architecture Lab, Intel Corporation, Hillsboro, Oregon, USA, 20 August 1998.
[7] Author interview with Carol Barrett, Marketing Manager, Intel Architecture Lab, Hillsboro, Oregon, USA, 5 August 1998. Also, "Intel Architecture Labs, Overview," undated Intel internal document.
[8] Intel internal document, "Intel Architecture Lab: Overview" (1998).

	Port)			
9	USB (Universal Serial Bus)	System interface	Y	Y
10	1394 (also called FireWire)	System interface	Y	Y
11	TAPI (Telephony Application Programming Interface)	System interface	Y	Y
12	H.323 (Computer telephony interface)	System interface	Y	N first/Y later
13	Home Radio-Frequency	System interface	Y	Y
14	DVD (Digital Video Disk)	System interface	Y	Y
15	CDSA (Security)	System interface	Y	Y
16	Indeo (Intel Video)	System interface	N first/Y later	N first/Y later

Source: adapted from Gawer (2000) and Gawer and Henderson (2007)

The Intel study and comparisons to other firms suggests that companies which aim to establish their products, technologies, or services as platforms should attempt to orchestrate third-party industry innovation on complements in the context of a *coherent* set of strategic moves. Gawer and Cusumano described these strategic options as the "four levers" of platform leadership: (1) firm scope (which, if any, complements to make in-house); (2) technology design (degree of modularity in the platform) and intellectual property strategy (for example, free and open access to platform interfaces or services versus not free and closed); (3) external relations with complementors (such as initiatives to promote investments in complementary innovations); and (4) internal organization (company structures and processes that help manage conflicts should they arise, such as when the platform leader makes complements that compete directly with ecosystem partners).

We can see successful platform leaders both encouraging and constraining innovation. Intel did separate internal product or R&D groups that might have conflicting interests among themselves or clash with third-party complementors, such as chipset and motherboard producers. The latter relied on Intel's advance cooperation to make sure their products were compatible. When Intel decided that these chipset and motherboard producers were not making new versions of their products fast enough to help sell new versions of microprocessors, Intel started making some of these intermediate products itself – to stimulate the end-user market. But it still kept its laboratories in a neutral position to work with ecosystem partners. This was crucial to establish and maintain Intel's reputation as a

trustworthy partner in the ecosystem, itself a difficult task because of strong short-term incentives to take advantage of innovation developed by less dominant complementors.[9]

Platform Leadership and the Innovator's Dilemma

Platforms supported by a global ecosystem of complementors and strong network effects should be more difficult for competitors to dislodge than standalone products that are more subject to competition based on fashion or price. But even the best firms face a potential challenge similar to that described by Clay Christensen in *The Innovator's Dilemma* (1997): Success ties a firm to its existing customers as well as products and business models associated with those customers. This makes it difficult for a firm to change its products or its platform, even though these probably need to evolve lest they become obsolete. A number of well-known platform leaders have experienced this type of innovator's dilemma.

IBM versus Intel and Microsoft

IBM created the first global platform in the modern computer era, based on the IBM System 360 mainframe software and family of compatible computers, introduced in the mid-1960s. Antitrust initiatives pressured IBM to release information to independent maintenance providers. This eventually led to an opening of the system architecture and an ecosystem of hardware "clone" makers like Amdahl and Fujitsu as well as software product and service companies focused on IBM customers. But IBM had the deepest knowledge of its market. It had sold primitive electronic computers since the early 1950s and for decades before that dominated in electro-mechanical tabulating machines and other office equipment. In the 2000s, this knowledge helped IBM continue to dominate the diminished mainframe market as well as do pioneering work in high-performance systems development. But IBM's role as a platform leader changed as enterprise computing evolved to become a much more heterogeneous world of machines and software, as well as competitors, of different shapes and sizes.

By 1980, a few key executives had realized that a platform shift was occurring and they introduced their own personal computer design in 1981. The operating system and microprocessor turned out to be the two key components of this new PC platform, and IBM

[9] See Gawer and Henderson (2000) and Farrell and Katz (2000) for further discussion on this issue.

ceded control over these elements to its supply-chain partners, Microsoft and Intel. So here we have a case where a supply-chain platform evolved to become an industry platform but under the control of the key suppliers, not the original platform architect and leader. To its credit again, though, after absorbing billions of dollars in losses, IBM found a way forward. Under new CEO Louis Gerstner, hired from RJR Nabisco in 1993, it became the champion of "open systems" (Linux, Java, the Internet, ubiquitous computing, and the cloud). Gerstner and his successors also sold off commodity hardware businesses and rebuilt the company around services and middleware software products that help customers utilize different platform technologies.

The insight here for both managers and researchers is the awareness of how quickly platforms can evolve and the leader of one generation lose control over the next. But we can also see that some of the leader's capabilities may actually transfer to the next generation. In this case, IBM had decades of experience that helped it understand – better than any other company – the data-processing needs of enterprise users and other large organizations. This is where the firm kept its focus. The shift in platforms away from the mainframe and the loss of control over the PC were both highly damaging financially. But these changes created a new beginning for a service-oriented IBM.

Google and Nokia

Google's platform was initially an Internet search engine that became nearly ubiquitous on PC desktops with the downloadable and free toolbar. The company then built an Internet portal, replete with email, maps, applications, storage, and other features, to surround and feed the search engine. Google monetizes its leadership position by selling targeted ads that accompany searches. But Google has not stopped there. The company realized years ago that most computing would one day be on mobile devices. So Google bought and then refined the Android operating system (which is based on Linux) and created the Chrome browser to facilitate mobile computing as well as mobile searches and advertising. Perhaps most important, though, is that Google in 2012 has become the largest smartphone OS provider. But not even Google has done everything right. It was slow to see the importance of social networking and has been trying for years (with limited success) to challenge Facebook and create a coalition of partners to gain access to more social networking and social media content – presumably, to sell more search and advertising.

Google competes fiercely with Apple in the smartphone market, but perhaps the company that has lost the most in this competition is Nokia. (Rim, with Blackberry phone, is a close second.) This Finnish company in 2012 remained the largest producer of cell phones, and its Symbian software was for a time the dominant software platform for basic handsets. However, from 2009-2010, mobile sales were quickly moving to smartphones that required more sophisticated software. Not surprisingly, Nokia saw its market share, market value, and financial performance suffer dramatically as Apple's iPhone handsets, and a variety of devices from different companies running Google's Android software, came to dominate the market. Nokia removed its CEO and hired a former Microsoft executive, Steven Elop. He then announced plans to abandon the Symbian operating system as well as another joint OS project with Intel. Instead, he chose to use Microsoft's Windows phone software for Nokia's next generation of smartphones, a move that may or may not work out for the company.

The insight here is that platform leaders must force themselves to think broadly about potential competitors from adjacent markets as well as manage the evolution of their platforms, business models, and technical or marketing capabilities. Google has always focused on search, but computing has been moving beyond the desktop for years and even beyond the Internet – to multiple devices as well as applications and content that reside within both open (such as the Internet) and closed (such as Facebook) networks. Moreover, Google has challenged the *modus operandi* of the computer industry – proprietary technology. Its software platform for mobile phones and other devices such as Netbooks and tablets is both free and open. It is hard for companies that charge for their technology and do not have large advertising income or other sources of revenue – like Nokia – to beat free and open. Platform leaders must also be prepared to discard their platforms, as IBM did, if that is what survival requires. If they fail to develop new technology internally or find suitable acquisitions, then they may well find themselves adopting the platform technology of a competitor.

Microsoft versus Apple

Steve Ballmer, CEO of Microsoft CEO since Bill Gates handed over the reins in 2000, was often criticized for not being able to move much beyond the PC platform. Indeed, in 2012, Windows desktop and server and the Office suite still accounted for nearly 80 percent of Microsoft's revenues and almost all its profits. Ballmer was under particular pressure because Microsoft's share price has been stagnant for more than a decade since the end of the Internet boom (though this was also true of Intel, Cisco, Nokia, and a host of other high-tech

firms). Arch-rival Apple, despite the small (but rising) global market share of the Macintosh personal computer, and despite its near bankruptcy only a few years ago, has been growing at some 50 percent a year and vaulted past Microsoft in market value during 2010. Apple was growing so fast because it had become a major player in consumer electronics as well as smartphones, tablets, and digital content as well as software product distribution.

On the strength of its high-margin digital service platforms (iTunes, App Store, and iCloud), Apple may someday match or surpass Microsoft in margins. Reproducing digital bits is much less costly than reproducing hardware boxes. But, for the time being, Microsoft remained the most profitable of the high-tech giants, including Apple and Google. It has survived radically disruptive technological transitions and daunting business-model challenges (character-based to graphical computing, the Internet, Software as a Service and cloud computing, mobile computing, and social networking). It has survived antitrust scrutiny and violations (remember Netscape). Withal, Microsoft continued to "print money," relying on the enormously profitable gross margins of the packaged software business. And change has always been in the works at Microsoft, albeit slowly. Billions of dollars in losses ("investment") from MSN and Bing over some 15 years prepared Microsoft for the online world and cloud computing funded by advertising revenue. It learned from the Vista debacle in the early 2000s how to break up Windows into smaller, more manageable chunks, which can also help deliver new Internet and cloud-based services. The Windows Azure cloud offering and SaaS versions of major products have had good receptions in the marketplace and appear to be competitive, though not dominant, offerings for the future. Microsoft's decision in early 2011 to buy Skype is also part of an attempt to move beyond the PC and get access to new customers as well as better Internet voice and video technology. Other moves include Microsoft's alliance with Nokia to take over its future smartphone software and an earlier alliance with RIM to take over the search business on the Blackberry smartphones.

The major insight here is how platform leadership can promote wealth or value creation as well as constrain innovation. Bill Gates, back in the late 1990s, insisted that Microsoft remain a Windows company rather than become a broader platform company and move quickly into new technologies and new markets. As a result, Microsoft engineers tried to squeeze Windows onto the new platforms, the Internet and then mobile phones, rather than create optimized software from scratch and then link the new platforms back to Windows. (Microsoft also cut down Windows for the Xbox video game console, but did not retain the additional constraint of Windows compatibility.) Of course, Windows on the desktop is the

modern-day equivalent of a gold mine. It is not hard to understand why Gates and Ballmer were reluctant to cannibalize this business. Apple, by contrast, was never wedded to the original Macintosh platform, which never caught on at the industry level and failed as a business in the 1980s and 1990s anyway. Apple later replaced the core of the Mac OS with NeXT software, which was based on UNIX. But Apple did remain wedded to its unmatched capabilities in user interface design and visionary product innovation. Those skills are the basis for Apple's business success with the iPod, iPhone, iTunes, and iPad and its remarkable transformation into a global platform leader with multiple integrated devices in several high-growth markets.

Conclusions

This paper has discussed some of the major differences between internal and external platforms, and suggested how both types of platforms can impact product and service innovation. Both kinds of platforms tend to be designed and managed strategically, to further the competitive advantage of the platform owner. While internal platforms allow their owner to achieve economic gains by re-using or re-deploying assets across families of products developed by either the firm or its close suppliers, industry platforms facilitate the generation of a potentially very large number of complementary innovations by tapping into the innovative capabilities of many external actors, and function as a technological foundation at the heart of innovative business ecosystems. Industry platforms guide technological innovation trajectories and stimulate innovation on complements.

The examples of Intel and other companies suggest there are particular practices that effective platform leaders follow (Table 2). Platform leaders who aim to tap into the innovative capabilities of an ecosystem of external firms need to develop a vision for their platform and promote this among potentially key players in a future ecosystem. They need to build a sufficiently open or modular architecture to facilitate third-party innovation. They need to build a vibrant coalition around their platform and carefully manage ecosystem relationships that are mutually beneficial for participants. They need to continue evolving the platform and the ecosystem to remain competitive as challengers emerge. Overall, the effective practice of platform leadership entails a set of internal processes that allow managers to make technological decisions on the one hand, and business decisions on the other, in a coherent manner – even if they may originate in different part of the organization.

This imperative for coherence creates challenges not only for practitioners, as internal divisions of labour lead to organizational silos, but also for scholars – who need to look across their own academic silos. For these and other reasons, the phenomenon of industry platforms offers a research opportunity to cross-fertilize several disciplines. In particular, we see three sets of platform-related research questions that should help advance our understanding of innovation, strategy, organizational behavior and networks, and technological change.

Table 2: Effective Practices for Platform Leadership

1. Develop a vision of how a product, technology or service could become an essential part of a larger business ecosystem
    a. Identify or design an element with platform potential (that is, performing an essential function, and easy for others to connect to).
    b. Identify third-party firms that could become complementors to your platform (think broadly, possibly in different markets and for different uses)
2. Build the right technical architecture and 'connectors'
    a. Adopt a modular technical architecture, and in particular add connectors or interfaces so that other companies can build on the platform
    b. Share the intellectual property of these connectors to reduce complementors' costs to connect to the platform. This should incentivize and facilitate complementary innovation.
3. Build a coalition around the platform: Share the vision and rally complementors into co-creating a vibrant ecosystem together
    a. Articulate a set of mutually enhancing business models for different actors in the ecosystem
    b. Evangelize the merits and potentialities of the technical architecture
    c. Share risks with complementors
    d. Work (and keep working) on firm's legitimacy within the ecosystem. Gradually build up one's reputation as a neutral industry broker
    e. Work to develop a collective identity for ecosystem members
4. Evolve the platform while maintaining a central position and improving the ecosystem's vibrancy
    a. Keep innovating on the core, ensuring that it continues to provide an essential (and difficult to replace) function to the overall system, making it worthwhile for others to keep connecting to your platform
    b. Make long-term investments in industry coordination activities, whose fruits will create value for the whole ecosystem.

First, we still do not understand very well how industry platforms emerge. The economics literature has so far not tackled this question, as researchers tend to assume that the platform already exists (as well as its associated markets on each "side" of the platform). The literature on technological change and competitive dynamics, and on organizational processes, could usefully address the question of platform emergence and ecosystem creation as well. The classification of platforms offered in this paper may indicate that under certain conditions

there could be an evolution from internal platforms to external platforms, but this hypothesis would need to be developed and tested.

A related important area of further research is that of the emergence and evolution of business ecosystems. The networks approach from the organizational literature (see Brass et al, 2004 for a review), by bringing its insights on network dynamics and field evolution (Powell et al, 2005) and strategic networks (Gulati et al., 2000; Lorenzoni and Liparinni, 1999), is well-positioned to make significant contributions in this area. In particular, recent work by Nambisan and Sawhney (2011), building on Dhanaraj and Parkhe (2006), develops explicitly the link between platform leadership and orchestration processes in network-centric innovation. The new institutional literature rooted in sociology offer concepts such as legitimacy, collective identity, and institutional work, which can be useful to determine whether and how platform leaders can successfully establish themselves as trustworthy brokers.

Third, our understanding of the impact of platforms on innovation and competition still needs to be refined. In the literatures we have reviewed (economics, innovation, operations, strategy), technological platforms are associated with a positive impact on innovation. The positive effect stems from the fact that, by offering unified and easy ways to connect to common components and foundational technologies, platform leaders help reduce the cost of entry in complementary markets, and provide demand for complements, often fuelled by network effects. Platforms offer therefore a setting where it is in the interest of private firms to elicit and encourage innovation by others. However, concern over the dominant positions that platform leaders such as IBM, Microsoft, Google, or Apple can achieve has raised awareness that platforms may have a potentially negative effect on competition and possibly on innovation, especially non-incremental innovation. We suggest that as scholars we need to further refine our argument about platforms and innovation.

For example, further theory development could examine the role of interfaces and architecture, and how platform design might focus the attention of innovators onto specific trajectories of technological change (Dosi, 1982). These might take the form of what Nathan Rosenberg (1969) called “inducement mechanisms and focusing devices.” It is possible that platform leaders tend to successfully stimulate a certain kind of externally-developed innovation (that would complement the platform), while aiming to discourage another kind of innovation (that would diminish the appeal or the perceived value of the platform). This type

of research would highlight the potential trade-offs between innovation on modules or discrete products versus innovation on systems.

APPENDIX TABLE A. INTEL COORDINATION INITIATIVES IN 1997-1998

IAL Initiative	Mission	Key programs	Diffusion
Networked Multimedia	Make multimedia pervasive on the Net and provide the best experience on the high-performance Connected PC	Scalable, MMX Technology optimized media engines; Efficient media network transports and services: tools and services	H.323 stack in Microsoft's Internet Explorer 4.0; supported by firewall vendors; but also products Indeo Video 5.0; and also building blocks WDE ships as part of Microsoft's Internet Explorer 4.0; RSVP and RTP ship in Windows 98 and Windows NT 5.0.
Manageability	Enable platform and network infrastructure to make Intel Architecture systems the most easily manageable and the best managed	Industry specifications and industry groups; software development kits	Specifications, Software Development Kits; but also products: Intel NIC [10] and LanDesk Software products; Also, diffused through Microsoft, as ingredients: Wake-on-LAN[11] and Wake-on-Ring NICs and Modems in NT, Win 98.
Big Pipes	Increase content delivery capacity of the connected PC to allow home and business customers to easily receive new broadband digital content	Common software architecture for PC broadband transport; reference designs	Networking connectivity products.
Security	Make PC interaction trustworthy for communications, commerce, and content	Industry specifications and industry groups, drives the CDSA standardization effort; software development kits	Open specifications and industry groups, CDSA R2.0, in OpenGroup; OpenGroup standard, IBM licensed. Products also: IBM and Intel shipping product based on CDSA standard. And also, licenses to Zoran: DVD copy protection
Anywhere-in-the-Home	Unleash the potential of home PCs with new uses that deliver computing power and content when, where, and how it's is needed in the home.	PC-friendly protocols and standards; concepts demos and prototypes.	Standards, Control-InfraRed – with Hewlett Packard, Microsoft, and Sharp; Home- Radio-Frequency – with Compaq, IBM, and HP; and Home Device Control.
Advance-the-Platform	Establish the media, communications, and interconnect building blocks for the next generation high performance Intel Architecture platforms	Interconnects USB, AGP, 1394 A/B; future processor optimizations, visual PC 2000	AGP drivers, USB compliance workshops, PC-friendly 1394A specifications. No commercialized products. Ingredients in Microsoft's products: Real-time services in WDM in Windows 98 and Windows NT 5.0.

Source: Gawer and Henderson (2007)

[10] NIC = Network Interface Card, an expansion board (i.e., a printed circuit board) that can be inserted into a computer so the computer can be connected to a network. Most NICs are designed for a particular type of network, protocol, and media, although some can serve multiple networks. (Source: www.webopedia.com)

[11] LAN= Local Area Network. A computer network that spans a relatively small area.

References

Anonymous (2006),' Vehicle profiles: A user's guide', *Consumer Reports* 71 (April), 39–78.

Armstrong, M. 2006. 'Competition in Two-Sided Markets', *RAND Journal of Economics*, 37, 668-691.

Baldwin, C.Y. and K.B. Clark. 2000. *Design Rules: The Power of Modularity*. Cambridge, MA, US: MIT Press.

Baldwin, C.Y, Woodard, J. 2009. The architecture of platforms: A unified view, in: Gawer, A. (Ed.), Platforms, Markets and Innovation. Edward Elgar, Cheltenham, UK and Northampton, Mass, pp. 19-44.

Boudreau, K. forthcoming. 'Let a thousand flowers gloom? An early look at large numbers of software "apps" developers and patterns of innovation', *Organization Science*.

Boudreau, K. and A. Hagiu. 2009., 'Platforms rules: Multi-sided platforms as regulators', in Gawer, A. (ed.), *Platforms, Markets and Innovation*, 163-191. Cheltenham, UK and Northampton, MA, US: Edward Elgar.

Brandenburger, A., Nalebuff, B.J., 1996. *Co-opetition:* . Currency Doubleday, New York.

Brass, D.J., Galaskiewicz, J., Greve, H.R., Tsai, W., 2004. 'Taking stock of networks and organizations: A multilevel perspective'. *Academy of Management Journal* 47 (6), 795-817.

Bremmer, R. 1999. 'Cutting-edge platforms', *Financial Times Automotive World*, September, 30-38.

Bremmer, R. 2000. 'Big, bigger, biggest', *Automotive World*, June, 36-44.

Bremner, B., G. Edmondson and C. Dawson (2004), 'Nissan's boss', *Business Week*, October 4, p. 50

Bresnahan, T. and S. Greenstein. 1999. 'Technological competition and the structure of the computer industry', *Journal of Industrial Economics,* 47, 1-40.

Brusoni, S. 2005. 'The limits to specialization: Problem-solving and coordination in modular networks', *Organization Studies*, 26 (12), 1885-1907.

Brusoni, S. And A. Prencipe. 2001. 'Unpacking the black box of modularity: Technologies, products and organizations', *Industrial and Corporate Change*, 10 (1), 179-204.

Brusoni, S. and A. Prencipe. 2006. 'Making design rules: A multi-domain perspective', *Organization Science*, 17 (2), 179-189.

Caillaud, B., and B. Jullien. 2003. 'Chicken and egg: Competition among intermediation service providers', *RAND Jurnal of Economics*, 34, 309-328.

Chesbrough, H.W. 2003. *Open Innovation; The New Imperative for Creating and Profiting from Technology*, Boston, Mass., US: Harvard Business School Press.

Cusumano, M.A. 2010. 'The evolution of platform thinking'. *Communications of the ACM*, 53(1), 33-35.

Cusumano, M.A. 2011. 'The platform leader's dilemma'. *Communications of the ACM*, 54(10), 21-24.

Cusumano, M.A. and A. Gawer (2002), 'The elements of platform leadership', *MIT Sloan Management Review*, 43 (3), 51-58.

Cusumano, M.A. and K. Nobeoka. 1998. *Thinking Beyond Lean*, New York, NY, US: Free Press.

Cusumano, M.A. and D. Yoffie. 1998. *Competing on Internet Time: Lessons from Netscape and its Battle with Microsoft*. New York, NY, USA: The Free Press.

Dhanaraj, C., Parkhe, A., 2006. 'Orchestrating innovation networks'. *Academy of Management Review* 31 (3), 659-669.

Doran, D. 2004. 'Rethinking the supply chain: An automotive perspective', *Supply Chain Management: An International Journal*, 9 (1), 102-109.

Dosi, G. 1982. 'Technological paradigms and technological trajectories: A suggested interpretation of the determinants and directions of technical change'. *Research Policy* 11, 147-162.

Eisenmann, T., G. Parker and M. Van Alstyne. 2009. 'Opening platforms: How, when, and why?', in Gawer, A. (ed.), *Platforms, Markets and Innovation*, 131-162. Cheltenham, UK and Northampton, MA, US: Edward Elgar.

Eisenmann, T., G. Parker and M. Van Alstyne. 2006. 'Strategies for two-sided markets', *Harvard Business Review*, October.

Evans, D.S. 2009. 'How catalysts ignite: The economics of platform-based start-ups', in: *Platforms, Markets and Innovation*, 99-128. Cheltenham, UK and Northampton, MA, US: Edward Elgar.

Evans, D.S. 2003. 'The antitrust economics of multi-sided platform markets', *Yale Journal on Regulation*, 20, 325-82.

Farrell, J. and M.L. Katz. 2000. 'Innovation, rent extraction, and integration in systems markets', *Journal of Industrial Economics*, 97 (4), 413-432.

Feitzinger, E. and H.L. Lee. 1997. 'Mass customization at Hewlett-Packard: The power of postponement', *Harvard Business Review*, 75 (1), 116–121.

Gawer, A. 2000. *The Organization of Platform Leadership: An Empirical Investigation of Intel's Management Processes Aimed at Fostering Innovation by Third-Parties*. MIT PhD Thesis.

Gawer, A. 2009. *Platforms, Markets and Innovation* (Ed.). Cheltenham, UK and Northampton, MA, US: Edward Elgar.

Gawer, A. 2009a. 'Platforms dynamics and strategies: From products to services', in Gawer, A. (ed.), *Platforms, Markets and Innovation*, 45-76. Cheltenham, UK and Northampton, MA, US: Edward Elgar.

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

Gawer, A. and M.A. Cusumano. 2008, 'How companies become platform leaders', *MIT Sloan Management Review*, 49 (2), 28-35.

Gawer, A. and R. Henderson. 2007. 'Platform owner entry and innovation in complementary markets: Evidence from Intel', *Journal of Economics and Management Strategy*, 16 (1), 1-34.

Greenstein, S. 2009. 'Open platform development and the commercial Internet', in Gawer, A. (ed.), *Platforms, Markets and Innovation*, Cheltenham, UK and Northampton, MA, US: Edward Elgar, pp. 219-248.

Gulati, R., Nohria, N., Zaheer, A., 2000. 'Strategic networks'. *Strategic Management Journal* 21, 203-216.

Hagiu, A. 2006. 'Pricing and commitment by two-sided platforms', *RAND Journal of Economics*, 37.

Hagiu, A. 2007a. 'Merchant or two-sided platform?' *Review of Network Economics*, 6 (2), 115-133.

Hagiu, A. 2007b. ‘Multi-sided platforms: From microfoundations to design and expansion strategies’, Harvard Business School, Working Paper No. 07-094, accessed 06 Feb 2012 at http://www.hbs.edu/research/pdf/07-094.pdf

Iansiti, M. and R. Levien. 2004. *The Keystone Advantage: What the New Dynamics of Business Ecosystems Mean for Strategy, Innovation, and Sustainability*. Boston, MA, USA: Harvard University Press.

Jacobides, M.G., T. Knudsen and M. Augier. 2006. ‘Benefiting from innovation: value creation, value appropriation and the role of industry architectures’, *Research Policy*, 35 (6), 1200–1221.

Krishnan, V. and G. Gupta. 2001. ‘Appropriateness and impact of platform-based product development’, *Management Science*, 47, 52–68.

Lehnerd, A.P. 1987). ‘Revitalizing the manufacture and design of mature global products’, in B.R. Guile and H. Brooks (eds.) *Technology and Global Industry: Companies and Nations in the World Economy*, Washington, D.C.: National Academy Press, pp.49–64.

Lorenzoni, G., Lipparini, A. 1999. ‘The leveraging of interfirm relationships as a distinctive organizational capability: A longitudinal study’. *Strategic Management Journal* 20 (4), 317-339.

McGrath, M.E. 1995. *Product Strategy for High-Technology Companies*, New York, NY, US: Irwin Professional Publishing.

Meyer, M.H. and A.P. Lehnerd. 1997. *The Power of Product Platforms: Building Value and Cost Leadership*, New York, NY, US: Free Press.

Muffato, M. 1999. ‘Platform strategies in international new product development’, *International Journal of Operations and Production Management*, 19 (5/6), 449-59.

Muffato, M. and M. Roveda. 2002. ‘Product architecture and platforms: A conceptual framework’, *International Journal of Technology Managemen*t, 24 (1).

Moore, J.F. 1996. *The Death of Competition: Leadership and Strategy in the Age of Business Ecosystems*. HarperBusiness.

Nambisan, S and M. Sawhney. 2011. ‘Orchestration processes in network-centric innovation: Evidence from the field’. *Academy of Management Perspectives*, August, 40-57.

Naughton, K., E. Thornton, K. and H. Kerwin. 1997. ‘Can Honda build a world car?’, *Business Week*, 100 (7).

Perrons, R.K., 2009. ‘The open kimono: How Intel balances trust and power to maintain platform leadership’. *Research Policy* 38, 1300-1312.

Pine, B.J. 1993. *Mass Customization: The New Frontier in Business Competition*, Boston, MA, US: Harvard Business School Press.

Pisano, G. P. and D.J. Teece 2007. ‘How to capture value from innovation: Shaping intellectual property and industry architecture’, *California Management Review*, 50 (1), 278-296.

Parker, G. and M. Van Alstyne. 2005. ‘Two-sided network effects: A theory of information product design’, *Management Science*, 51, 1494-1504.

Pine, B.J. 1993. *Mass Customization: The New Frontier in Business Competition.* Boston, MA: Harvard Business School Press.

Rechtin, M. and R. Kranz. 2003. ‘Japanese step up product charge’, *Automotive News*, 77 (August 18), 26–30.

Robertson, D. and K. Ulrich. 1998. ‘Planning for product platforms’, *MIT Sloan Management Review*, 39 (4), 19-31.

Rochet, J.-C. and J. Tirole 2006. 'Two-sided markets: A progress report', *RAND Journal of Economics*, 35, 645-667.

Rochet, J.-C. and J. Tirole. 2003. 'Platform competition in two-sided markets', *Journal of the European Economic Association*, 1 (4), 990-1029.

Rosenberg, N. 1969. 'The direction of technological change: Inducement mechanisms and focusing devices'. *Economic Development and Cultural Change* 18 (1), 1-24, Part 1. October.

Rothwell, R. and P. Gardiner (1990), 'Robustness and product design families', in Oackley, M. (ed.), *Design Management: A Handbook of Issues and Methods*, 279-292. Cambridge, MA, USA: Basic Blackwell Inc..

Sabbagh, K. 1996. *Twenty-First Century Jet: The Making and Marketing of the Boeing 777*. New York, NY, US: Scribner.

Sako, M. 2003. 'Modularity and outsourcing: The nature of co-evolution of product architecture in the global automotive industry', in Prencipe, A., A. Davies and M. Hobday (eds) , *The Business of Systems Integration*, 229-253. Oxford , UK: Oxford University Press.

Sako, M. 2009. 'Outsourcing of tasks and outsourcing of assets: Evidence from automotive suppliers parks in Brazil', in Gawer, A. (ed.), *Platforms, Markets and Innovation*, Cheltenham, UK and Northampton, MA, US: Edward Elgar, pp. 251-272.

Sanderson, S.W. and M. Uzumeri. 1997. *Managing Product Families*, Chicago, IL, USA: Irwin.

Sawhney, M.S. 1998. 'Leveraged high-variety strategies: From portfolio thinking to platform thinking', *Journal of the Academy of Marketing Science*, 26 (1), 54–61.

Schilling, M.A. 2009. 'Protecting or diffusing a technology platform: Trade-offs in appropriability, network externalities, and architectural control', in Gawer, A. (ed.), *Platforms, Markets and Innovation*, 192-218. Cheltenham, UK and Northampton, MA, US: Edward Elgar.

Simpson, T.W., Siddique, Z. and J. Jiao. 2005. 'Platform-based product family development: introduction and overview', in Simpson, T.W., Siddique, Z. and Jiao, J. (eds), *Product Platforms and Product Family Design: Methods and Applications*, New York, NY, US: Springer, pp. 1-16.

Staudenmayer, N., M. Tripsas and C.L. Tucci. 2005. 'Interfirm modularity and its implications for product development', *Journal of Product Innovation Management*, 22, 303-321.

Szczesny, J. 2003. 'Mazda ushers in new Ford era: Platform sharing across global brands is Ford's new way of doing business', Viewed February 14, 2006, http://www.thecarconnection.com/index.asp?article=6574pf=1.

Tierney, C., A. Bawden and M. Kunii. 2000. 'Dynamic duo', *Business Week* (October 23), p. 26.

von Hippel, E. 2005. *Democratizing Innovation.* Cambridge, MA: MIT Press.

West, J. 2003. 'How open is open enough? Melding proprietary and open source platform strategies', *Research Policy*, 32, 1259-1285.

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

Whitney, D.E. 1993. 'Nippondenso Co. Ltd: A case study of strategic product design', *Research in Engineering Design*, 5 (1), 1-20.

Zirpoli, F. and M.C. Becker. 2008. ‘The limits of design and engineering outsourcing: Performance integration and the unfulfilled promises of modularity’, Mimeo, presented at the International Workshop on Collaborative Innovation and Design Capabilities, Mines ParisTech, Paris.

Zirpoli, F. and M. Caputo (2002), ‘The nature of buyer-supplier relationships in co-design activities: The Italian auto industry case’, *International Journal of Operations and Production Management*, 22 (12), 1389-1410.