To Hunt or to Scavenge: Competitive Advantage and Competitive Strategy in Platform Industries*

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ABSTRACT

Firms choose their competitive strategies to achieve competitive advantage. With the help of a dynamic model we demonstrate that in platform industries, any market structure can be mapped into different types of competitive (dis-) advantage. Numerically simulating the model allows us to find the optimal competitive strategy for each competitive position of a firm within a given market structure. Combining the two concepts, we derive guidelines for determining a firm's optimal competitive strategy conditional on the firm's competitive position within its platform and the position of its platform within the industry. We apply those guidelines to discuss the micro-computer market.

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1. INTRODUCTION

Platform products have become ubiquitous in recent decades: computer hardware and software, DVDs, smart-phones and video-games to name a few. It is well established that in platform markets, the value of a component innovation, such as software, crucially depends on the market share of the compatible platform. This has been extensively discussed in the literature for the classic example of computer hardware and software (e.g., Church and Gandal, 1992). Choosing an optimal competitive strategy in these markets, however, is not as straight forward. Specifically, what is the optimal investment strategy for a firm that wishes to achieve or foster its competitive advantage? As it turns out, in platform industries, the simple "invest more!" strategy is more often false than true.

Bresnahan and Greenstein (1999) define a platform as a "[…] bundle of standardized components around which buyers and sellers coordinate their efforts."[1] Platform markets, often referred to as hardware-software markets, typically exhibit indirect network effects — the more attractive a software, the more consumers want to buy its compatible hardware. This, in turn, attracts more firms to develop software for this hardware.[2] For example, the large selection of apps for the iPhone is frequently cited as an important driver of the iPhone’s success. Indirect network effects thus create synergies between competitors on the same platform: additional competitors on the same platform increase the size of the platform and thus grow the pie (Brandenburger and Nalebuff, 1997) which then can be split between competitors. The strategic role of investment in determining how this pie will be split and its effect on the firm’s competitive advantage in the market, however, has not been analyzed.

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[1] Bresnahan's and Greenstein's definition reveals their insight that the division between hardware and software from an analytical perspective is not the defining feature of platforms - it is the interoperability relationship between standardized components. We will use the words “platform” and “hardware” interchangeably in this paper.

[2] This is in contrast to direct network effects, where the size of the installed base directly influences consumers' choice (see e.g., Katz and Shapiro, 1985; Farrell and Saloner, 1985).

Lippman and Rumelt (1982) and Adner and Zemsky (2006) are two examples in the literature for studies that develop stylized models to demonstrate the importance of certain factors on firms' competitive advantage and competitive strategy. We follow their approach to identify software[3] firms' competitive strategy in platform markets. In our model, firms can affect their competitive position within a platform and simultaneously their platform's market share through investment in quality upgrades. To identify firms' competitive strategy, we therefore need to find firms' optimal investment strategies. We find these with the help of a formal model in which software firms invest in R&D based on expected future profits, taking competitive responses from other firms into account. These responses come from competitors offering software for the same or for a competing platform. Furthermore, firms' decisions are not only affected by consumers' software choices, but also by consumers' platform choices, which in turn are based on firms' investment strategies. These responses create highly complex interactions that make it virtually impossible to solve the model analytically for optimal equilibrium investment strategies. Consequently, following Ericson and Pakes (1995), we use numerical analysis to derive conditions for optimal investment behavior in our model. While the model structure helps identify categories of market leadership that fuel competitive advantage, the numerical analysis delivers interesting and conceptually useful drivers of optimal investment behavior. The two joint together proffer relatively easy-to-follow guidance for the choice of competitive strategy in platform industries.

In order to identify firms' competitive strategy, we first need to determine what factors affect competitive advantage. Markovich and Moenius (2010) analyze this question and find that the main drivers of competitive advantage in platform markets are competitive position and market position. Competitive position is determined by product or process leadership (in our model product quality) within the platform, while market position is determined by the compound competitive positions of all firms on a platform relative to firms on competing platforms. Given those drivers, we then examine competitive strategy. Specifically, we study market structures under

[3] While we will use the term "software" throughout this paper, it can be thought of more generally as any type of component within a platform. We will demonstrate this with a detailed example towards the end of this paper.

which a firm should respond aggressively or complacently to a successful quality upgrade of a competitor. Finally, we interact firms' competitive position, market position and optimal strategy to determine optimal investment levels and thus provide guidance for competitive strategy in platform markets.

We find that in general, a firm's choice of competitive strategy depends on the nature of its competitive advantage, that is, the type and degree of quality leadership it, or its platform, has achieved. A firm's choice of competitive strategy is affected more by its degree of quality leadership within its platform—its competitive position—than by the market position of its platform. Specifically, the competitive strategy of within-platform followers and leaders does not depend on whether the compatible platform is in lead or behind - it only changes when platform leadership is contested. Interestingly, in this latter case, we find that strategic homogeneity, where firms on the same platform choose the same competitive strategy, is common and profitable. Finally, the strength of competitors on the same platform has a large effect on the firm's prospect for success: A firm that has sufficiently strong competitors with it on the same platform only needs to be a little ahead or at least keep up with the pack. A firm that goes it alone on a platform needs to be ahead a lot - a rule that Apple Inc. has learned the hard way, but now seems to understand very well.

This paper contributes to four lines of literature. We add to the literature on the analysis of competitive advantage as pioneered by Porter (1985) and revisited by Adner and Zemsky (2006), by identifying drivers of competitive advantage in platform industries. We also contribute to the platform literature in economics, advanced by Church and Gandal (1992), and in business with advances from Gawer and Cusumano (2002). While the previous economics literature suggests exit as the only viable strategy for companies on a lagging platform, we show that this does not need to be the case, and if it has to be, which competitive strategy is optimal before exiting. The platform leadership literature, on the other hand, only identifies "winning" strategies for leaders, but not for followers. We close this gap. We also document the dynamics of innovation in the context of platforms and thus contribute to the literature on innovation. Interestingly, our within platform results resemble those of the existing innovation literature (e.g., Grossman and Shapiro 1987), while our across platform results find previously undocumented dynamics. Finally, we contribute to the competitive strategy literature, as in Porter (1980). We not only show how competitive strategy leads to competitive advantage in platform industries, but also how achieved competitive advantage shapes competitive strategy.

The paper is organized as follows: we first present our model, then discuss and document competitive advantage in its context. This allows us to define competitive strategy for different market environments. We then map those competitive strategies into competitive advantage space, which allows us to derive simple guidelines for competitive strategy choices given market condition. We then discuss an application of our methodology before we summarize and conclude.

2. THE MODEL

We present our model in two steps. First we state the ideas that motivated the model specification and the assumptions that attempt to reflect them. Then, we present a formal version of the model, which can be skipped without loss of comprehension for readers not interested in the technical details.

2.1 Model Assumptions

For ease of exposition we focus on two types of components in our platform industry: shorter lived software and longer lived hardware. Hardware-software markets typically feature the following characteristics: software requires compatible hardware to operate on, and consumers, typically, keep their hardware for longer than just one software cycle. Therefore, when making hardware decisions consumers form expectations regarding future quality levels of all software on all platforms. Software firms have higher incentives to upgrade their product the larger the potential market they can address. Consequently, firms' incentives to invest in quality upgrades depend on the current as well as future number of consumers who own the compatible hardware. To reflect dependence on future opportunities, we assume an infinite horizon discrete choice model where consumers live forever and derive utility from the consumption of software. Consumers' willingness-to-pay increases in the quality of the currently available software, and decreases in its price. We assume that software needs compatible hardware to operate on, but that hardware provides no stand-alone benefits. Consumers choose the hardware for which software promises the best expected quality-price relationship. To keep the setup simple, we assume that consumers can only choose from two incompatible hardware platforms, and that there are no more than two software firms producing for each platform. Every period, all consumers need to renew or replace their software licenses. Consumers need to replace their hardware, on average, every two periods, and can either repurchase the same type of hardware or switch to the competing hardware – assuming it offers them higher net benefits.[4] Since consumers own the hardware for two periods, when deciding on hardware, consumers must form expectations about future software qualities.

The investment process is assumed to be stochastic were the probability of successful innovation increases with the firm's level of investment. A successful investment increases the firm's quality by one unit, while an unsuccessful investment becomes obsolete. Firms base their investment strategies on their relative position in their platform market, as well as on their platform's position relative to the competing platform.

The industry as a whole will be larger if it offers higher value to consumers than substitute markets do. For example, TV broadcasts, DVDs and on-demand streaming may lose attractiveness for certain age groups if new developments in the gaming industry progress further. Consumers will then be less likely to pursue next best alternatives to video games and the video game industry will consequently be larger. We therefore measure software quality relative to the quality of the next best alternatives. In order to capture advances in the quality of those next best alternatives, we assume that if the quality level of them increases by one unit, the quality level of all

[4] We define net benefit to be the benefit to the consumer (or the consumer's willingness to pay) net of the price of the product.

available software (on both platforms) decreases by one unit. Finally, in order to innovate effectively, software firms frequently possess platform-specific knowledge: developing software for more than one platform can be prohibitively costly. We therefore restrict firms to only one platform, and, for simplicity, to only one software product.

The timing of the game is as follows: in the first stage, consumers and firms observe current qualities of available software on both platforms as well as platforms' market shares. Consumers choose which hardware to buy and software firms simultaneously choose how much to invest in quality. In the second stage, firms compete in prices, and consumers buy one unit of software or their next best alternative. In the third stage, nature determines which firms' investments were successful, and whether there was an increase in the quality of the next best alternative. Note that investment realization affects qualities only in the following period.

2.2 Formal Analysis

We employ the same basic set-up as in Markovich (2008) and adapt Pakes and McGuire (1994) to incorporate dynamics in consumers' decisions. For simplicity, we assume that all firms develop the same type of software (e.g., spreadsheets, word-processors, or office suites) and allow for no more than two platforms, *A* and *B*, as well as no more than two software firms on each platform. Since the analysis for platform *B* mirrors that of *A*, we present here the analysis for only platform *A*.

Let W={0,1,2,…,K} be a finite set of possible quality levels of software, and let $a_j \in W$ represent the quality of software firm *j* producing for platform A. $a \equiv (a_1, a_2)$ is the vector of quality levels of both firms producing for hardware *A*, and σ is the market share of platform *A*.[5] Finally, $S \equiv (\sigma, a, b)$ denotes the state of the industry, where *b* is the vector of the quality levels of all firms producing for platform *B*.

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5 σ is the formal equivalent of the "installed base," as defined in the introduction (see Farrell and Saloner, 1986).

2.2.1 Willingness to Pay

Consumers derive benefits solely from software, which needs compatible hardware to operate. We assume that hardware does not provide any benefit on its own. In each period, half of the consumers who own a particular hardware are randomly selected to replace their units. These consumers can elect to either stay with the type of hardware they already have or switch to the alternative. Firms license software to consumers for one period. After that, consumers can either renew the license at the then-available quality level and price, or they can elect to switch to another software firm. Consumers who are not randomly selected for hardware choice have to select software for the hardware they already possess. For any given period, the willingness-to-pay of consumer l who owns hardware A and holds a license from software firm 1 for software with quality level a_1 is $WP_{1l}^{A}(a) = a_1 + \varepsilon_{1l}$, where ε_{1l} denotes differences in taste among consumers (e.g., within the spreadsheet market, some consumers like Lotus while others prefer Excel).

Software Choice. Consumers select software from the set of qualities and prices available to them. They acquire a license for one unit of software, unless the best consumption alternative, denoted by ε_0, provides them with higher benefits. We assume that consumers' preferences, ε, are independently and identically distributed according to a standard double exponential distribution. As McFadden (1973) shows, denoting the price of software k by p_k, consumer l acquires a license from firm 1 with probability:

$$D_1(a_1, a_2; p_1, p_2) = \frac{\exp(a_1 - p_1)}{1 + \exp(a_1 - p_1) + \exp(a_2 - p_2)} \tag{1}$$

Hardware Choice. Consumers who can replace their hardware in a given period do so by evaluating current and future software qualities for each hardware platform. If consumers purchase hardware A, their expected benefit is the sum of the benefits from software they purchase during the two periods they own the hardware.[6] Consumer l's expected net benefit from purchasing hardware A is then:

$$U_l^A(\sigma,a,b) = E\{[WP_{lj}^A(a) - p_j] \mid \sigma,a,b\} + \beta E(E\{[WP_{lk}^A(a') - p'_k] \mid \sigma,a,b\})) + \xi_l^A \tag{2}$$

$E(WP_{lj}^A(a))$ and $E(E[WP_{lk}^A(a')])$ are the consumer's expected willingness to pay for licensing software j in the current period and software k in the next period, respectively. ξ_l^A represents consumer l's preferences over platforms (e.g., viewing operating systems as hardware, some consumers prefer the Windows platform while others favor Linux). a' and p'_j are next period's qualities and prices, respectively. In order to assess equation (2), consumers form expectations about future availability, quality and prices of software based on the current state, (σ,a,b).

Consumers will choose hardware A over hardware B if and only if hardware A offers a higher net benefit than hardware B. That is, setting hardware A's and B's prices at P^A and P^B, respectively, consumer l buys hardware A if and only if $U_l^A(\sigma,a,b) - P^A > U_l^B(\sigma,a,b) - P^B$. Once more, we assume that consumers' preferences, ξ_l^k, are distributed independently and identically and follow a standard double exponential distribution. Then, again, employing McFadden (1973), consumer l purchases platform A with probability:

$$\Psi(A,a,b;P^A,P^B) = \frac{\exp(U^A - P^A)}{\exp(U^A - P^A) + \exp(U^B - P^B)} \tag{3}$$

Given our assumptions and eq. (3), platform A's market share in the next period is given by

$$\sigma'(\sigma,a,b;P^A,P^B) = \sigma/2 + \Psi(\sigma,a,b;P^A,P^B)/2 \tag{4}$$

2.2.2 The Market for Software

6 As noted before, consumers replace hardware on average every two periods. Consequently, while some of the consumers replace hardware after one period, some hold their hardware for many periods. For simplicity, we assume that consumers expect to hold the hardware for two periods, and make decisions based on these expectations.

We now turn to the dynamics in the software market.[7] Each software firm only develops one type of software, which is compatible with only one of the platforms.[8] Software firms compete oligopolistically on quality and prices. If software firms want to improve the quality of their product, they need to invest. We assume that the outcome of this investment is stochastic and depends on the level of each firm's investment. Whether the investment is successful is revealed in the following period.

Each firm's quality level in the next period is determined by three factors: its current quality level, its level of investment, and whether the substitute industry improved the quality of its products. We assume that quality levels for each firm follow a Markov process where future qualities depend only on current qualities, regardless of how the firm reached this level. As noted before, advances in the PC games market negatively affect the video game market. That is, advances in substitute industries erode quality advantages of software in our market. We therefore measure software qualities relative to the quality of those substitute industries. Any innovation in substitute industries reduces the quality advantage of all software on both platforms by one unit. Consequently, if a_j is firm *j*'s current quality level, $\tau_j \in \{0,1\}$ is the realization of firm *j*'s investment, and $\nu \in \{0,1\}$ represents the success of substitute industries in upgrading their quality, then next period's quality level, a'_j, is described by the following Markov process: $a'_j = a_j + \tau_j - \nu$. We let δ denote the probability of an improvement in the quality of the outside good in each period: $p(\nu = 1) = \delta$. We assume that there are no research spillovers: each firm's probability of a

7 In this paper, we study only investment strategies of software firms. Software firms, however, can also decide to enter or exit the industry, which we ignore here to keep the analysis simple. See Markovich (2008) for details. Innovation in hardware can be viewed as a "platform quality shifter", and can thus be represented by simultaneous innovation in the software market. While interesting in itself, we stay focused on the more complex interactions in the software market in this paper.

8 The set up costs and additional development costs required in order to port a certain software from one hardware to another are high and the porting is typically done by a different unit within the organization. Once can, therefore, think of these two units as two different companies.

successful investment depends only on its own investment. In particular, if firm *j*'s investment level is x_j, then its transition probability is:

$$P(a'_j \mid a_j, x_j) = \begin{cases} (1-\delta)\dfrac{x_j}{1+x_j} & if \quad a'_j = a_j + 1 \\ (1-\delta)\dfrac{1}{1+x_j} + \delta\dfrac{x_j}{1+x_j} & if \quad a'_j = a_j \\ \delta\dfrac{1}{1+x_j} & if \quad a'_j = a_j - 1 \end{cases} \tag{5}$$

Firms' Profits. While investment decisions are dynamic, we assume that the pricing game is a static game with no future effects or dynamics.[9] Firms choose prices to maximize profits in the current period and cannot strategically discount their software in order to attract more consumers in the future. All software firms on both platforms take software demand as given from equation (1) and set prices such as to maximize per-period profits. Per-period profits for firm 1 on platform *A* are given by:

$$\max_{p_1 \geq 0} \sigma * M * D_1(a_1, a_2; p_1, p_2) * p_1 \tag{6}$$

where M>0 is the total size of the market and, in the interest of parsimony, we abstract from marginal and fixed costs of production. σ is the percentage of consumers who own platform A. The first-order condition (FOC), the derivative of (6) with respect to p_1, is

$$0 = 1 - \frac{1+\exp(a_2 - p_2)}{1+\exp(a_1 - p_1) + \exp(a_2 - p_2)} p_1$$

It can be shown that there exists a unique Nash equilibrium $(p_1^*(a_1,a_2), p_2^*(a_1,a_2))$ of the pricing game (Caplin and Nalebuff, 1991). This Nash equilibrium can be computed by numerically solving the system of FOCs. The per-period profit of firm 1 in the Nash equilibrium of the pricing game is then given by $\sigma M \pi_1(a_1,a_2)$, where

9 Despite the static nature of the pricing game and the fact that prices are independent of quality levels on the other platform, profits do depend on the market share of the hardware a firm produces for. However, this market share is influenced by the quality levels of firms producing for the competing hardware.

$$\pi_1(a_1,a_2) \equiv D_1(p_1^*(a_1,a_2), p_2^*(a_1,a_2); a_1,a_2) * p_1^*(a_1,a_2) \tag{7}$$

is firm 1's profit per consumer. Equation (7) relates the measure of competitive advantage of Adner and Zemsky (2006) to those of other contributors to the literature: profits depend on willingness to pay which can be increased through the process of value creation, namely investment in quality upgrades. However, due to competition, each firm can only appropriate part of this value created. Since production costs are assume to be zero, firms with superior value creation – quality – also have above average profits, at least on their platform.

Taking the state of the industry $S=(\sigma,a,b)$ as given, incumbent software firms select optimal investment strategies by solving an intertemporal maximization problem. For example, firm 1 on platform A maximizes its expected future payoff, $V_1^A(S)$, by solving the following Bellman equation:

$$V_1^A(S) = \sup_{x_1 \geq 0} \left[\begin{array}{l} \sigma M \pi_1(a,p) - x_1 + \\ \beta \left(\sum_{a',b'} V_1^A(S') P(a_1' \mid a_1, x_1^A, \nu=0) P(a_2' \mid a_2, x_2^A(S), \nu=0) P(b_1' \mid b_1, x_1^B(S), \nu=0) P(b_2' \mid b_2, x_2^B(S), \nu=0) \right) (1-\delta) \\ + \beta \left(\sum_{a',b'} V_1^A(S') P(a_1' \mid a_1, x_1^A, \nu=1) P(a_2' \mid a_2, x_2^A(S), \nu=1) P(b_1' \mid b_1, x_1^B(S), \nu=1) P(b_2' \mid b_2, x_2^B(S), \nu=1) \right) \delta \end{array} \right] E(\sigma') \tag{8}$$

where x_1^A is firm 1's investment on platform A. x_2^A, x_1^B and x_2^B are defined similarly. *P(·)* is given by equation (5), and E(σ'|*S)* is given by equation (4). The right-hand side of equation (8) consists of two parts: the profits from the pricing game in this period, $\sigma M \pi_1(a,p)$, and the expected discounted value of all future profits. The expected value of future profits depends on the state of the industry, *S= (σ,a,b)*, as well as on all active firms' investment levels.

Note that the expected value of future profits is the market value of the firm. As can be seen from the dependence of (8) on current and expected quality levels of all firms, a firm can only have sustained higher profits as compared to its competitors if it has superior value creation

– in our model quality upgrades through investment – over time. This implies that relative market value of firms can be used to capture the idea of sustained competitive advantage as proposed by several authors. Note, however, that market value only reflects the value creation that firms are actually able to capture. We get back to this point in the next section.

Equilibrium. Following the literature, we consider the Markov Perfect Equilibrium (MPE) of the game (see Maskin and Tirole, 2001). Each period, firms simultaneously decide on their investment levels given the current state of the industry, *S*, and their future expectations. Investment strategies are defined for every state of the industry, regardless of how this state has been reached. A *Markov Perfect Equilibrium* for the game described above is defined by

- Investment strategies $x_j^k(\sigma, a, b)$ for j=1,2; $k=A,B$ and every possible state (σ,a,b).
- Value functions $V_j^k(\sigma, a, b)$ for i=1,2; $k=A,B$, and every possible state (σ,a,b).

Such that:

(i) The strategies $x_j^k(\sigma, a, b)$ are optimal given the value functions $V_j^k(\sigma, a, b)$.

(ii) For every state $S=(\sigma,a,b)$, the value functions describe the present value of profits realized when both firms play the equilibrium strategies $x_j^k(\sigma, a, b)$.

A full formal equilibrium definition and the computational algorithm can be found in Markovich (2008).

2.2.3 Parameterization.

We chose the following set of parameter values for the equilibrium computation. We assume a total of ten consumers in the market, i.e., M=10. Since our focus is on software, we normalize hardware prices $P^A = P^B$ to be equal to zero. Market shares of platforms run from 0% to 100%, and are calculated in increments of 5%. We think of each period as one year and set the discount factor β = 0.92. Given these parameter values, software firms find it unprofitable to invest in quality upgrades, regardless of market structure, if they reach a quality level of K=6. Once a software firm has reached this quality level, it chooses not to invest at all. We therefore fix K at 6.

We will present all of the results with graphs. Since it is impossible to display our results for all possible value combinations of the model, we select intermediate starting values for the graphs: each platform starts with a market share of 50%, and the level of outside competition, δ, is also set to 0.5. Departing from these values only changes the relative magnitude of the effects, while the principle mechanisms stay the same.[10]

3. COMPETITIVE ADVANTAGE IN PLATFORM INDUSTRIES

Various definitions of competitive advantage have been proposed in the literature (See Rumelt, 2003). In the context of platforms, identifying and categorizing firms with competitive advantage is even harder than in markets without platforms: for example, does the firm with the highest quality software and the highest profit margin have competitive advantage, even if it is on an otherwise inferior platform? Alternatively, does a firm that is a follower in terms of quality and profit margins have competitive advantage when it is on the leading platform? A simple leader-follower classification as in Grossman and Shapiro (1987) is therefore not useful in the context of platform industries. Similarly to Besanko et al. 2000 (p. 389), we find value creation relative to competitors i.e., leadership, and market conditions, specifically market structure, to be the most useful concept of competitive advantage for the purpose of this analysis. In our model, value creation relative to competitors has two dimensions: Quality leadership within- and across-platforms. As we will see, relative value creation within- and across-platforms is the main driver for the selection of competitive strategy, while specific market conditions expand or shrink the applicability of each competitive strategy.

[10] Figures with other parameter values are available upon request from the authors.

For our analysis, we define platform position as the sum of qualities of the software compatible with that platform. To study how quality leadership and market structure play out in the context of platforms, we display possible quality combinations of firms on platform A, and fix the quality levels on platform B. We call the quality difference between the two firms within a platform Δ-intra, and the difference between the sums of qualities of both firms on each platform Δ-inter. We select all cases from our model that allow us to avoid corner solutions (where one or more of the firms has no incentive to invest) as much as possible. The quality combinations for all Δ-intra and Δ-inter that fulfill this criteria are displayed in figure 1. In particular, we set the quality level of both firms on platform B to 3, so the total quality level on platform B is equal to 6. Platform leadership is reflected in the areas where Δ-inter is positive. If the firms on platform A, for example, assume quality levels 5 and 3, the sum of their qualities is 8, which leads platform B by two quality units and Δ-inter = 2. If both firms on platform A assume a quality level of 1, platform A is behind and Δ-inter = –4. Within platform leadership on platform A is reflected by a positive Δ-intra. Using the same examples from above, Δ-intra = 2 in the first example and Δ-intra = 0 in the second. The figure provides a complete list of quality combinations for all Δ-intra and Δ-inter used in the graphs.

We divide the space into nine sections based on the dimensions of leadership: (1) Leader, Contested Leadership, and Follower within platform - the firm's quality relative to the competing firm on the same platform; (2) Leader, Contested Leadership, and Follower across platforms - the platform's position relative to the competing platform. For example for firm 1 on platform A, section LF corresponds to the case where firm 1 is a leader within its own platform (L), and platform A is a follower as it lags behind platform B (F).

		Δ-inter								
		-4	-3	-2	-1	0	1	2	3	4
Δ-intra	4	n.a.	(0,4), n.a.	(0,4)	(1,5), (0,4)	(1,5)	(2,6), (1,5)	(2,6)	n.a., (2,6)	n.a.
	3	(0,3), n.a.	(0,3) LF	(1,4), (0,3)	(1,4) L	(2,5), (1,4) C	(2,5)	(3,6), (2,5)	(3,6) LL	n.a., (3,6)
	2	(0,2)	(1,3), (0,2)	(1,3)	(2,4), (1,3)	(2,4)	(3,5), (2,4)	(3,5)	(4,6), (3,5)	(4,6)
	1	(1,2), (0,1)	(1,2)	(2,3), (1,2)	(2,3)	(3,4), (2,3)	(3,4)	(4,5), (3,4)	(4,5)	(5,6), (4,5)
	0	(1,1)	(2,2), (1,1) CF	(2,2)	(3,3), (2,2) C	(3,3) C	(4,4), (3,3)	(4,4) C	(5,5), (4,4) L	(5,5)
	-1	(2,1), (1,0)	(2,1)	(3,2), (2,1)	(3,2)	(4,3), (3,2)	(4,3)	(5,4), (4,3)	(5,4)	(6,5), (4,5)
	-2	(2,0)	(3,1), (2,0)	(3,1)	(4,2), (3,1)	(4,2)	(5,3), (4,2)	(5,3)	(6,4), (5,3)	(6,4)
	-3	(3,0), n.a.	(3,0) FF	(4,1), (3,0)	(4,1) F	(5,2), (4,1) C	(5,2)	(6,3), (5,2)	(6,3) FL	n.a., (6,3)
	-4	n.a.	(4,0), n.a.	(4,0)	(5,1), (4,0)	(5,1)	(6,2), (5,1)	(6,2)	n.a., (6,2)	n.a.

Figure 1: Types of quality leadership in platform industries.

The horizontal dotted lines in the figure separate the within-platform quality leader from the follower, with the middle row corresponding to the case where leadership within a platform is contested, that is both firms are competing for leadership within their platform. The vertical dotted lines separate the leading platform from its follower, where the middle column corresponds to head-to-head platform-competition. We have thus mapped relative value creation through quality leadership into the matrix of absolute value created, or the quality distribution of firms which together with market shares represent market structure. To see the link between competitive advantage and competitive strategy, we need to complete two more steps: First we need to map firms' competitive strategies into the quality distribution of firms; second, we need to analyze the role of market structure as a determinant of competitive advantage and thus, ultimately, as a determinant of competitive strategy to reach competitive advantage.

4. COMPETITIVE STRATEGY

The analysis above suggests that firms' competitive strategy depends on their type of competitive advantage. In our model, superior advantage is achieved through investment, and thus competitive strategy in our case is about firms' investment strategy. In order to capture the dynamics in firms' optimal investment behavior given its relative position in the market, we study firms' investment responses to their own successful quality upgrade, as well as their response to a competitor's quality upgrade.[11] We define a firm's own-investment-response to be the percentage change in the firm's investment given a one percent change in its own quality level.[12] A firm's cross-investment-response is the percentage change in a firm's investment given a one percent change in its competitor's quality level. Figure 2 shows firm 1's (on platform A) own- and cross- investment-responses as a function of firm 1's relative position in the market. In all figures below we set the quality level of both firms on platform B to 3.

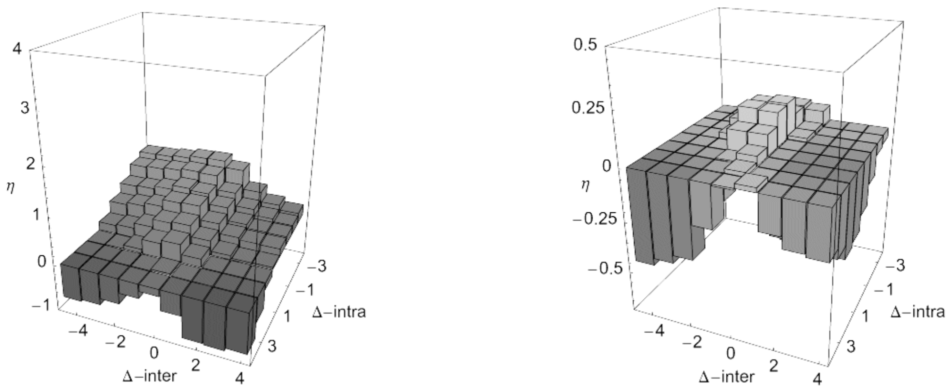


Figure 2: Own- and cross-investment-responses.

In general, a firm can increase or decrease its investment in response to an own- or a cross-quality-upgrade. We call an increase in the firm's investment an *aggressive* response, and call a decrease in investment a *complacent* response. We start with own-investment responses. As the

[11] Unless explicitly stated otherwise, in the rest of the paper we always refer to the competitor on the same platform.

[12] Formally, responses in our calculations are elasticities. Since our model can only handle discrete changes in qualities, the percentage changes for the responses have been calculated based on unit changes. For example, an increase from quality 4 to quality level 5 represents a 25% change.

left panel shows, the more firm 1 lags behind firm 2 (Δ-intra < 0), the more aggressive its investment response to its own quality upgrade. Once firm 1 leads, the opposite effect can be observed. The intuition behind this is as follows: if a firm lags behind, a successful upgrade increases the probability of catching up and gaining competitive advantage and thus increases the firm's incentives to invest in quality upgrades. The increase in incentives is the largest when quality differences between firms are still large. However, once a firm has become a far leader, it cannot win additional market share on its own platform – only from the other platform – decreasing the leading firm's incentives to invest. Therefore, a far leader behaves complacently and decreases its investment in response to its own quality increase.

The effect of platform position on investment is quite different. Specifically, firms' investment-responses to own increases in quality are the strongest when quality differences across platforms are small - the market is very competitive and small changes in quality levels have relatively large effects on market shares. Firms therefore increase investment aggressively to gain platform leadership and enhance the attractiveness of their platform. Once their platform is ahead or behind, incentives are lower—the effect of changes in quality on market share and attractiveness to consumers is not as large—and so is the investment response to an increase in their own quality.

In general, cross-investment responses are mostly complacent. A firm responds complacently when one platform's lead is large, and responds mostly aggressively when this lead is small. We consider first the case when one platform's lead is large. In this case, in equilibrium, the leading platform commands a large market share and competitors on this platform behave as if they were alone in the market—focusing on their leadership position within-platform. Consequently, reactions (both aggressive and complacent) are the strongest when both firms on the leading platform are of similar quality and Δ-intra is small. For a lagging firm on a lagging platform, if the leading firm successfully upgrades its quality, two effects happen simultaneously: the firm continues to lose market-share within the platform, which reduces its incentive to invest even further; but the platform overall gets stronger. This latter effect increases the platform's survival probability and future profit opportunities for the firm; thus, it increases the firm's incentives to invest.[13] When the second effect is larger than the first (typically when the platform does not lag too much behind), the firm responds aggressively and increases its investment. The opposite is true for the leading firm. A quality upgrade by the lagging firm strengthens the survival probability and thus the overall attractiveness of the lagging platform. For the leading firm, this means the burden to ensure platform survival is reduced. The reduction in within-platform market share and the reduction of burden to ensure survival both work in the same direction, thus the leading firm reacts the more complacently to a successful quality upgrade by its competitor the more it is ahead of it.

Cross-investment responses are positive when intra-platform differences are small: the smaller intra-platform differences the stronger are cross-investment responses. When platforms are of similar quality levels, a quality upgrade by the competing firm improves the market position of the entire platform. This, in turn, increases the firm's incentives to upgrade its software. This is also true in the other direction: a quality upgrade by the firm itself leads to increased investment from the competing firm. Consequently, investments by the two firms on the same platform are gross complements. This relationship exists only in the neighborhood of equally strong platforms, and it is the strongest when firms are close competitors on the same platform. Once inter-platform differences increase, firms on the same platform find it more profitable to fight each other rather than to fight their rivals on the competing platform.

4.1 A Taxonomy of Competitive Strategies

The graphs above isolated the response to a firm's own upgrade and its competitor's upgrade. We now investigate the interaction of these two upgrades—i.e., a change in a firm's competitive

[13] In accordance with the previous literature in economics, Markovich and Moenius (2009) define the second effect as the *network effect* - the change in a platform's market share driven by an increase in the quality level of one of its firms.

position. Given firms' own- and cross-investment-responses, the matrix below identifies the optimal competitive strategy for firms in platform industries.

		An increase in your ***competitor's*** quality makes you …	
		Aggressive	Complacent
An increase in your ***own*** quality makes you …	Aggressive	Pack Hunter	Lone Wolf
	Complacent	Puppy Wolf	Scavenger

Table 1: Competitive Strategies

As table 1 shows, we call a firm that responds aggressively both to its own upgrade and its competitor's upgrade a "Pack Hunter". This is the case when both firms "work together" to improve the relative position of their platform. We call a firm that seeks to get ahead by itself a "Lone Wolf." A "Lone Wolf" firm is encouraged by its own success and discouraged by the success of other firms. Thus, its own quality upgrade makes it aggressive but its competitor's quality upgrade makes it complacent.[14] A "Puppy Wolf" firm seeks to keep the current distance from its competitors: Thus, it reacts aggressively to a competitor's upgrade and complacently to its own quality upgrade. Finally, we call a firm that finds it optimal to seize current profits and is neither encouraged by its own nor by its competitors' success a "Scavenger." This will be the case when a firm reacts complacently to both upgrades. As discussed above, firms' strategic behavior depends on their competitive position and the market position of their platforms. Figure 3 plots the different types of competitive strategies as a function of market structure based on the results of our numerical simulations.

[14] Note that the Lone Wolf corresponds to the behavior found in the typical R&D literature; e.g., Grossman and Shapiro (1987).

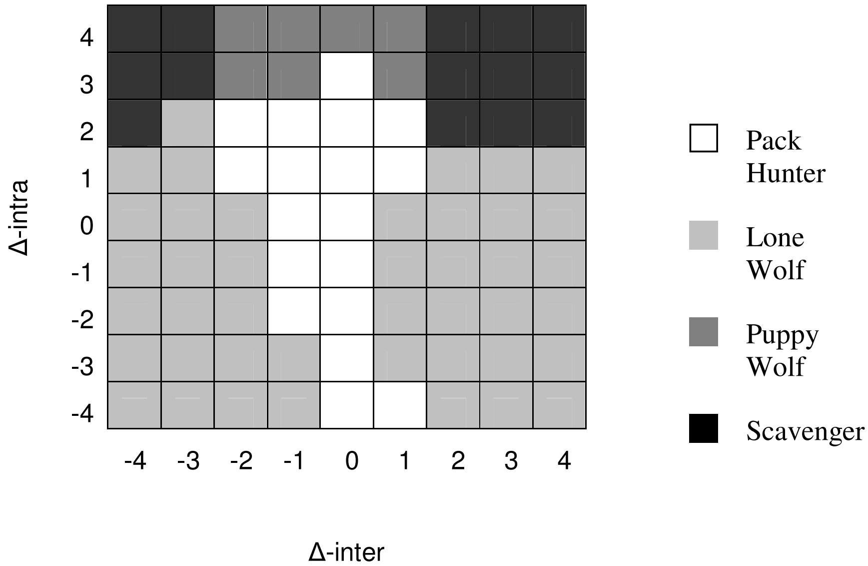


Figure 3: Market Structure and Optimal Competitive Strategies

According to the graph, when platforms are of similar market positioning, a firm behaves as if it were "hunting" in a pack – it reacts aggressively to its own and its competitor's quality upgrade. The firms behave as if they join forces and invest aggressively in order to strengthen the relative market position of their platform. They do so as long as both firms are of similar competitive positions and platforms are of similar market position. A firm behaves as a "Lone Wolf" when it is in a competitive position-disadvantage on a platform with either a large market position disadvantage or a sufficient market position advantage. In these cases, competition is mostly centered within platform rather than across platforms. Successful investment then makes the firm more aggressive, since it can steal business from its competitor on the same platform. The "Scavenger" reacts complacently to its own- and its competitor's quality upgrade. "Scavengers" are firms with little incentives to upgrade the quality of their software. For example, a leading firm on a leading platform has no incentive to further increase its investment as it is not jeopardized by neither its competitor nor by the other platform; the firm thus prefers to hold onto most of its profits instead of reinvesting them. When the Scavenger is a leading firm on the lagging platform, it cannot win against the competing platform alone. Consequently, it just "feeds" on whatever market share its platform already has. The "Puppy Wolf" reacts aggressively to a competitor's quality upgrade, but complacently to its own quality upgrade. This happens when the platforms' market positions are similar but there is a large discrepancy between the quality levels of firms on the platform. In this case, any catch-up of the lagging firm increases the chance to win platform leadership and thus makes the "Puppy Wolf" more aggressive, if it cannot keep the competitor at a distance, it turns into a "Pack Hunter."[15]

5. COMPETITIVE ADVANTAGE AND COMPETITIVE STRATEGY

In the final step of our analysis, we overlap the matrix of the types of competitive advantages with the matrix of competitive strategies as suggested by the numerical simulation. This allows us to analyze the structural relationship between the two which we believe is largely independent from the particular set-up of the model and the resulting specific numerical results. For ease of presentation we provide the stylized results in a table where the firm's optimal strategy is at the bottom-left of the box and its competitor's optimal strategy is at the top left corner of the box.

		Δ-inter		
		Follower	**Contested**	**Leader**
Δ-intra	**Leader**	Lone Wolf Scavenger	Pack Hunter Puppy Wolf	Lone Wolf Scavenger
	Contested	Lone Wolf Lone Wolf	Pack Hunter Pack Hunter	Lone Wolf Lone Wolf
	Follower	Scavenger Lone Wolf	Puppy Wolf Pack Hunter	Scavenger Lone Wolf

Table 2: Types of quality leadership and competitive strategy

[15] Note that the matrix is not perfectly symmetric since the quality levels on the other platform are fixed at (3,3)

The overlap reveals several interesting features. First, the effect of within platform leadership on firms' competitive strategy is almost uniform regardless of platform leadership. As long as platform leadership is not contested, while followers and leaders within a platform choose different competitive strategies, they choose the same respective strategy regardless of the position of their platform within the market. Furthermore, followers do not change their strategy as they start contesting within-platform leadership. Leaders, in contrast, change strategy and become more aggressive once their within platform leadership is contested. Interestingly, both leaders and followers on a platform change strategy - get more aggressive, again - once they start contesting platform leadership. The closer the competition within and across platforms the more aggressive competitors become—fighting for across-platform leadership in addition to within-platform leadership.

A closer look at the different competitive strategies reveals that leaders within-platform behave as Scavengers and live mainly on past investment. The marginal return from investment for these firms is relatively small, and thus they do not find it profitable to invest aggressively.[16] Pack-Hunters and Puppy Wolfs can be found right where platform leadership may change. In this case, firms fight for competitive advantage across platforms, regardless of their competitive advantage within the platform. Finally, as the literature on innovation suggests, the Lone Wolf is the dominant species. Nevertheless, the Scavenger on the leading platform may have the longest lifespan - especially if eventually standardization occurs.

Table 2 presents the investment-response of both firms within the same platform. Since the market position of a platform determines the market position of the competing platform, the table allows us to analyze strategic homogeneity across firms within the same platform as well as across platforms. The results show that both firms respond in the same way—exhibit strategic homogeneity within platform—when firms within platform compete head-to-head. In this case, if platforms also compete head-to-head, both firms respond aggressively to an own and a cross

[16] Note that being a Scavenger does not mean that the firm does not invest at all. It rather corresponds to the change in investment level given the change in market structure.

quality upgrade in the hope to win platform leadership and become the leader within the platform. In contrast, if the platform is either in the lead or lags behind, firms remain competitive, but respond aggressively only to their own quality upgrade. In this case, a firm's aggressive response enhances any advantage the firm has already succeeded to acquire.

In general, aggressive firms typically wish for their competitors to step back and behave complacently. Our analysis, however, shows that this does not hold when competition within- and across-platforms is close.. In this case, both firms behave as Pack-Hunters; any less-aggressive response of the competitor would decrease the firm's value as it reduces the probability that its platform becomes the leader. Consequently, strategic homogeneity is optimal for both firms.

6. DISCUSSION AND AN APPLICATION

The discussion above suggests that knowing the type of competitive advantage a firm enjoys—within and across platform—determines the choice of competitive strategy the firm should employ. Furthermore, the firm's type of competitive advantage conveys when the firm should change its strategic response and become more or less aggressive. In general, one can summarize the results with the following two practices:

If your platform does not compete for dominance:

- If you think you command a safe lead over your competitors on the same platform, enjoy a Scavenger feast—enjoy profits from your investments and reinvest moderately. In all other cases, behave like a Lone Wolf - whenever you are successful, be more aggressive next time around.

If your platform competes for dominance:

- If you think you command a safe lead over your competitors on the same platform, be a Puppy Wolf—when others are successful, bark back to keep the distance, but also to make winning platform leadership more likely. In all other cases, be a Pack Hunter: be aggressive whenever anyone on your platform is successful - including yourself.

While a full empirical examination is beyond the scope of this paper, next we demonstrate how the forces we identify played out in the competition between Apple and IBM in the micro-computing market. Our analysis will focus on two mechanisms in reference to Apple and IBM-compatible computers: (1) the effect of the intensity of competition in components on the speed of innovation, and (2) the role of competitive responses.

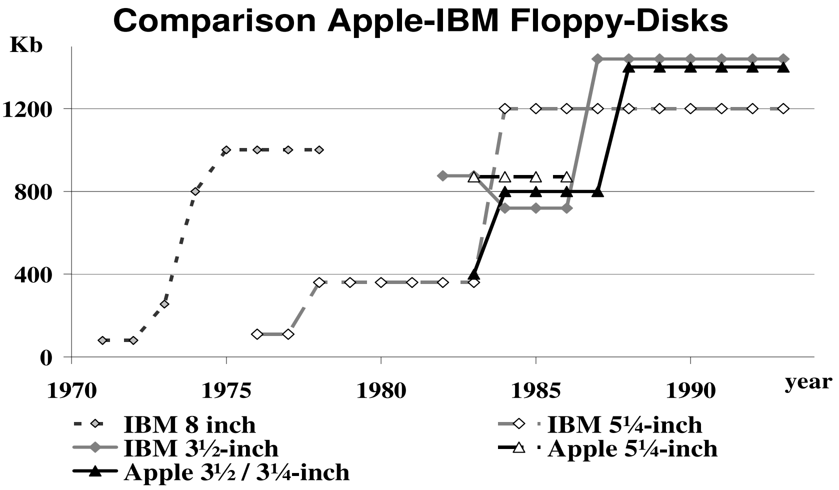
Our model predicts that the intensity of investment in quality upgrades and the resulting speed of innovation in components are crucial for the success of a platform. Within micro-computing, two platforms existed – the IBM-compatible PC and the Apple computer. Apple was initially far ahead of the PC in terms of market share.[17] While IBM chose an open architecture—allowing large groups of firms to participate in technological innovation of applications and compatible components (e.g., CPUs, floppy-disc drives, screens etc.)—Apple only allowed competition in the applications market. Translated into competitive strategy categories, IBM chose a strategy that created first Lone Wolves and later Pack Hunters. Apple's limited (monopolistic) competition model in the component market is consistent with one of the complacent strategies - the Scavenger or Puppy Wolf. Our model predicts that the complacent investment-responses on Apple's platform would result in slow innovative upgrading of components, leading to lower available qualities relative to IBM. Our simple practices suggest that initially, when Apple had a large lead, the Scavenger strategy may have been indeed optimal. However, once IBM-compatibles started to threaten Apple's platform leadership, our rules suggest that a switch for a more aggressive investment-response strategy—i.e., to a Pack-Hunter or Lone Wolf—should have been called for.

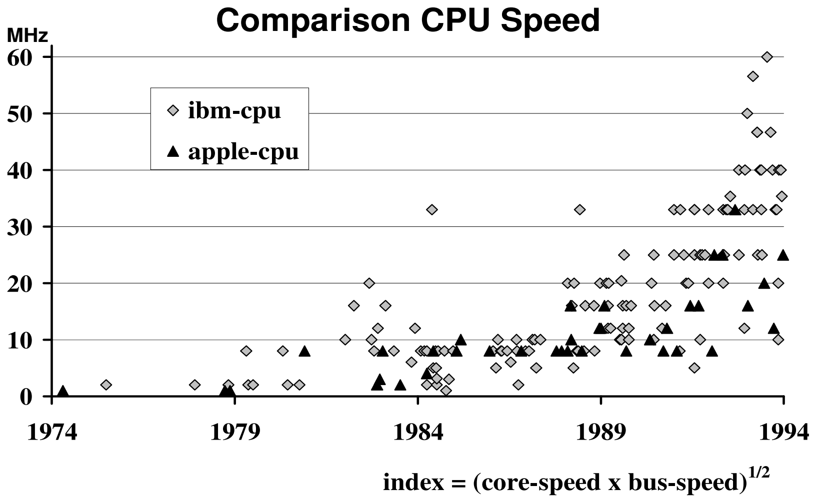
We think of hardware and software in terms of relative life duration, and take hardware to be longer-lived and software to be the shorter-lived. Given this broad definition, since the components above are all shorter-lived than the computers' architecture, components can be viewed as "software." Apple's and IBM-compatible PC's architectures can be then viewed as "hardware."

We found reasonably useful data for CPUs, floppy discs and graphics adapters. The following three graphs provide some insight into the competitive situation in the components market for Apple and IBM-compatible computers. Remarkably, all three graphs show the same basic pattern:

17 See http://www.pegasus3d.com/total_share.html for exact numbers of market shares for the two systems, downloaded on 1/23/06.

at almost any point in time, the components for IBM-compatible PCs outperformed those used by Apple.[18]





[18] A more detailed description of the construction of the graphs as well as data sources can be found in the appendix.

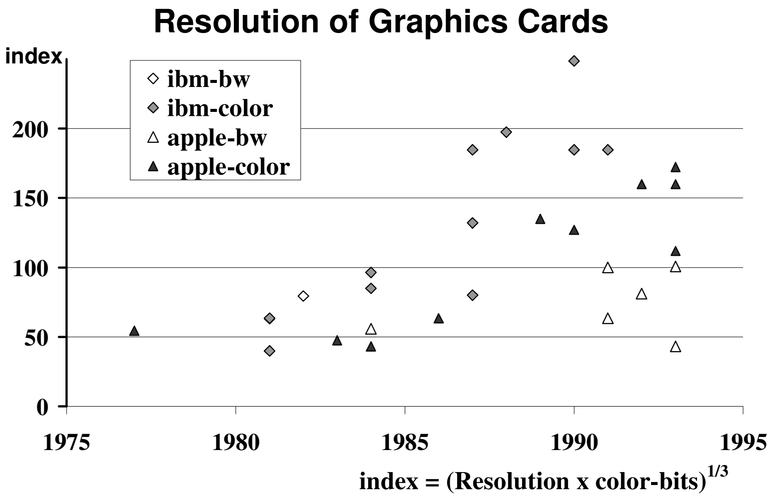


Figure 4: Evolution of the Components Market: Apple vs. IBM

While Apple users could only choose models from the Apple family, and for those models could only customize a limited set of components, users of IBM-compatible PCs could choose from a wide variety of vertically (and horizontally) differentiated models. The graphs show that there was substantial quality competition and upgrading in components on both platforms. Nevertheless, IBM-compatible machines not only clearly had a technical edge in all component markets over Apple's machines for prolonged periods of time, Apple's component upgrades almost always lagged those of IBM-compatible machines. The recent switch of Apple to also use Intel as its main supplier of CPUs shows that Apple indeed perceived its CPU to underperform the IBM-compatible CPUs.

This highlights the importance of investment in quality under various circumstances. Components' manufacturers on the IBM platform rapidly and forcefully orchestrated their competitive efforts to win market share from Apple. This can be easily translated into our investment response matrix above: in the early stages of the micro-computer industry, components' manufacturers "joined" forces and became "Pack Hunters" when they closed in on Apple. More generally, whenever competitors, on any of the hardware-platforms IBM tried to control, including their mainframe computers, caught up with IBM, we saw IBM responding aggressively. In these cases, IBM's position moved from being a "Scavenger" that does not invest much to being a "Lone

Wolf", or, as in the Micro-computer segment, a "Pack-Hunter". Arguably, while Microsoft still enjoys the "Scavenger" position for some of its products (like its operating system), Intel, for example, was pushed towards being a "Lone Wolf" in its segment of components by AMD.

Four lessons can be learned from this discussion. First, firms on the lagging platform will more eagerly cooperate than firms on the dominant platform as long as initial quality differences across platforms are small. Second, firms on the lagging platform will also more eagerly invite competition in order to beat the dominant platform, while firms on the dominant platform will try to monopolize the market. Third, if a competitor on the leading platform gets into the realm of a dominant firm, competitive responses will be aggressive (e.g., Intel). Finally, strategic flexibility is necessary to pick the optimal competitive strategy at any point in time.

7. SUMMARY AND CONCLUSION

In this paper, we study how the existence of competing platforms influences competitive advantage and competitive strategy in the form of investment in quality upgrades. We find that investment behavior is driven by competition across platforms, as well as competition between firms on the same platform. At any point in time, past value creating activities determine a firm's current competitive advantage. The nature of the competitive advantage that a firm achieved, manifested in its own or its platform's leadership position, then determines which one of four competitive strategies the firm should choose: If platform leadership is not contested, the "Lone Wolf" strives to achieve leadership within its platform. Once within-platform leadership was achieved, the "Scavenger" lives off past success and takes profits. If platform leadership is at stake, joining forces as "Pack Hunters" is optimal for roughly equally strong competitors to either win or defend platform leadership. Finally, only a far leader can afford to act as a "Puppy Wolf" that keeps the distance to competitors and simultaneously contributes to winning platform leadership.

Competitive strategy may look different if software firms can produce for both platforms, only facing an adaptation cost. Hardware upgrades may introduce additional uncertainty, again changing optimal strategy choice. Differences in firm specific resources across platforms may further alter the picture. While we believe that we address the most salient issues of competitive strategy in the presence of indirect network effects, we intend to investigate some of these additional issues in our future research.

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APPENDIX A: DATA

Data comes from the following sources. All information about Apple computers was obtained from http://www.apple-history.com. Data on all microprocessors was downloaded from http://www.cpu-collection.de. Data on the video adapters for monitors comes from http://bugclub.org/beginners/history/MonitorsHistory.html, and finally data on floppy discs comes from http://www.fortunecity.com/marina/reach/435/storage.html. www.wikipedia.com was used as a supplementary source for all of the above items. All web pages were repeatedly accessed in the months of March to May 2005.

There is an inherent difficulty in comparing the quality of components. Any measure we might use does some injustice to certain aspects of the components we study. For example, floppy disks are characterized by capacity, size, and speed of access. However, we have no supplementary data to find out which one of these features is valued the most by consumers. Therefore, we tried to obtain as simple measures as possible that allow us to compare quality of the components used in both systems and leave it to the reader to evaluate the appropriateness of these comparisons by manipulating the raw data herself, which we are very happy to provide on request and will post on a web page later on.

Different lines of floppy discs are simply ranked by capacity. For CPU comparison, we chose the geometric mean of core speed and bus speed, ignoring the lines of processors as well as their threading capabilities. For graphics cards, we again chose the geometric mean of the resolution measured as pixels per line and column, as well as the numbers of bits the colors were coded with. While these are very rough measures, we still think that more-sophisticated measures would not lead to very different results.