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Industry Platforms and Ecosystem Innovation

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This paper brings together the recent literature on industry platforms and shows how it relates to managing innovation within and outside the firm as well as to dealing with technological and market disruptions and change over time. First, we identify distinct types of platforms. Our analysis of a wide range of industry examples suggests that there are two predominant types of platforms: internal or company-specific platforms, and external or industry-wide platforms. 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. We define external (industry) platforms as products, services, or technologies that act as a foundation upon which external innovators, organized as an innovative business ecosystem, can develop their own complementary products, technologies, or services. Second, we summarize from the literature general propositions on the design, economics, and strategic management of platforms. 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 important phenomenon and what firms can do to manage platform-related competition and innovation.

Introduction

This paper brings together some of the recent literature on "industry platforms" and shows how it relates to managing innovation within and outside the firm as well as to dealing with technological and market disruptions and change over time. First, we define the term "platform" and why this concept seems to have become increasingly important for researchers and managers. Second, we clarify differences in the literature with regard to how to define different types of platforms and associated economic, managerial, 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 important phenomenon and what firms can do to manage platform-related competition and innovation.

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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 many other firms, small and large, build hardware and software products for computers, cell phones, and consumer electronics devices that in one form or another serve as what we can call industry platforms. These firms and their hundreds if not thousands of partners also participate in platform-based "ecosystem" innovation (Iansiti and Levien, 2004; Moore, 1996). Platforms are distinct in that they are 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 to a growing set of complementary innovations. In other words, there are increasing incentives for more firms and users to adopt a platform and join the ecosystem as more users and complementors join.[1]

[1] We use the term "complementor" in the sense defined by Brandenburger and Nalebuff (1997), as a shorthand 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.

Industry platforms and associated innovations, as well as platforms on top of or embedded within other platforms have become increasingly pervasive in our everyday lives (for example, 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.). 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 management field (Meyer and Lehnerd, 1997; Simpson, Siddique, and Jiao, 2005); in technology strategy (Cusumano and Gawer, 2002; Eisenmann, Parker, and Van Alstyne, 2006; Gawer and Cusumano, 2002, 2008); and in industrial economics (Armstrong, 2006; Evans, 2003; Rochet and Tirole, 2003). Our analysis of a wide range of industry examples, however, suggests 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; Muffatto and Roveda, 2002). We define external (industry) platforms as products, services, or technologies that are similar in some ways 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, 2009; Gawer and Cusumano, 2002). These are somewhat high-level definitions, however, and it is instructive to see how researchers have treated the distinctions between these two types of platforms at a more detailed level.

BIOGRAPHICAL SKETCHES

Dr. Annabelle Gawer is assistant professor in strategy and innovation at the Imperial College Business School in London. She specializes in strategic management and high-tech business strategy. A thought leader in high-tech strategy, she is a pioneering contributor to the field of research on technological platforms. She has published two books and a number of articles in this research area. Her first book, *Platform Leadership: How Intel, Microsoft, and Cisco Drive Industry Innovation* (Harvard Business School Press, 2002), coauthored with Massachusetts Institute of Technology (MIT) Prof. M. Cusumano, has become a reference in business and academia. Her latest book, *Platforms, Markets and Innovation* (Edward Elgar, 2009), is an edited volume dedicated to the growing field of platform research. Her research articles have been published in *Organization Studies*, *Journal of Economics and Management Strategy*, *MIT Sloan Management Review*, *European Management Review*, *Research in the Sociology of Organizations*, and *Communications and Strategies*. Her work has also been published in the *Wall Street Journal* and the *European Business Review*. Her books and articles have been translated in Japanese and Chinese. She has consulted for a number of international corporations and is a member of the steering committee on the future of e-Skills for Europe for the European Commission. Annabelle received a Diplôme d'Ingénieur Civil des Mines from Ecole des Mines de Nancy (France), a Master of Science in Applied Mathematics from Université Paris 6 (France), a Master of Science in Industrial Engineering from Stanford University, and a PhD in Management from the MIT Sloan School of Management.

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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. In many ways, this is an old idea: Brown (1995) indicated in his history of Baldwin Locomotive Works that as early as 1854, the U.S. locomotive manufacturer developed a "rigorous program to standardize locomotive parts. Now standard components could be used across a number of Baldwin-standard engines or even in custom designs" (Brown, 1995, p. 21). Product designers and engineers more

[2] This section follows Gawer (2009, pp. 45–76).

broadly are generally trained to systematically reuse patterns and design rules from previous work and improve upon prior art and the work of others (Baldwin and Clark, 2000; Le Masson, Hatchuel, and Weil, 2011; Le Masson, Weil, and Hatchuel, 2010; Norman, 1988). Creating a reusable foundation for product development within the firm requires specific planning and management. For example, Wheelwright and Clark (1992) describe how various companies have developed "product platforms" to meet the needs of different customers simply by modifying, adding, or subtracting different features. McGrath (1995), Meyer and Lehnerd (1997), Cusumano and Nobeoka (1998), Krishnan and Gupta (2001), and Muffatto and Roveda (2002) all have done research in a similar vein. They have defined these kinds of platforms as subsystems and interfaces that form a common structure from which a company can efficiently develop and produce a family of products, such as new automobiles 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 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 researchers 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 customization" (Pine, 1993).

The empirical evidence indicates that, in practice, companies have successfully used product platforms to increase product variety, control high production and inventory costs, and 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 (Cusumano and Nobeoka, 1998; Feitzinger and Lee, 1997; Lehnerd, 1987; Rothwell and Gardiner, 1990; Sabbagh, 1996; Sanderson and Uzumeri, 1997; Simpson et al., 2005; Whitney, 1993).

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 Woodard, 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 suboptimization 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 paper.

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 owner or the final product assembler. The objective of supply-chain 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, the 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 (Brusoni, 2005; Brusoni and Prencipe, 2006; Sako, 2003, 2009; Szczesny, 2003; Tierney, Bawden, and Kunii, 2000; Zirpoli and Becker, 2008; Zirpoli and Caputo, 2002). 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). The research, though, 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 do they 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 and potentially generate network effects. There is a similarity to internal platforms in that industry platforms provide a foundation of reusable common components or technologies, but they differ in that this foundation is "open" to outside firms. The degree of openness can also 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) (see, for example, Anvaari and Jansen, 2010).

There are some similarities between the concept of industry platform and that of a dominant design. A "dominant design" (Abernathy and Utterback, 1978), when it emerges, sets the standard for what form and features users expect a particular product to take in the future. Early research on dominant designs highlighted that once a dominant design emerges, it shifts the focus of competition from design to manufacturing, and the focus of innovation from product innovation to process innovation. It also suggested that the product life-cycle dynamics that lead to a dominant design is a long process of problem solving characterized by a logic that progressively leads an industry to standardize core components. Recent theoretical developments on dominant designs (Murmann and Frenken, 2006), recognizing that earlier research had been imprecise on products' architectural hierarchies, have proposed a systematic hierarchical model of dominant designs. This line of research articulates a model of dominant designs as a nested hierarchy of technology cycles, and makes a distinction between "core" and "peripheral" subsystems and components, where the stabilization of one level of the hierarchy allows for more innovation at peripheral levels.

The two concepts differ, however, in that while the concept of dominant design rests on industry-level evolutionary mechanisms with no particular agency, industry platforms are "manageable objects" that organizations purposefully manage to bring multiple parties within the industry together—primarily users and complementors.[3] Industry platforms, like internal company platforms, do not simply emerge without deliberate, firm-driven agency or deliberate managerial decisions and actions. And in platform markets—those industries characterized by a foundation technology around which third-party firms create complementary innovations, with adoption driven by positive feedback loops and network effects—the most likely winner is not necessarily the originator of the dominant design or the owner of the most elegant product. The most likely winner is the owner of the "best" platform, the characteristics of which we discuss later in this section.

Despite different degrees of openness to outside complementors, various products and technologies have served as industry platforms: the Microsoft Windows and Linux operating systems (OS); Intel and ARM microprocessors; Apple's iPod, iPhone, and iPad designs along with the iOS operating system; Apple's iTunes and 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 the Internet itself. We can even view payment technologies, ranging from credit and debit cards to micropayment schemes, as platforms that enable different types of financial transactions (Leblebici, 2012).

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 Levien (2004) called a "keystone firm" (similar to what Gawer and Cusumano [2002] referred to as a platform leader) 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.

[3] We thank one of our anonymous reviewers for this insight.

Taken together, these studies suggest several generalizations with regard to what makes for the best industry platform and how this can 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. 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 in adoption, they become harder to dislodge by rivals or new entrants, with the growing number of complements acting like a barrier to entry. The rise of industry platforms may also raise complex social welfare questions regarding trade-offs between the social benefits of platform-compatible innovation versus the potentially negative effects of preventing competition on overall systems.

It follows that the design principles or "design rules" for industry platforms overlap somewhat with those for internal and supply-chain platforms but go beyond them to serve a larger purpose. For example, the stability of the platform architecture is still essential, but there are important differences. In contrast to what happens for internal and supply-chain platforms, the logic of design for industry platforms 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, for truly successful industry platforms, the end use of the end product or service does not seem to be fully predetermined by the platform owner. 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 and governance of the platform.

This leads to another apparent design rule for effective industry platforms: The interfaces around the platform should 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 highlights the complex trade-offs between "open" and "closed" (Eisenmann, Parker, and Van Alstyne, 2009; Gawer and Cusumano, 2008; Greenstein, 2009; Schilling, 2009). These researchers suggest that, while opening up interfaces should 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 simple benefits of opening interfaces.

Specific strategic questions also 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 still 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 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. 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. Intel thereby retained control of the architecture at the same time it renewed incentives for complementors to innovate "on top of" the newly extended platform.

Another challenge is that, as technology is constantly evolving, platform leaders need to make business decisions and technology or design decisions in a coherent manner. For example, consider a firm that designs open interfaces to its platform: this will stimulate innovation on complements, and the firms that will act as complementors by designing these complements need therefore to be treated by the focal firms as allies, not potential competitors. This will mean that the focal firm should probably refrain from entering as a competitor in complementors' markets if it wishes to sustain the complementors' incentives to innovate. This need for coherence across business decisions and technological design decision can be difficult to achieve since these decisions are often made by different teams within the organization. The coherence imperative requires top management's awareness of the interdependencies between these decisions, and the right internal process in place to allow ongoing coordination across functional silos. Hence, to make the whole greater than the sum of the parts, 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" (Gawer and Cusumano, 2002).

Network Effects and Multisided Markets

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 number of 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, such as how Facebook attracts users, friends of users, and friends of friends of users. In some cases, these network effects are also reinforced by a technical standard that makes using multiple platforms ("multihoming") or switching from one platform to another difficult or costly. For example, some Windows applications require other users to have the same application. 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 equally or even more powerful. Indirect effects occur when, for example, advertisers become attracted to the Google search engine or to Facebook 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 et al., 2006). There may be some limits to network effects, however. For example, in a study of ecosystems for mobile computing and communications platforms, Boudreau (2012) has found that the positive feedback loop to the number of complementors does not perpetuate itself *ad infinitum*. Too many complementors at some point may 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 "multisided 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, 2006). While the concept of a multisided market can sometimes apply to supply-chain platforms as well as industry platforms, it does not entirely conform to either category. Nonetheless, there are important similarities between industry platforms and multisided 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, 2006).

At the same time, not all multisided 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 multisided market that stimulates external innovation could be regarded as an industry platform. However, while all industry platforms function in this way, not all multisided markets do. For example, dating bars and web sites, a common example used in the literature, are double-sided markets in that they facilitate transactions between two distinct groups of customers, although there need not be a market for complementary innovations facilitated by the existence of the platform.

The emerging literature on double-sided markets (Armstrong, 2006; Caillaud and Jullien, 2003; Evans, 2003; Rochet and Tirole, 2003, 2006) is particularly useful to understand the "chicken-and-egg problem" of how to encourage access to a platform for distinct groups of buyers or sellers. Nonetheless, the literature has limitations as 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, 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 research focuses 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 nonprice 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 double-sided (or multi-sided) research 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

We have learned from industry case studies that platform leaders can occupy both an enviable and problematic strategic situation: They are central players in an ecosystem but may be 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 to influence the direction of innovation in complementary products and services by third parties. In our view, therefore, platform leaders are organizations that 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 these partner firms. Platform leadership is therefore always accompanied by some degree of architectural control (Schilling, 2009) as well as interdependence. Again, 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, in contrast to internal product platforms, establishing an industry platform requires more than technical efforts and astute decisions about design and architecture. The industry-wide goal is to facilitate complementary innovations by third-party firms. 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.[4]

For example, Gawer and Cusumano (2002, 2008) have studied several examples of industry platforms and the behavior of leading companies in those markets. In particular, based on their analysis of Intel, with comparisons to Microsoft, Cisco, Palm, and NTT DoCoMo, they developed a specific concept of "platform leadership," along with associated strategic activities and practices. Their 2002 study in particular describes 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.[5]

Beginning in the early 1980s, Intel (founded in 1968) has contributed an essential hardware component, the microprocessor, to personal computers originally designed by IBM in 1981. Meanwhile, Microsoft (founded in 1975) 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), which introduced the successful Apple II in 1977, to IBM, and then to Intel and Microsoft. Intel executives in the early 1990s, however, became convinced it would be increasingly difficult to continue growing PC demand for at least two reasons: First was a nearly 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.

In other words, Intel entered the market merely as a component supplier to IBM. Fairly quickly, though, the aging IBM-compatible PC became a problem in that the system architecture and limited software prevented Intel chips from reaching their maximum performance levels. This was especially clear when compared to the Macintosh computer (introduced in 1984) and high-performance work stations using reduced instruction-set computing architectures. The problem was serious for

[4] 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.

[5] The following section follows Gawer and Cusumano (2002, chapter 2).

Intel because what had become its primary business—designing and manufacturing microprocessors for personal computers—was an enormous growth opportunity that required 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. Dozens if not hundreds of companies (in particular, all the suppliers for this architecture) had a stake in the IBM-compatible PC design. Yet no single supplier of software or other components (chip sets, screens, keyboards, printers, the operating system, or applications) could evolve the overall system by itself, let alone change it significantly.

Therefore, the first challenge Intel faced was that the architecture of the system was less advanced and much more difficult to use than competing computer systems such as the Macintosh. The second was that no one seemed capable of moving the platform technology forward in a way that was satisfactory for users or for Intel. Intel executives, led by cofounder and chairman Gordon Moore, and Chief Excutive Officer (CEO) Andy Grove, were also thinking ahead to the trajectory of innovation in which they were planning to invest. They intended to develop a stream of more powerful microprocessors frequently and regularly in subsequent years. (This investment pattern, where microprocessor power increases on a predictable basis while prices fall, came to be known as "Moore's Law.") A solution to the problem of the PC architecture, from Intel's perspective, had to accommodate management's future vision for the company.

In 1991, Intel executives established a laboratory 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 already been involved in a previous system design effort within Intel, to tackle this issue that the PC platform was not moving ahead as fast as Intel would like. Kinnie went on to head the IAL for the next 10 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."[6] 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."[7]

During the mid-1990s, IAL's mission evolved so that IAL became "a catalyst for innovation in the industry."[8] More specifically, IAL became proactive in helping Intel with what company people called "Job 1"—selling more microprocessors, the main source of Intel's revenue and profit. 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.[9] 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."[10] 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. The Appendix provides further details on the industry initiatives aimed at coordinating industry innovation.

The Intel case and comparisons to other firms suggests that companies aiming to establish their products, technologies, or services as industry platforms need to orchestrate third-party 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 (the decision on 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

[6] Author interview with Dr. Craig Kinnie, Director, Intel Architecture Lab, Intel Corporation, Hillsboro, Oregon, USA, 11 November 1997.

[7] Author interview with Dr. Craig Kinnie, *op. cit*.

[8] Author interview with Dave Johnson, Director of the Media and Interconnect Technology Lab, Intel Architecture Lab, Intel Corporation, Hillsboro, Oregon, USA, 20 August 1998.

[9] 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.

[10] Intel internal document, "Intel Architecture Lab: Overview" (1998).

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 port)	System interface	Y	Y
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).

complementors (such as initiatives to promote investments in complementary innovations), and (4) internal organization (company structures such as IAL or processes that minimize 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 separated internal product or research and development (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 with Intel's latest products. When Intel decided that these chipset and motherboard producers were not making new versions of their products available fast enough to help sell new versions of its microprocessors, Intel started making some of these intermediate products itself—to stimulate the end-user market. Nonetheless, it still kept its laboratories in a neutral position to work with ecosystem partners. This decision 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. (See Gawer and Henderson [2007] and Farrell and Katz [2000] for a further discussion on this issue.)

Platform Leadership and the Innovator's Dilemma

Market positions supported by a widely adopted platform, a global ecosystem of complementors, and strong network effects should be more difficult for competitors to dislodge than competitive advantage stemming from standalone products more subject to rapid change based on technology trends, fashion, or short-term pricing. Yet even the most powerful platform leaders may face challenges similar to the issues described by Clay Christensen in *The Innovator's Dilemma* (1997): Success ties a firm to its existing customers as well as the technology, products, and business models associated with those customers. This dependence can make it difficult for a firm to change and counter innovations that are lower priced and initially less capable but on a trajectory for improvement.

A number of well-known firms have experienced this type of "innovator's dilemma" in their product businesses, such as computer disk drives. We argue here that, although platform leadership gives the central firms an important advantage, it does not make them immune to this same innovator's dilemma. While we need more systematic research on this topic, in some cases, it may become even more difficult for leading firms to evolve their platforms when they have millions of customers and hundreds if not thousands of ecosystem partners helping to sustain a platform position. As seen in the case of Intel, and in the examples below, platform leaders first have to evolve their own internal capabilities and approaches to technological innovation and business strategy. Equally important, they must bring along with them an entire ecosystem of users and partners, and coordinate at least incremental innovation on a broad scale.[11]

IBM versus Intel and Microsoft

Again, we find it useful to return to the case of IBM, whose origins date back to the 1880s and a business based on electro-mechanical tabulating machines and time-punch devices. This company created the first global platforms in the modern computer era, beginning with the System 360 mainframe in the mid-1960s. Antitrust initiatives pressured IBM to release information to independent maintenance providers, which eventually led to an opening of the system architecture and an ecosystem of hardware "clone" makers led by Amdahl and Fujitsu as well as software product and service companies focused on IBM customers (Grad, 2002, p. 71). IBM faced more competition in the 1970s and in later years from vendors of smaller computers, and, as we discussed earlier, lost architectural control over its personal computer to Microsoft and Intel during the 1980s (Campbell-Kelly and Aspray, 1996; Fisher, McKie, and Mancke, 1983). Nonetheless, IBM remained a major player in the computer industry due to its deep expertise in data-processing solutions. It had sold primitive electronic computers since the early 1950s and for decades before that dominated in tabulating machines and other office equipment. In the 2000s, this deep customer knowledge and technical capabilities helped IBM continue to dominate the diminished mainframe market as well as move into Internet servers and do pioneering work in high-performance systems. IBM's role as an industry platform leader clearly changed as enterprise computing evolved to become a much more heterogeneous world of computer hardware and software of different shapes and sizes.

To IBM's credit, by 1980, a few key executives had realized that a platform shift was occurring, and their decisions led to the introduction of the IBM PC in 1981. The operating system and microprocessor turned out to be the two key components of the new PC platform, and IBM had outsourced these technologies to Microsoft and Intel. Here, we have a case where supply-chain partners evolved to become the new industry platform leaders. To its credit again, though, after absorbing billions of dollars in losses during the latter 1980s and early 1990s, IBM reinvented a major part of its business again. 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 refocused the company around services and middleware software products that help customers utilize different platform technologies (Gerstner, 2002).

The insight here for both managers and researchers is the need to be aware of how quickly platforms and markets can evolve, and how the leader of one generation can lose control over the next, even to ecosystem partners. We can also see that, with the right management and strategy, as well as organizational flexibility, the platform leader's most critical capabilities and customer knowledge may transfer to the next generation. In this example, IBM had decades of experience that helped personnel understand the data-processing needs of enterprise users and other large organizations. This is where Gerstner kept his focus, despite years of prior disagreements within IBM on what strategy and structure the firm should adopt in the future. The market shift away from the mainframe and the loss of control over the PC platform were both highly damaging financially to IBM, but these changes also created the basis for a more service-oriented company and a new business model.

JVC and Sony

In the 1970s, video-cassette recorders (VCRs) became the highest volume consumer electronics product as everyone with a television set became a potential customer. Although Sony established what we can call a dominant design with an earlier product (the 1971 U-Matic) and then won the race to produce a viable home device, the Japan Victor Corporation (JVC) ended up as the market winner. Several Japanese firms had studied Ampex's technology for broadcasters in the late 1950s, and both JVC and Sony found ways to miniaturize and improve the technology for a broader market. They beat several rivals in Japan, the United States, and Europe, including Toshiba, RCA, and Philips. It took 15 years or so of experimentation and R&D before Sony introduced the Betamax in 1975, and JVC countered with the VHS in 1976. By 1978, however, VHS had passed Betamax in sales. It became a global platform in that JVC licensed the VHS technology widely, allowed other companies like RCA and General Electric in the United States to influence feature development (such as recording time),

[11] This section is based on Cusumano (2011).

and cultivated a large set of outside firms for video content licensing and distribution. The Sony Betamax was first to market and may have had slightly better recording quality. It also initially had a shorter recording time, and Sony was not very eager to make design changes in its discussions with potential partners. JVC went on to become a multibillion-dollar company, based mainly on the VHS platform (Cusumano, Mylonadis, and Rosenbloom, 1992; Rosenbloom and Cusumano, 1987).

Compared to JVC, Sony had a much broader product line, deeper technical skills, and more financial resources. After the Betamax, it also learned to cooperate better with other firms when it came to setting digital video standards, or introducing the PlayStation platform for video games and the Blu-ray format for DVDs. Nonetheless, although both Sony and JVC earned billions of dollars in revenues from their VCR products, and JVC in particular rose to global prominence based on this one major success, both firms also failed to grasp how new software and networking technologies were changing the world of consumer electronics. JVC diversified from audio and video equipment to computer storage products, but never evolved to dominate another market and in 2008 merged with Japanese audio equipment producer Kenwood. The Sony Walkman, introduced in 1979, generated large revenues after Betamax sales faded and could have been the foundation for a new type of platform, like Apple's iPod and iPhone as well as iTunes. Yet, Sony chose to focus mainly on standalone hardware products, with the exception of the PlayStation.

The insight here again is that platform leaders need to prepare for both technological and business model change, in their internal product platforms and in their external platforms. This may be especially true when they are highly focused and successful with a particular type of technology and business. If we compare Sony and JVC with our prior example, it even seems that IBM, a much larger firm with an even longer history, has been able to evolve customer and technical knowledge as well as its business models more flexibly and creatively. For example, JVC probably would have performed better after the VCR era had it evolved its skills more quickly from analogue to digital technology, and to networked systems and hardware driven by software rather than software driven by hardware. Sony faced the same challenges and did better with its greater resources but still has had major difficulties competing with leading firms around the world, such as Apple or even Samsung. Though it still makes Walkman multimedia devices as well as PCs, smart phones, and video game consoles, and owns its own music label and movie studio, Sony continues to look for hit hardware products and always seems to find itself trailing in more complex, multisided platform markets (Tabuchi, 2012).

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 e-mail, maps, applications, storage, and other features, to surround and feed user traffic to 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. Google bought and then refined the Android operating system (which is based on Linux) and created the Chrome browser and operating system to facilitate mobile computing as well as mobile searches and advertising (Levy, 2011). Perhaps most important is that Google in 2012 became the largest smartphone OS provider with Android. Not even Google, however, has done everything right. It was slow to see the importance of social networking and has been trying for years (with limited success) to create a coalition of partners to gain access to more social networking and social media content—again, presumably, to sell more search and advertising. It has not built much following for its Chrome-based "netbook" computers. Its 2011 acquisition of Motorola Mobility may also create tensions with Google's hardware partners for Android phones, such as Samsung and HTC.

Another platform leader that probably has lost the most revenue and market value due to the transition to smartphones is Nokia. The Finland-based company in 2012 remained the largest producer of cell phones; its Symbian operating system was for years the dominant software platform for basic handsets. From 2009–2010, however, mobile sales quickly moved to smartphones that required more sophisticated software. Not surprisingly, during this period and afterwards, 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 (Kenney and Pon, 2011). 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. Nokia has now adopted Microsoft's Windows phone software for its next generation of smartphones.

The insight here is that platform leaders, like any market leader, must think broadly about potential competitors from adjacent markets as well as manage the evolution of their technology, business models, ecosystem partnerships, and marketing capabilities, no matter how successful they may be. Google has always focused on search, but computing has been moving beyond the desktop for years and even beyond the Internet—to multiple devices, especially mobile phones, as well as applications and content that reside within both open (such as the Internet) and closed (such as Facebook) networks. Google has been evolving successfully while continuing to challenge the modus operandi of the computer industry—proprietary technology, such as from Microsoft and Apple. Its software is both free (no license fees) and open (there is access to the source code and developers can modify some parts of the software). It is hard for companies that charge for their technology and do not have large advertising income or other sources of revenue to beat Google's Android platform strategy. Platform leaders must be prepared to supplement or even discard their platforms, as IBM has done, 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, as Nokia has recently done with Microsoft Windows.

Microsoft versus Apple

Steve Ballmer, CEO of Microsoft since Bill Gates handed over the reins in 2000, has sometimes been criticized for not moving the company much beyond the PC platform. Indeed, in 2012, Windows desktop and server as well as the Office suite still accounted for nearly 80 percent of Microsoft's revenues and almost all its profits. Microsoft was under particular pressure because its share price and market value have been stagnant or declining since the end of the Internet boom (though this was also true of Intel, Cisco, Nokia, and a host of other high-tech firms). By contrast, despite the small (but rising) global market share of the Macintosh personal computer, and despite its near bankruptcy only a few years ago, Apple has been growing sales at 50 or more annually in recent years and surpassed Microsoft in market value back in 2010. Apple was growing so fast because, unlike Microsoft, it evolved beyond the slow-growing PC business and became a major player in newer, more rapidly growing markets—smartphones, tablets, digital content, and software product distribution (Cusumano, 2010; Isaacson, 2011).

To be fair, Microsoft remains extremely profitable with PC software products, which have a marginal cost approaching zero and generally much higher profit margins than tangible products (Cusumano, 2004). It has also survived disruptive technological transitions and daunting business-model challenges (character based to graphical computing, the Internet, Software as a Service (SaaS) and cloud computing, mobile computing, and social networking) as well as survived global antitrust scrutiny and major violations (for example, with Netscape and Internet browsers). Billions of dollars in losses from MSN and Bing over some 15 years have prepared Microsoft for the online world of "cloud computing" funded by advertising revenue, even though this threatens its traditional packaged software business. In addition, Microsoft has recently learned how to break up Windows into smaller, more manageable modules, which should help it compete better and may also facilitate the delivery of new Internet-based services. At the same time, the Windows Azure cloud offering and SaaS versions of major products have had good receptions in the marketplace. Microsoft's decision in 2011 to buy the Internet telephony service Skype also seems part of an attempt to move beyond the PC and get access to new customers. Other moves include Microsoft's alliance with Nokia in smartphone software and an earlier alliance with RIM to take over the search business on the Blackberry smartphones.

Conclusions

This paper has discussed some of the major differences between internal and external platforms and how these can impact product innovation. Both kinds of platforms should be designed and managed strategically to accomplish the goals and further the competitive advantage of the platform owner. Internal platforms allow their owners to achieve economic gains by reusing or redeploying assets across families of products developed by either the firm or its close suppliers. By contrast, industry platforms allow firms to manage a division of innovative labor that originates beyond the confines of the firm or its supply chain. Industry platforms can facilitate the generation of a potentially very large number of complementary innovations by tapping into the innovative capabilities of an a priori unconstrained set of external actors, and provide the technological foundation at the heart of innovative business ecosystems. As the skills to innovate in technologies (such as ICT) have become globally distributed, the concept of industry platforms provides a useful template for the management of exploration of possible avenues for collective value creation structured along technological trajectories. Importantly, this is an inherently dynamic process. As our examples indicate, a critical issue for managers is to learn to manage the evolution of their industry platforms and accompanying ecosystems and make interrelated technological and business decisions. For example, ecosystem governance should include reinforcing the business models of members, which is essential to sustain their incentives to invest and produce complementary innovations.

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 external ecosystem need to develop a vision for their platform and promote this among potentially key players in the present and the future. 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, as well as associated business models, to remain competitive as challengers emerge and as markets and technologies change. Overall, the effective practice of platform leadership entails a set of internal processes that enable managers to make technological decisions on the one hand and strategic business decisions on the other in a coherent manner—even if the decisions must take place in different parts of the organization.

This imperative for coherence creates challenges not only for practitioners, as internal divisions of labor 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 rich 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 management of technological change.

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, dominant designs, and on organizational processes, could usefully address the question of platform emergence and ecosystem creation as well (see, for example, Adner and Kapoor, 2010; Murmann and Frenken, 2006; Suarez and Utterback, 1995). The difficulty to follow the emergence of platforms may be compounded by the inherent methodological difficulty involved when attempting to follow the emergence of an unknown entity, when one cannot know ex ante who the actors involved in the emergence process will be. Attempting to address this issue, empirical studies such as Le Masson, Weil, and Hatchuel (2011) whose focus is on collective design processes for developing industry platforms, open up useful theoretical and methodological avenues by utilizing design theory methodologies that allow us to follow objects as they emerge. 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.

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 (i.e., 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 cocreating 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

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, Galaskiewicz, Greve, and Tsai, 2004 for a review), by bringing its insights on network dynamics and field evolution (Powell, White, Koput, and Owen-Smith, 2005) and strategic networks (Gulati, Nohria, and Zaheer, 2000; Lorenzoni and Lipparini, 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 offers 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 therefore offer 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 nonincremental 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.

References

Abernathy, W. J., and J. M. Utterback. 1978. Patterns of innovation in industry. *Technology Review* 80 (7): 40–47.

Adner, R., and R. Kapoor. 2010. Value creation in innovation ecosystems: How the structure of technological interdependence affects firm performance in new technology generation. *Strategic Management Journal* 31 (3): 306–33.

Anvaari, M., and S. Jansen. 2010. *Evaluating architectural openness in mobile software platforms*. Copenhagen: 2nd Workshop on Software Ecosystems.

Armstrong, M. 2006. Competition in two-sided markets. *RAND Journal of Economics* 37 (3): 668–91.

Baldwin, C. Y., and K. B. Clark. 2000. *Design rules: The power of modularity*. Cambridge, MA: MIT Press.

Baldwin, C. Y., and J. Woodard. 2009. The architecture of platforms: A unified view. In *Platforms, markets and innovation*, ed. A. Gawer, 19–44. Cheltenham, UK: Edward Elgar.

Boudreau, K. 2012. Let a thousand flowers bloom? An early look at large numbers of software "apps" developers and patterns of innovation. *Organization Science* 23 (5): 1409–27.

Boudreau, K., and A. Hagiu. 2009. Platforms rules: Multi-sided platforms as regulators. In *Platforms, markets and innovation*, ed. A. Gawer, 163–91. Cheltenham, UK: Edward Elgar.

Brandenburger, A., and B. J. Nalebuff. 1997. *Co-opetition*. New York: Currency Doubleday.

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

Bresnahan, T., and S. Greenstein. 1999. Technological competition and the structure of the computer industry. *Journal of Industrial Economics* 47 (1): 1–40.

Brown, J. K. 1995. *The Baldwin locomotive works, 1831–1915: A study in American industrial practice*. Baltimore, MD: The Johns Hopkins University Press.

Brusoni, S. 2005. The limits to specialization: Problem-solving and coordination in modular networks. *Organization Studies* 26 (12): 1885–907.

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): 179–89.

Caillaud, B., and B. Jullien. 2003. Chicken and egg: Competition among intermediation service providers. *RAND Journal of Economics* 34 (2): 309–28.

Campbell-Kelly, M., and W. Aspray. 1996. *Computer: A history of the information machine*. New York: Basic Books.

Chesbrough, H. W. 2003. *Open innovation: The new imperative for creating and profiting from technology*. Boston, MA: Harvard Business School Press.

Christensen, C. 1997. *The innovator's dilemma*. Boston: Harvard Business School Press.

Cusumano, M. A. 2004. *The business of software*. New York: Free 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., Y. Mylonadis, and R. S. Rosenbloom. 1992. Strategic maneuvering and mass-market dynamics: The triumph of VHS over Beta. *Business History Review* 66 (1): 51–94.

Cusumano, M. A., and K. Nobeoka. 1998. *Thinking beyond lean*. New York: Free Press.

Dhanaraj, C., and A. Parkhe. 2006. Orchestrating innovation networks. *Academy of Management Review* 31 (3): 659–69.

Dosi, G. 1982. Technological paradigms and technological trajectories: A suggested interpretation of the determinants and directions of technical change. *Research Policy* 11 (3): 147–62.

Eisenmann, T., G. Parker, and M. Van Alstyne. 2006. Strategies for two-sided markets. *Harvard Business Review* 84 (10): 92–101.

Eisenmann, T., G. Parker, and M. Van Alstyne. 2009. Opening platforms: How, when, and why? *Platforms, markets and innovation*, ed. A. Gawer, 131–62. Cheltenham, UK: Edward Elgar.

Evans, D. S. 2003. The antitrust economics of multi-sided platform markets. *Yale Journal on Regulation* 20 (2): 325–82.

Evans, D. S. 2009. How catalysts ignite: The economics of platform-based start-ups. In *Platforms, markets and innovation*, ed. A. Gawer, 99–128. Cheltenham, UK: Edward Elgar.

Farrell, J., and M. L. Katz. 2000. Innovation, rent extraction, and integration in systems markets. *Journal of Industrial Economics* 97 (4): 413–32.

Feitzinger, E., and H. L. Lee. 1997. Mass customization at Hewlett-Packard: The power of postponement. *Harvard Business Review* 75 (1): 116–21.

Fisher, F., J. McKie, and R. Mancke. 1983. *IBM and the U.S. data processing industry*. New York: Praeger.

Gawer, A. 2000. The organization of platform leadership: An empirical investigation of Intel's management processes aimed at fostering innovation by third-parties. Unpublished PhD Thesis, MIT Sloan School of Management, Cambridge, MA.

Gawer, A. 2009. *Platforms, markets and innovation*. Cheltenham, UK: Edward Elgar.

Gawer, A., and M. A. Cusumano. 2002. *Platform leadership: How Intel, Microsoft, and Cisco drive industry innovation*. Boston, MA: 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.

Gerstner, L. 2002. *Who says elephants can't dance? Inside IBM's historic turnaround*. New York: Harper Business.

Grad, B. 2002. A personal recollection: IBM's unbundling of software and services. *IEEE Annals of the History of Computing* 24 (1): 64–71.

Greenstein, S. 2009. Open platform development and the commercial internet. In *Platforms, markets and innovation*, ed. A. Gawer, 219–48. Cheltenham, UK: Edward Elgar.

Gulati, R., N. Nohria, and A. Zaheer. 2000. Strategic networks. *Strategic Management Journal* 21 (3): 203–16.

Hagiu, A. 2006. Pricing and commitment by two-sided platforms. *RAND Journal of Economics* 37 (3): 720–37.

Hagiu, A. 2007a. Merchant or two-sided platform? *Review of Network Economics* 6 (2): 115–33.

Hagiu, A. 2007b. Multi-sided platforms: From microfoundations to design and expansion strategies. Harvard Business School, Working Paper No. 07-094, Boston, MA. Available at http://www.hbs.edu/research/pdf/07-094.pdf (accessed 6 February 2012).

Iansiti, M., and R. Levien. 2004. *The keystone advantage: What the new dynamics of business ecosystems mean for strategy, innovation, and sustainability*. Boston, MA: Harvard Business School Press.

Isaacson, W. 2011. *Steve Jobs*. New York: Simon & Schuster.

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): 1200–21.

Kenney, M., and B. Pon. 2011. Structuring the smartphone industry: Is the mobile Internet OS platform the key? *Journal of Industrial Competition and Trade* 11 (3): 239–61.

Krishnan, V., and G. Gupta. 2001. Appropriateness and impact of platform-based product development. *Management Science* 47 (1): 52–68.

Leblebici, H. 2012. The evolution of alternative business models and the legitimization of universal credit card industry. *Advances in Strategic Management: History and Strategy* 29: 117–51.

Lehnerd, A. P. 1987. Revitalizing the manufacture and design of mature global products. In *Technology and global industry: Companies and nations in the world economy*, ed. B. R. Guile and H. Brooks, 49–64. Washington, DC: National Academy Press.

Le Masson, P., A. Hatchuel, and B. Weil. 2011. The interplay between creativity issues and design theories: A new perspective for design management studies? *Creativity and Innovation Management* 20 (4): 217–37.

Le Masson, P., B. Weil, and A. Hatchuel. 2010. *Strategic management of design and innovation*. Cambridge: Cambridge University Press.

Le Masson, P., B. Weil, and A. Hatchuel. 2011. Platforms for the design of platforms: Collaborating in the unknown. In *Platforms, markets and innovation*, ed. A. Gawer, 273–305. Cheltenham, UK: Edward Elgar.

Levy, S. 2011. *In the plex: How Google works, thinks, and shapes our lives*. New York: Simon & Schuster.

Lorenzoni, G., and A. Lipparini. 1999. The leveraging of interfirm relationships as a distinctive organizational capability: A longitudinal study. *Strategic Management Journal* 20 (4): 317–39.

McGrath, M. E. 1995. *Product strategy for high-technology companies*. New York: Irwin Professional Publishing.

Meyer, M. H., and A. P. Lehnerd. 1997. *The power of product platforms: Building value and cost leadership*. New York: Free Press.

Moore, J. F. 1996. *The death of competition: Leadership and strategy in the age of business ecosystems*. New York: HarperBusiness.

Muffatto, M., and M. Roveda. 2002. Product architecture and platforms: A conceptual framework. *International Journal of Technology Management* 24 (1): 1–16.

Murmann, J. P., and K. Frenken. 2006. Towards a systematic framework for research on dominant designs, technological innovations, and industrial change. *Research Policy* 35: 925–52.

Nambisan, S., and M. Sawhney. 2011. Orchestration processes in network-centric innovation: Evidence from the field. *Academy of Management Perspectives* 25 (3): 40–57.

Norman, D. A. 1988. *The design of everyday things*. New York: Doubleday.

Parker, G., and M. Van Alstyne. 2005. Two-sided network effects: A theory of information product design. *Management Science* 51 (10): 1494–504.

Perrons, R. K. 2009. The open kimono: How Intel balances trust and power to maintain platform leadership. *Research Policy* 38: 1300–12.

Pine, J. 1993. *Mass customization: The new frontier in business competition*. Boston, MA: 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): 278–96.

Powell, W. W., D. R. White, K. W. Koput, and J. Owen-Smith. 2005. Network dynamics and field evolution: The growth of inter-organizational collaboration in the life sciences. *American Journalof Sociology* 110 (4): 1132–205.

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

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

Rochet, J.-C., and J. Tirole. 2006. Two-sided markets: A progress report. *RAND Journal of Economics* 35 (3): 645–67.

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

Rosenbloom, R. S., and M. A. Cusumano. 1987. Technological pioneering and competitive advantage: The birth of the VCR industry. *California Management Review* 29 (4): 51–76.

Rothwell, R., and P. Gardiner. 1990. Robustness and product design families. In *Design management: A handbook of issues and methods*, ed. M. Oackley, 279–92. Cambridge, MA: Basic Blackwell.

Sabbagh, K. 1996. *Twenty-first century jet: The making and marketing of the Boeing 777*. New York: Scribner.

Sako, M. 2003. Modularity and outsourcing: The nature of co-evolution of product architecture in the global automotive industry. In *The business of systems integration*, ed. A. Prencipe, A. Davies, and M. Hobday, 229–53. Oxford: Oxford University Press.

Sako, M. 2009. Outsourcing of tasks and outsourcing of assets: Evidence from automotive suppliers parks in Brazil. In *Platforms, markets and innovation*, ed. A. Gawer, 251–72. Cheltenham, UK: Edward Elgar.

Sanderson, S. W., and M. Uzumeri. 1997. *Managing product families*. Chicago, IL: 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: Tradeoffs in appropriability, network externalities, and architectural control. In *Platforms, markets and innovation*, ed. A. Gawer, 192–218. Cheltenham, UK: Edward Elgar.

Simpson, T. W., Z. Siddique, and J. Jiao. 2005. Platform-based product family development: Introduction and overview. In *Product platforms and product family design: Methods and applications*, ed. T. W. Simpson, Z. Siddique, and J. Jiao, 1–16. New York: Springer.

Staudenmayer, N., M. Tripsas, and C. L. Tucci. 2005. Interfirm modularity and its implications for product development. *Journal of Product Innovation Management* 22 (4): 303–21.

Suarez, F., and J. Utterback. 1995. Dominant designs and the survival of firms. *Strategic Management Journal* 16 (6): 415–30.

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

Tabuchi, H. 2012. How the tech parade passed Sony by. *The New York Times*, April 14.

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: 1259–85.

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. Unpublished 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): 1389–410.

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[12] and LanDesk Software products; also, diffused through Microsoft, as ingredients: Wake-on-LAN[13] 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).

[12] 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: http://www.webopedia.com)

[13] LAN = local area network. A computer network that spans a relatively small area.