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Platform control during battles for market dominance: The case of Apple versus IBM in the early personal computer industry

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ABSTRACT

We conduct a case study of the battle for market dominance between the industry platforms led by Apple and by IBM in the early personal computer industry (1977–1986). Platform leaders such as Apple or IBM need to consider many technological, strategic, and network factors in managing their industry platforms. We explore how platform leaders deploy these factors and their interactions during a battle for market dominance. We find that platform leaders choose various control modes to do so, ranging from central control to distributed control. The adoption of these control modes is dependent on the choice of being first entrant with a technological discontinuity (central control) or follower (distributed control). Within a control mode, technological, strategic, and network factors are managed in a coherent way.

1. Introduction

How do platform leaders deploy technological, strategic, and network factors to manage their industry platforms during a battle for market dominance? Are industry platforms that attain market dominance managed differently from those that do not? To answer these questions, we extend existing literature by providing an integrated approach, taking technological, strategic, and network factors, as well as their interactions into account. We introduce the concept of central and distributed control modes to manage platforms, and we discuss the relationship between control mode choice, platform flexibility, and the stage of technology evolution. We indicate implications for the tension between standardization and innovation.

Competition between de facto standards often takes place at the platform level, i.e., among industry networks that form around the standards (Gomes-Casseres, 1994; Vanhaverbeke and Noorderhaven, 2001). When multiple industry platforms emerge to meet a comparable market need, such competition may take the shape of a battle for market dominance. Usually, in such battles, a few major companies act as platform leaders: they invest in technological innovation during the risky early stages of the battle, they maneuver strategically, and they shape the network (Gawer and Cusumano, 2008). Other companies act as platform followers, supporting one or more of the emerging industry platforms by providing complementary hardware, software, or services.

Researchers of battles for market dominance have identified technological, strategic, and network-related factors for winning or losing such battles (for overviews, see Schilling (1998), Suarez (2004), Van de Kaa et al. (2011)). While the importance of these factors is supported by empirical research, researchers do not always agree on their effects. Although technological superiority is recognized as an important factor (Suarez, 2004), many researchers report that technology in general, or technical performance specifically is not decisive for winning or losing the battle, certainly not on its own (Cusumano et al., 1992; Gallagher and Park, 2002; Sillanpää and Laamanen, 2009). Strategic maneuvering is generally found to be important, but entry timing-one of the most important strategic decisions – is sometimes reported not to be decisive (Cusumano et al., 1992; Gallagher and Park, 2002). Likewise, some researchers report that the network of complementary partners is important (Cusumano et al., 1992; Gallagher, 2012; Rosenkopf and Tushman, 1998), whereas others find it to be of limited importance (e.g., Suarez, 2005). A possible explanation for these non-convergent results is that, next to the

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direct effects of the individual factors, interaction effects are important.

In this paper we therefore explore how platform leaders deploy technological, strategic, and network factors simultaneously to manage their industry platforms during a battle for market dominance. We also examine whether the leader of a platform that attained dominance managed these factors and their interactions differently compared to the leader of a platform that did not attain dominance. Specifically, we study the battle between the industry platforms led by Apple and by IBM in the early personal computer industry between 1977 and 1986. Suarez (2004) notes that various labels have been used in the literature to describe such battles, e.g., 'standards battles', 'standards wars', 'technological trajectories', 'technology battles', 'battles for technological dominance' or 'battles for market dominance'. We refer to the battle between the industry platforms as a 'battle for market dominance' and we define market dominance in terms of market share. Our unit of analysis is the industry platform, which has technological aspects, strategic aspects and network aspects.

We adhere to the platform framework as put forward by Gawer (2014) and Gawer and Cusumano (2014). They distinguish between product or technology platforms, supply chain platforms, and industry platforms. Gawer and Cusumano (2014, p.417) define 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." This definition includes the technological, strategic and network aspects as we identified in the literature. Technologically, a platform consists of a technological architecture with core and periphery subsystems and interfaces (Meyer and Lehnerd, 1997). With the personal computer platform there are core subsystems, such as the basic input–output system, the operating system, the central processing unit or the system board, and peripheral subsystems such as application software, random access memory, keyboard, monitor or printer (see Langlois and Robertson (1992)). The subsystems connect through interfaces. Many de facto and de jure standards are applied in the subsystems and the interfaces. The technology aspect of our paper does not focus on the specific subsystems or interfaces, nor on the (technical) standards used in them, but on the platform as "an architecture of related standards" (West, 2003, p.1260).

2. Theory

Battles for market dominance have been studied from several theoretical perspectives. Below we discuss the technology management and standardization perspectives to identify technological factors, the strategic management perspective to identify strategic factors and the network perspective to identify network factors. To place these factors in a dynamic framework, we subsequently discuss an evolutionary perspective on such battles.

2.1. Technological factors

Technological factors are considered in technology management and standardization literature. Scholars in the area of technology management emphasize innovativeness, technical quality, and modularity. Technological innovativeness is important, because a radical or architectural innovation is necessary to create a technological discontinuity and start an era of variation (Tushman and Rosenkopf, 1992). Gallagher and Park (2002) find that although technological superiority is important for entry, it might not be enough to ensure market dominance of a technology.

Technical quality can be defined as objective technical performance or as utility in the eyes of the relevant customer. Most researchers seem to agree that technical quality is not a factor that decides battles for market dominance, certainly not on its own (Cusumano et al., 1992; Gallagher and Park, 2002; Sillanpää and Laamanen, 2009). Likely, the competitive process during the battle forces a platform to continually match the competing platforms (e.g., Sillanpää and Laamanen, 2009) by putting offerings in the market that are more or less equivalent in technical quality or at least 'good enough' in the eyes of the customer. In the early personal computer example, this became visible through continual updates of the operating systems, of hardware (e.g., processor speed), and of operating and application software. In other words, technical quality seems to be a minimum requirement for platform success.

Modularity is a central aspect of a technological architecture (Gawer, 2014) and an important enabler of change in technology (Schilling, 2000). It implies that the technological architecture consists of components as building blocks that can be separated and combined (Schilling, 2000) according to the rules of the platform (e.g., swapping hard disk drives, installing application software, connecting various printers or monitors). When the interfaces are strictly specified, it is possible to remove, add, or replace the components and thereby influence technical performance, i.e., it enables modular innovation (Langlois and Robertson, 1992). Memory cards for cameras and consumer electronics are examples of modular design, because users can replace them to increase their devices' performance.

Scholars of standardization emphasize compatibility and flexibility as important characteristics of a technological architecture. There are two types of compatibility between components: compatible complements and compatible substitutes (David and Bunn, 1988). Compatible complements, i.e., components that can work with each other, enable the emergence of a platform for which many complementary products are available. Examples are the ability of a music player to interoperate with a computer, or the availability of cartridges for a printer. The availability of complementary goods has a positive effect on platform dominance (Cenamor et al., 2013). Compatible substitutes are manifested when one component of a system can be replaced by another, competing component; e.g., hard disk drives that function in different computer systems. To make components work well together, standardized interfaces as well as coding similarity is required.

Flexibility of a platform can be conceptualized as the ability to change the subsystems within an architecture (see Olleros (2008) and Tiwana et al. (2010)). As such, modularity combined with standardized interfaces contributes to platform flexibility within the architecture (Meyer and Lehnerd, 1997). A modular configuration keeps the platform flexible for supply partners: it is easy to upgrade or replace modules. This flexibility increases product variety and/or improves technical quality for the customer without changing the internal coherence of the (less flexible) architecture. Cusumano et al. (1992) point out that in the Betamax-VHS battle, Sony introduced a high quality but fairly inflexible platform into the market, while JVC welcomed improvements to the platform as suggested by its partners and as a result, the VHS platform was more flexible.

2.2. Strategic factors

Scholars in strategic management who focus on battles for market dominance emphasize the importance of strategic maneuvering, strategic capabilities and resources of the platform leader. Choosing the timing of entry is an example of strategic maneuvering. Examples of strategic capabilities and resources are operational supremacy in terms of production and distribution, reputation, installed base, and appropriability. Most of these scholars stress that these resources and capabilities are mainly relevant in combination with each other and with strategic maneuvering (Casey and Töyli, 2012; Gallagher and Park, 2002). For example, financial resources are needed for the initial investments in technology, but they remain important throughout the battle. Battles for market dominance are characterized by intense rivalry and may result in bankruptcy of firms that are involved (Sillanpää and Laamanen, 2009). Financial resources are important in combination with strategic maneuvering when deciding the right time to enter the market. Financial resources may be used to apply pricing strategies. Early on in the battle, penetration pricing can be important to gain market share quickly. For example, in the HD DVD versus Blu-ray battle, the HD DVD platform had an initial advantage because of its lower prices. However, this advantage significantly diminished when Sony cut the prices of its Blu-ray players as well (Gallagher, 2012). Being first also entails the burden of having to educate the market on the new technology. The second entrant has a disadvantage in lead time, but enjoys advantages in positioning and in the ability to improve on the incumbent technology in terms of technical quality or features. Gallagher and Park (2002) find that being first-to-market is not a guarantee for success, and Schilling (2002) finds an inverse U-shaped effect of timing of entry on technology success. Financial resources may also be used to develop and execute marketing campaigns. Pre-announcements and strategic commitments are important, especially at the beginning of the battle when the pressure builds up in the market and the various platforms leapfrog each other in the quality of their offerings (Gallagher, 2012; Sillanpää and Laamanen, 2009). At this stage, each platform tries to win customer trust, because powerful network effects are unleashed when the market reaches a tipping point, and after that point it is difficult to change the course of events (Sillanpää and Laamanen, 2009).

2.3. Network factors

Various authors who focus on the effect of networks on market dominance borrow from the literature on social networks. They emphasize that financial resources in combination with the reputation and the credibility of partners may influence other firms to engage in partnerships with platform leaders. Partnerships may be established with providers of complementary products, because the provision of such products is crucial for the success of a platform (Cenamor et al., 2013). From their study of five generations of game consoles, Gallagher and Park (2002) find a strong effect of the provision of complements: platforms with strong complementary support mostly emerge as winners. Many game console platform leaders provide a number of 'killer app' games themselves, relying on the network of complementary partners to provide the rest. Since a large network can provide many more complements than the platform leader itself, there is a strong interaction between the strategy of providing complements and the size and diversity of the network. In fact, guaranteeing a large availability of complementary products is so important that some firms may even use financial resources to persuade firms to join a platform. Allegedly, Warner Bros. switched from HD DVD to Bluray because they received side payments (Gallagher, 2012). Apart from guaranteeing a sufficient supply of complementary products, network partnerships may increase capacity for mass production and distribution, which is important for achieving platform success (Cusumano et al., 1992).

In particular, three network characteristics have been identified to affect market dominance of a platform: network size, network diversity, and network structure. First, network size, i.e., the number of partners supporting the platform is important (Cusumano et al., 1992; Gallagher and Park, 2002) because it indicates the occurrence of network effects (Shapiro and Varian, 1999). The effect of network size is especially apparent in interaction with other factors such as network diversity (Soh, 2010). Second, network diversity, i.e., the different types of partners around the platform, influences its success (Gallagher, 2012,; Gallagher and Park, 2002; Vanhaverbeke and Noorderhaven, 2001). Again, this effect is especially apparent in interaction with other strategic and technological factors (Gallagher, 2012). A third factor is network structure, i.e., a combination of actor centrality and network density Three *ideal types of* networks can be identified: (1) a star-shaped network with high centrality and low density, (2) a fully connected network with low centrality and high density, and, (3) a core–periphery network that combines a densely connected network 'core', comprising a limited number of partners with a lowly connected periphery, comprising a large number of partners that are only connected to one of the 'core' partners. Vanhaverbeke and Noorderhaven (2001) propose that the structure of the network depends on the strength of the central player: strong central players may be able to dominate the network, which will result in a star-shaped structure. If this is not possible, a consortium may be formed, structured as a fully connected sub-network, and finally, a weak central player may not have the capabilities to organize a consortium, which will also result in a star-shaped structure, albeit a weak one. Capaldo (2007) argues that a core–periphery network structure is particularly effective for innovation purposes: it has strong connections in the core of the network that may increase network effectiveness, it may lock the core partners together into executing their existing ideas, and it may limit opportunistic behavior while the connections with the periphery keeps the network varied and open to new partners. Suarez (2005) study shows the importance of forming a strongly connected technology consortium, which resembles a strongly connected network core.

2.4. An evolutionary perspective

In the previous subsections we identified explanatory effects of technological, strategic and network factors for market dominance. Authors who took an evolutionary perspective described the technological dynamics involved in battles for market dominance (e.g., Gallagher and Park, 2002). The introduction of a technological discontinuity starts off a new cycle with a variation stage (Tushman and Rosenkopf, 1992). When this technological discontinuity becomes visible in the market, it partly determines the reactions of market actors, who may decide to bring their own technological architectures to the market. When multiple competing technological architectures are available, an era of ferment starts, in which parallel processes of substitution, competition, and ongoing technical change unfold due to the behaviors of all actors involved (Tushman and Rosenkopf, 1992). The introduction of a new technological architecture can set off a new cycle. To measure the timeline of technology evolution in practice, Ortt and Schoormans (2004) formulate a technology evolution pattern using three hallmarks: (1) invention: the first time that a technological principle is demonstrated, (2) introduction: the time that the first products in the category are sold or applied in practice, and (3) industrial production and large-scale diffusion of products. The pattern is now subdivided in three subsequent phases referred to as the innovation phase (from invention to first market introduction), the adaptation phase (from first market introduction to large-scale industrial production and large-scale diffusion), and the market stabilization phase (from large-scale industrial production and diffusion to the moment that the technological product is no longer sold).

3. Methodology

We choose an exploratory case study approach (Yin, 1994), because the concepts we study are abstract and the boundaries between the phenomena and their context are unclear. For theoretical reasons (Eisenhardt, 1989) we chose a case study where the technological, strategic, and network factors are relevant in determining market dominance of an industry platform, and the winner of the battle is clear within the chosen time frame. We study the battle for dominance in the early personal computer industry, starting with the introduction of the Apple II in 1977 and ending with the market dominance of the IBM PC platform in 1986. We focus on the main contenders in hindsight: the Apple-led and IBM-led industry platforms. We abstract from other contenders that were important during the early stages of the battle, but that disappeared afterwards.

We collected data from secondary sources in the form of academic publications and business reports. First, we defined and described each of the industry platforms. Second, we specified a timeline for the battle, based on identification of important technological events (i.e., invention, prototypes, commercialization, diffusion, and large-scale production), followed by an analysis and decision on the hallmarks proposed in the Ortt and Schoormans (2004) framework. Third, we assessed the values over time for each of the separate technological, strategic, and network factors discussed in the literature review and we measured market share of the platforms over the timeline. We do not aggregate the factors. Table 1 lists the factors and explains how they were measured. Two researchers independently analyzed the data to judge whether a certain factor played a part in the battle, and if so how. We checked the obtained evidence across multiple sources and between the independent researchers.

4. Case Apple versus IBM

In the 1970s, the first personal computers emerged, such as the Apple I in 1976 (Ceruzzi, 2003). In 1977, three personal computers were introduced that, for the first time, sold as a complete system: the Apple II, the Commodore PET and the Tandy TRS80. According to Helmers (1977, p.10) The Apple II was the first computer that was "*… a completed system which is purchased off the retail shelf, taken home, plugged in and used.*" We interpret this as a technological discontinuity in the form of an architectural innovation. From that moment onwards, various rival platforms would fight for dominance in the personal computer industry.

Apple, a new entrant in the computer industry, together with several carefully selected suppliers, managed to create a carefully designed technological architecture of computer-hardware, operating system, user interface, and software. Apple wanted to own and control the primary technology in their products (Burrows, 2004), and as a result, its platform was fairly closed and strictly controlled (Thomke and Feinberg, 2009). In technical quality, the first Apple computers were superior to the IBM PCs that would emerge later on. Apple, with its integrated, high-quality computers, decided to target different customer segments than personal computer hobbyists and enthusiasts. Its complementary software VisiCalc (a 'killer app'), was a serious business tool for companies that wanted to check their balance sheets and perform financial calculations. Later, it focused on specific niches of professional users, such as graphical designers and text editors. Apple was able to create a large and growing network of partners by providing complementary products such as printers and software. It centrally controlled the network in order to safeguard the integration of components and the technical quality of the entire system.

IBM entered the personal computer market later, in 1981

Table 1
Factors in battles for market dominance.

Factor	Explanation	Range of values
1. Technology		
Technological innovativeness	Innovativeness according to the Henderson and Clark (1990) framework	Radical, incremental, architectural, or modular
Technical quality	Performance on objective technical quality metrics and on relevant customer utility metrics	Low to high on multiple dimensions
Modularity	Whether the technology consists of components as building blocks that can be separated and combined	Fully integrated system to fully modular system
Compatibility of substitutes	Compatible substitutes are modules that can also work with other (competing) platforms	Easy to difficult
Compatibility of complements	Compatible complements are modules that can work with each other	Easy to difficult
Flexibility of platform	Ability to change subsystems or interfaces	Flexible to inflexible
2. Network		
Network size	Number of (supply-side) partners supporting the platform	Low to high
Size of platform leaders	Identification of platform leaders, including their size in terms of turnover	Large to small for every platform leader
Network diversity	Number of various groups of complementary partners supplying complementary hardware, software, and services	Few to many
Network governance structure	The closest ideal type structure of the network	Star-shaped, fully connected, or core–periphery
3. Strategy		
Entry timing	Year in which the first product based on the technological architecture is introduced; order of entry	Year; first or second
Product range	Range of products, features, and prices	Small range to large range
Operational supremacy: production	Number of production facilities	Few to many
Operational supremacy: distribution	Number of distribution facilities	Few to many
Pricing	Prices and pricing strategy after introduction	Low to high; penetration pricing or skimming
Provision of complementary products	Hardware, software, and services working together with the platform technology	Few to many
Installed base	Other complementary products or product lines to increase platform adoption	Low to high, or none
Reputation	Reputation of platform leader(s) in the industry	Low to high
Financial support	Financial resources to realize platform adoption	Low to high
Appropriability	Extent to which basic technology of the platform is proprietary and protected	Low to high
Dominance		
Market dominance	Market share of the main product bundles (personal computers) based on the platform	Percentage

(Ceruzzi, 2003), and benefitted from a solid reputation as world leader in mainframe computers. IBM noticed that Apple with VisiCalc could compete with IBM's more expensive mainframe systems, and responded promptly. IBM allied with two main partners: Intel, a small company that produced the 8080 processor and Microsoft, which was virtually unknown at that time and created the operating system. The IBM PC was rather quickly developed as an architecture with interchangeable components. This created an open platform to which producers from all over the world could supply components (Ceruzzi, 2003), and within which manufacturers from all over the world could assemble their own PC compatible clones. IBM opted for diversity and flexibility in its platform by initially allowing various operating systems and processors of which, eventually, Microsoft (with DOS) and Intel prevailed. Software developers were invited to develop compatible software. As a result, IBM announced the availability of a variety of software programs: word processing, accounting, games, and Lotus 1-2-3, a spreadsheet that took advantage of the IBM PC architecture, and outperformed the Apple platform's VisiCalc.

Up to the early 1980s, Apple seemed to have the best starting position for the battle that was to come. It created a vast, centrally controlled network of partners to support its platform. Its computer systems were technically superior compared to its later rivals. However, the diversity of partners involved in producing and developing hardware and software for the IBM PC grew faster. New partners, such as component producers, PC manufacturers, and software suppliers, could easily join the platform because the information how to make their products compatible was publicly available. The open structure that characterized both the hardware and software of the IBM platform facilitated partners from all over the world to enter the network. The number of software applications for IBM PC compatible personal computers soon outnumbered those for Apple's (Gilbert, 1999). This facilitated the diffusion of the IBM PC in different regions and across different market segments. The resulting growth of the installed base of IBM PCs, in turn, allowed the IBM platform to improve its hardware and software quickly, and to deliver a user experience of comparable technical quality, but with more complementary hardware and software applications. In 1986, the IBM platform reached market dominance (55% market share of IBM-compatible PC's) and won the battle from Apple and from the other competing platforms, such as Commodore (Reimer, 2012).

In Table 2 we present the data for each of the variables taken into account. It shows that Apple was the first supplier of a professional personal computer platform with superior technical quality and an advanced yet intuitively understandable user interface. The technical quality of their personal computer and the availability of specialized complements (e.g., laser printers) allowed Apple to enter professional market niches that had been supplied by far more expensive microcomputers. Thus, Apple competed with these microcomputer producers rather than with the first PC producers. Because Apple entered the market earlier than IBM, it was able to benefit from network effects, and managed to create a fast growing network of suppliers providing complementary products and services.

However, the open platform approach of IBM with its PC architecture, and the accompanying strategy that facilitated other partners to join the network, resulted in much higher growth compared to that of the Apple platform. Due to this growth, IBM could attract even more partners and customers, and was able to

Table 2
Data from the case.

Factor	Apple platform	IBM platform
Mode	Central control	Distributed control
1. Technology		
Technological innovativeness	Architectural	Architectural, incremental
Technical quality	High	Good enough
Modularity	Integrated/modular, with core modules not easily replaceable by partners or users	Modular, with modules (incl. core modules) replaceable by partners or users
Compatibility of substitutes	Difficult	Difficult for products based on another platform; easy for products based on the same platform (i.e., clones)
Compatibility of complements	Easy for consumers; difficult for partners	Easy for partners; easy for consumers
Flexibility of platform	Inflexible: core modules defined or provided by Apple, change controlled by Apple	Flexible: core modules interchangeable, change defined by key partners
2. Network		
Network size	Comparatively large in the beginning, comparatively smaller later on	Comparatively small in the beginning, comparatively larger later on
Size of platform leaders	Single platform leader that was still relatively small	Large
Network diversity	Few groups; strong in specific niches	Many varied groups of complementary partners
Network governance structure	Star-shaped, central governance	Core–periphery, distributed governance
3. Strategy		
Entry timing	1977: first	1981: second
Product range	Limited, integrated range of products	Large range of products due to possible recombination of modules
Operational supremacy: production	Few	Many
Operational supremacy: distribution	Few	Many
Pricing	High prices, skimming	Range of prices from high to low
Provision of complementary products	Limited, strong in niches, partly provided by Apple	Extensive and specialized, mainly provided by the many network partners
Installed base	None	IBM: office equipment
Reputation	Innovative runner-up	IBM: very reputable; Microsoft: initially unknown, later known as smart copier; Intel: reputation on DRAM business, switched to microprocessors
Financial support	Low	High
Appropriability	High	Low
Dominance		
Dominance	1981: around 15% 1986: less than 10%	1981: around 2% 1986: around 55%

invest in fast product improvement. Thus, it appears that both networks of partners had a core, but that these networks were governed differently: Apple adopted a central control mode, whereas IBM employed a distributed control mode The effect of a more open platform approach and the distributed control of the IBM platform facilitated the entrance of new partners in the network and tilted the balance of power.

5. Discussion

5.1. Platform control modes

From the case study, we see that platform leaders choose a control mode for managing their platform during a battle for market dominance. Apple created a platform in which the company itself integrated the hardware, operating system, user interface, and accompanying software to ensure a seamless customer experience. To safeguard the technical quality of the platform, Apple used a central control mode. In contrast, IBM defined the technological architecture, but chose for an open platform so that any supplier could provide components. IBM's platform initially lacked the technical quality that was attained by Apple, but it was more flexible than Apple's, allowing for easier innovation of modules. We conclude that Apple adopted a more centralized control mode, making all the important platform decisions itself, whereas IBM employed a more distributed control mode, allowing multiple partners to contribute to the platform.

These platform control modes resemble the ones used by Sony and JVC in the Betamax-VHS battle. Cusumano et al. (1992) describe how Sony led a high-quality, coherent platform, of which it was reluctant to license out the technology. In contrast, JVC, the platform leader of the VHS platform, involved other partners, notably RCA and its own mother company Matsushita, and welcomed technology improvement suggestions. JVC also licensed the technology to partners including Hitachi, Sharp, Mitsubishi, who were allowed to make their own designs that were compatible with the VHS platform.

These control modes of managing a platform can be seen as choices on a continuum that ranges from a complete in-house control mode to a completely open and market-based mode (see Fig. 1). An example of complete in-house control is the original Xerox copier platform: Xerox supplied almost every complementary product to their copiers itself, even the paper (Chesbrough, 2006). An example of a mode close to the market-based extreme is the development of open-source software, where there is only a committee of volunteers who authorize the official releases, but where any party can make unofficial releases should they want to do so. This continuum connects to Gawer's (2014) conceptual classification of platforms.

5.2. Control mode choice and platform flexibility

The use of these control modes by platform leaders is dependent on choices made early on regarding entry timing and technological innovativeness. To start off a new technology cycle and open up new markets and opportunities, it is necessary to generate a radical or architectural technological innovation (Gallagher and Park, 2002; Tushman and Rosenkopf, 1992). In the early stage of the technology cycle, uncertainty is high and relevant technological knowledge is not freely available in the market. The platform leader therefore needs to make large upfront investments in an uncertain technology. This favors a high-risk, high-return approach, where the platform leader should be able to recover its investments by reaping most of the benefits for itself rather than sharing them. This favors a centrally controlled approach. Innovation *of* the architecture was exclusively Apple's domain, and innovation of modules *within* the architecture could only happen with Apple's explicit consent. In their description of the Betamax-VHS-battle, Cusumano et al. (1992) observe a similar interaction between entry timing, technology development, and the involvement of partners: if the aim is to be first to market and to keep tight control over the platform so as not to compromise its technical quality, it is difficult to involve many partners.

In contrast, a later entrant may find that some of the basic technical problems have already been solved, and can concentrate on putting an offering in the market that is more attractive to customers than that of the first entrant. If the introduction of the initial platform is at least a moderate success, other firms may become interested in the market potential. If there is enough

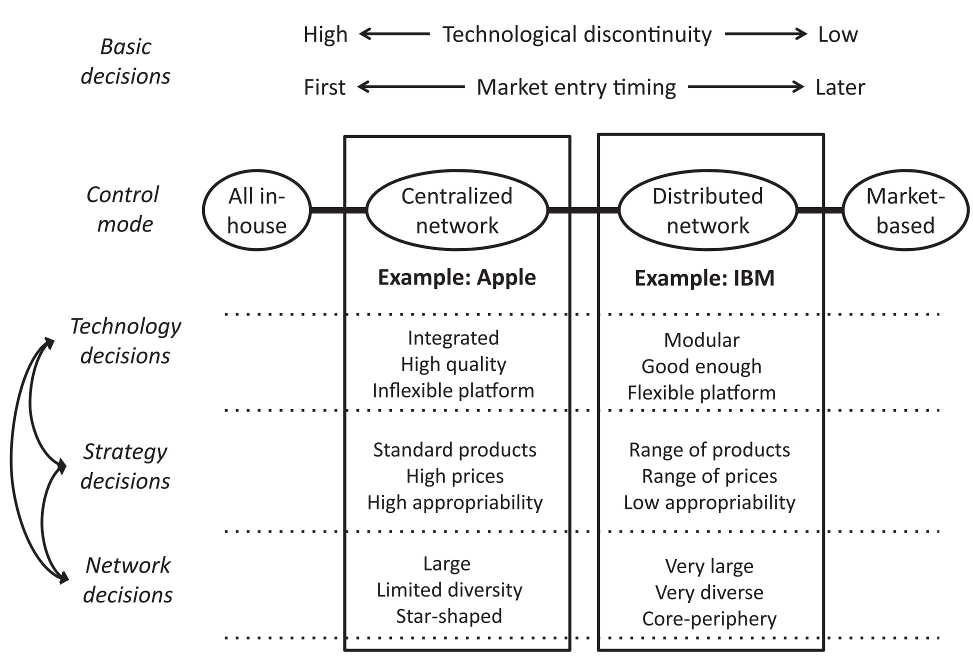

Fig. 1. Platform control modes.

momentum, various partners may be willing to join forces and to create a competing platform that can match the initial one, either in the range of products, features, or prices, in the available complementary hardware, software, and services, and/or in the operational capabilities of large-scale production and distribution. All this favors a mostly distributed control approach, with a relatively open platform. This also means that innovation is more distributed, which clearly happened in the IBM case: initially IBM managed the innovation *of* the technological architecture, while innovation of modules *within* the architecture was almost completely open (even including core modules, such as the BIOS and the operating system).

These findings relate to the question whether standardization constrains innovation or not (see Blind and Gauch. (2009), Ortt and Egyedi (2014), Swann and Lambert (2010)). At first sight, standardization and innovation seem to be conflicting. Standardization aims to limit the number of technological variants, whereas innovation aims to increase them. Upon closer inspection, however, relentless increase in the number of technological variants can create a level of market and technology uncertainty that paralyzes actors in the market, and thereby blocks the wide-scale application of these variants. This will limit further innovation efforts. In contrast, standardization can provide some certainty and thereby direct collective innovation efforts and stimulate the application of these innovations. Platform flexibility is a key characteristic here. A completely rigid platform creates certainty at the expense of innovation. A completely flexible platform does not create any certainty, but it allows all kinds of innovation. Choosing the degree of platform flexibility is essential, and it is interesting to see how Apple and IBM chose different kinds of flexibility in their platforms, while avoiding the extremes of becoming too rigid or too flexible.

5.3. *Coherent management of technological, strategic and network factors*

The management of technological, strategic, and network factors of platforms appear to be co-dependent on the control mode chosen by the platform leader. Within a control mode, we detect coherence in the management of the factors, which is a clear indication of interaction effects between the factors.

A central control mode enables optimization into a well-integrated technological architecture. This enables high technical quality, as the various modules are designed to work together seamlessly. The modules are partly in a fixed relation and are not easily user-replaceable. The customer buys into a well-integrated technological architecture, which increases switching costs, enabling higher margins for the supplier. Higher pricing favors serving the higher end of the market. To be attractive to customers, a large amount of complementary hardware, software, and services needs to be available. As the network is centrally controlled by the platform leader, and therefore less attractive to outside partners, the platform leader provides many of these complements itself. Given the central control mode, the resulting network of companies will resemble a star shape around the central actor. This central control mode strongly resembles the way in which Apple managed the technological, strategic, and network factors to develop its industry platform (see Table 2).

A more distributed control mode of an open platform starts from the network structure: rather than a star-shape, the network has a densely connected core of platform leaders. In the PC case, IBM was the platform leader, but the platform was open to other companies such as Microsoft, Intel, and the PC clone manufacturers. With the core partners connected to a large number of complementary partners, the network shape resembles a core–periphery configuration. Cooperation between the various partners without central control may compromise technology quality. Modules may not always work together seamlessly and technical quality may suffer. The modular architecture, however, allows any actor in the network to innovate modules or complete systems, which results in a fast-evolving platform. In the PC case, this became visible in a continual innovation race of increasing processor clock speed, improved memory, better graphics, and more powerful software. Any actor in the network can develop, produce, and distribute modules or complete systems within the technology architecture. This modularity results in more choice for customers: instead of a single, optimized system, they can now choose from a range of systems with many different features in various price classes. Switching costs to modules or complete systems of other manufacturers within the platform are low. Because of the openness of the platform, the network of companies will be also more open and loosely governed, encouraging niche players to join and resulting in a more diverse network. This distributed control mode strongly resembles the way in which IBM managed the technological, strategic, and network factors to develop its industry platform (see Table 2).

Based on four case studies of open platforms, Olleros (2008) concludes that the successful ones were all designed around a lean network core that enabled the periphery to innovate, which stimulated fast up-scaling and rapid evolution. Likewise, in our Apple versus IBM case, we find that the resulting evolutionary process of variation, selection, and retention ultimately created faster network growth for the more open and distributive controlled PC platform compared to the more centrally controlled Apple platform.

5.4. *Implications for theory*

Our research contributes to the literature on standards and innovation in several ways. First, we provide an integrated approach towards understanding battles for market dominance, as recommended by Narayanan and Chen (2012, p.1392), by using technological, strategic and network perspectives. We show that our understanding of battles for market dominance between industry platforms increases if we consider technological, strategic, and network factors simultaneously. In addition, we find that these technological, strategic, and network factors are related, and therefore need to be managed in a coherent way, which points to interaction effects between the factors.

Second, we introduce the concept of control modes for managing platforms during battles for market dominance: central versus distributed control as choices on a continuum that are related to the stage of technology evolution. Early entry favors a centralized approach whereas late entry favors a distributed approach. This extends research by Olleros (2008), which strongly argues for distributed control to ensure success of platforms. It also connects to Gawer's (2014) classification of platforms, which proposes that industry platforms should be open and distributed, whereas firm-specific product or technology platforms should be closed and centralized.

Third, we put the use of these control modes in a context of punctuated equilibrium theory, innovation, and platform flexibility. Central control is favored for a first entrant in case of a technological discontinuity. It ensures an architecture that tightly integrates complementary hardware, software, and services, which is important for early market acceptance (see, for example, the 'complete system' and 'killer app' aspects of the Apple computer). Early on, it provides innovation opportunities within the architecture for the network of actors involved. Later on, the same centralized control and integrated architecture can hamper innovation, especially innovation aimed at changing or extending the architecture. In contrast, distributed control is preferred for a fast follower. Early on, this approach can create uncertainty as to the integrity and technology quality of the architecture, which may make network actors hesitant to join the platform. Later on, it may stimulate platform innovativeness and flexibility, even allowing innovations that change or extend the architecture. These findings illustrate the tensions between standardization and innovation (Blind and Gauch., 2009; Ortt and Egyedi, 2014; Swann and Lambert, 2010).

Finally, our contributions address Tiwana et al.'s (2010) call for research on the links between industry platform, technology architecture, platform governance, and evolutionary dynamics.

5.5. Implications for practice

This research generates implications for managers of platform-leading companies. First, they need to carefully consider the choice of the control mode to manage their platform: centralized or distributed. The control mode choice that is made early on can influence the outcome of the battle. Second, the control mode chosen is related to the stage of technology evolution and entry timing: early entry with a radical or architectural innovation favors a centralized approach, while later entry as a fast follower favors a distributed approach. Third, the control mode choice influences innovation and flexibility: centralized control stimulates innovation early on by providing an integrated architecture, but limits platform flexibility. Distributed control may limit innovation early on due to uncertainties, but higher flexibility provides wider innovation opportunities. Fourth, within a control mode, technological, strategic, and network factors are managed in a coherent way. Centralized control means an integrated, inflexible platform with high technical quality. The variety of offerings is limited and prices are high to enable the platform leader to appropriate value so as to recuperate investments. The network of actors is centrally controlled and diversity is carefully managed. Distributed control means a modular, flexible platform with sufficient technical quality, and a high variety of offerings and prices. It may be difficult for platform leaders to appropriate value created. The network of actors is large and diverse, and network control is limited. Fifth, the choice of a control mode may influence the outcome of the battle for market dominance. For the Apple versus IBM battle, our results show that IBM's distributed control mode was instrumental in winning the battle for market dominance. However, this result should be interpreted with some care because winning and losing can be determined in different ways. IBM won the battle because its platform attained market dominance. However, IBM later had to give up its platform leadership role to Microsoft and Intel. In the current battle between Apple iOS and Android, the distributed approach of Android is more successful in terms of market share, but the central control approach of Apple generates more profit. Measuring winning and losing in terms of market dominance, technology leadership, or profitability may lead to different conclusions.

5.6. Limitations and areas for further research

There are various limitations to this study that may serve as inspiration for further research. First, we studied a single case, and its findings may extend only to other cases of comparable industry platforms in comparable contexts. This limitation calls for further research using multiple cases, including cases with platforms of a different nature (e.g., software platforms), or with de jure or committee-based standards, or in different sectors or with different technology evolution patterns. Second, by scoping our study as the battle between the Apple-led and IBM-led platforms in the early personal computer industry, we left out a number of potentially interesting aspects. At the time of the battle, Commodore and Tandy were important contenders. During the last stages of the battle, the PC clone manufacturers gradually replaced IBM as the dominant manufacturer, a process that culminated in the 1990s. Also, from the late 1980s onwards, Microsoft and Intel displaced IBM as the platform leader. Including these aspects might generate additional insights. Third, a limitation of studying a past battle is that platform leaders learn from the past, from their own experiences, and from earlier cases, something that can be observed by comparing case studies over time. Platform leaders will increasingly be able to coherently manage their technological, strategic, and network factors to a very high level of sophistication. Inevitably, the factors that decide such battles may shift over time. Further research could address how such learning takes place over time. Fourth, we studied a battle over time, but we did not distinguish the events and influence of factors in various stages of the battle in detail. Doing so, while incorporating the co-evolution of technological, strategic, and network factors, may generate important insights into the time dependency of platform leaders' decisions.

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