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DO CONSUMERS ALWAYS GAIN WHEN MORE PEOPLE BUY THE SAME BRAND?

by

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Abstract

We analyze markets for goods in which the consumer's value for a specific brand increases with an increase in the variety of the brand's specific supporting services. We demonstrate that consumers are not always better off with an increase in the number of consumers purchasing the same brand even though the variety of the brand specific supporting services may increase. The paper also analyzes the effects of changing the distribution of consumer tastes on the market shares of brand producing firms and the variety of services supporting each brand. Then, we ask whether consumers and firms benefit from having supporting services that are compatible with all brands.

Keywords: Network Effects, Brands, Supporting Services, Compatibility, Computer Industry, Software Industry.

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1. Introduction

It is observed that in many markets the consumer's value for a specific brand increases with an increase in the variety of the brand's specific supporting services. Cars, aircraft, and agricultural equipments will not work (and therefore consumers will not purchase) without having separate industries producing a variety of spare parts and accessories that generally fit only the specific brand they designed to support. Computer firms will never introduce a new generation of machines unless they are convinced that the software industry will produce software packages that will run on these machines. The reason for this is that consumers do not derive any satisfaction from computers with no software. In fact, one can say that in such markets, once the consumer is committed to purchasing a specific brand, his/her satisfaction is attributed to the variety of its supporting services.

In this paper we provide a welfare analysis of such markets. Our approach concentrates on the endogenous determination of the variety of supporting services and its major effects on the welfare of consumers as well as firms' behavior. Perhaps the key feature of the present analysis is that we model asymmetric market equilibria in the sense that firms producing different brands do not have equal market shares. This is done by allowing a non-uniform distribution of consumer tastes for different brands. Our analysis focuses on the following questions. a) Do consumers purchasing a certain brand benefit when the number of other consumers purchasing the brand increases? b) What are the effects of changing the distribution of consumer tastes on the market shares of brand producing firms and the variety of services supporting each brand? c) How would our conclusions change by comparing markets where firms produce incompatible brands with markets where firms produce compatible brands (brands that are supported by identical services).

The recognition of 'bandwagon' effects in consumers' choice goes back to Liebenstein (1950). Recently there has been an extensive amount of literature analyzing consumers' choice among incompatible brands in the presence of positive network externalities, see for example Farrell and Saloner (1985), Katz and Shapiro (1985). The approach developed in the present paper is different from the network externalities approach in that we do not analyze markets where consumer's value for a brand increases with an increase in the number of consumers purchasing a compatible or an identical brand. While many such markets do exist (for example, fashion clothing and telecommunication networks), here we wish to internalize the effects of a growing number of users of a specific brand on the welfare of users. Our framework here also does not address the situation where the firms who produce the brands produce it in components, see Economides (1989) and Matutes and Regibeau (1988), or where firms can introduce converters that would make the systems more compatible, see Farrell and Saloner (1989).

Following Chou and Shy (1990) and Church and Gandal (1990), we develop a duopoly model in which consumers derive satisfaction from computer systems. A computer system is defined as one computer and a collection of computer specific software packages. Consumers have different preferences for computer systems. In equilibrium, each consumer purchases one computer and all the existing variety of software. Each computer firm is engaged in a price game with the other firm taking into consideration the effect of its pricing strategy on the number of users of each brand and the variety of software written for each machine. We analyze two cases. In the first case, we assume that the two computers are compatible in the sense that they can run the same software. In the second case, the computers are incompatible implying that each machine is supported by an independent software industry. In this paper, we find out that the demand function faced by a computer firm is less elastic under the compatibility case compared with the case where the two machines are incompatible. The reason for this is that an increase in the price of a computer when the two machines are compatible will have a smaller effect on the variety of software compared with the incompatibility case. Also, we find out that when the two systems are incompatible, the more important software variety is to consumers, the higher is the elasticity of demand faced by the computer firm. When the demand elasticity is low (such as in the compatible systems case or when software variety is less important to consumers in the incompatible systems case), an increase in the relative number of consumers oriented towards a specific brand will substantially increase the price of the computer brand. Therefore, although variety of software available for the machine may increase, all existing users may become worse off. Thus, negative network effects are more likely to occur either when computers are compatible or when variety of software is less important.

We also show that when consumers' tastes are uniformly distributed, the competition between the two duopoly computer firms is the most intense, in the sense that the sum of their profits is at the lowest level. In this case, if the two machines are compatible, the variety of software reaches the highest level. Finally, we show that the profit of a computer firm is always higher when the two systems are compatible since the demand curve for computers is generally less elastic compared with the incompatibility case. On the other hand, although the variety of software is larger when the systems are compatible, consumers are generally better off when the systems are incompatible since under the compatibility case computer firms charge higher prices.

In this paper we are able to demonstrate positive and negative network effects without assuming network externalities or switching costs.[1] In Chou and Shy (1990), we demonstrated only the possibility of having positive network effects. Here, we propose an explanation for why some markets exhibit positive network effects whereas

[1]In general, location models yield negative network effects. Klemperer (1987) uses of this property in analyzing the effects of switching costs. As he points out, in location models a firm with a larger market share may charge a higher price.

others exhibit negative network effects.

The paper is organized as follows. In section 2, we set a computer industry duopoly model and analyze the case where the computers are *compatible*. Proposition 2 shows that the aggregate variety of supporting software is at the highest level when consumers' tastes are uniformly distributed. Proposition 3 demonstrates the possibility of negative network effects. Section 3 analyzes the situation where the two computers are *incompatible*. Proposition 5 gives conditions under which negative network effects are possible when the two brands are incompatible. Section 4 provides welfare comparisons of an economy with compatible systems to an economy with incompatible systems. Section 5 concludes.

2. The Compatible Systems Model

We consider a two company computer industry producing two brands named brand A and brand B. There is a continuum of potential software firms producing software packages. In this section we assume that both computers run the same software. Section 3 analyzes the case where software packages are machine specific. The (endogenously determined) number of actually produced software packages is denoted by μ.

2.1 Consumers

The economy consists of a continuum of consumers indexed by z, $z \in [0, 1]$. We normalize the total number of consumers to equal 1. We assume that each individual is endowed with I dollars to be spent on computers and software. A consumer derives utility from computer systems. We define a system i, $i = A, B$, as one computer of brand i and a collection of software packages and assume that a consumer purchases only one system. Denote the price of a computer brand i by P_i, $i = A, B$. Since a system contains only one computer, if a consumer is a system i user then his expenditure on software (denoted E_i) is given by $E_i = I - P_i$. The service of an i-system for an individual is denoted by S_i, and is assumed to take the form of[2]

$$S_i = E_i \mu^\theta, \quad \theta > 0, \quad i = A, B. \tag{1}$$

Thus, the service provided by a system is an increasing function of the number of available software packages (μ), and the expenditure on software.[3] Here, θ measures the importance of the variety of software to consumers. If σ denotes the degree of substitution amongst software packages, it can be shown that $\theta = 1/(\sigma - 1)$.

We define the utility of an individual type z by

$$U^z = \begin{cases} (1-z)S_A & \text{if he chooses system } A \\ zS_B & \text{if he chooses system } B \end{cases} \tag{2}$$

In the above, a high z indicates a consumer with a stronger preference towards system B. Thus, a consumer indexed by a high z ($z > 0.5$) is computer B oriented and a consumer indexed by a low z ($z < 0.5$) is computer A oriented. Therefore, the consumer's index number represents his preferences towards systems A and B.[4] We assume that the density function of consumers' types is given by

$$f(z;\, \epsilon) = \frac{1+\epsilon}{(1+\epsilon z)^2}, \quad \text{where } z \in [0,1] \text{ and } \epsilon > -1. \tag{3}$$

When $\epsilon = 0$ the density function (3) becomes a uniform density representing the case where consumers are evenly distributed on [0, 1]. Figure 1 shows that when

[2]Equation (1) can be derived by assuming a constant elasticity of substitution among software packages, increasing returns to scale production of each software firm, and a monopolistic competition *a la* Dixit and Stiglitz (1977) market structure. For such a derivation see an earlier version of this paper Chou and Shy (1989b).

[3]In view of the previous footnote, the price level of software packages is constant. Therefore, there is no loss of generality by assuming that the service level of software packages depends on the expenditure on software.

[4]Naturally, we assume that the consumer's index number z is independent of whether the two brands are compatible or incompatible. For example, we can think of heterogeneous consumers where some prefer laptop machines over desktop computers and this relative preference is independent of whether the two brands are compatible or incompatible.

ϵ increases the distribution shifts towards A-oriented consumers in the sense that when ϵ increases there are more A-oriented consumers.

INSERT FIGURE 1

Therefore, the parameter ϵ will be used to capture a change in the relative number of consumers with a particular taste without changing the total number of consumers in the economy. Observe that the population parameter ϵ does not enter a consumer's utility function (2), which means that we do not assume that preferences exhibit network externalities. By $\delta(z)$ we denote consumer z's position relative to the number of consumers who are "more" A-oriented. That is, $\delta(z)$ is defined as the number of consumers that have a stronger preference towards A-systems compared with consumer z. Formally, we define

$$\delta(z) \equiv \int_0^z f(z,\epsilon)dz = \frac{(1+\epsilon)z}{1+\epsilon z} \tag{4}$$

Thus, δ is an increasing function of z. Solving (4) for z as a function of δ and substituting for z into (2), after normalization (dividing by $(1+\epsilon-\epsilon\delta)$) we have that the utility of a consumer of a relative type δ is given by

$$U^\delta = \begin{cases} (1+\epsilon)(1-\delta)S_A & \text{if consumer } \delta \text{ is an } A\text{-user} \\ \delta S_B & \text{if consumer } \delta \text{ is a } B\text{-user.} \end{cases} \tag{5}$$

Observe that from (4), since δ is the cumulative distribution function of z, it is uniformly distributed on $[0, 1]$ independently of the parameter ϵ. Therefore, the utility function (5) is easier to handle when deriving the profit functions.

2.2 Technology, market structure, and the determination of software variety

The computer hardware industry is assumed to be a price setting duopoly, where each firm takes the price of the other firm as given. Each computer company i

produces computers under constant cost of M_i dollars per computer, $i = A, B$. With no loss of generality we set $M_i = 0$ for $i = A, B$. Denote by ρ_i the equilibrium number of consumers who purchase system i, $i = A, B$, where $0 \leq \rho_i \leq 1$ and $\rho_A + \rho_B = 1$. Thus, the aggregate expenditure on software is given by $\rho_A E_A + \rho_B E_B$. Each software firm operates under increasing returns to scale. It is known that in a monopolistically competitive environment the equilibrium variety of software is proportional to the total expenditure on software. Therefore, we can assume that the variety of software is given by[5]

$$\mu \equiv k(\rho_A E_A + \rho_B E_B) = k[\rho_A(I - P_A) + \rho_B(I - P_B)], \quad k > 0. \tag{6}$$

Equation (6) summarizes the decision rules of the (potential) software firms for the case where there is a large number of software firms who cannot individually affect the demand for computers and the other software firms.

2.3 Consumers' selection of systems

Substituting (6) into (1) and then into (5), we obtain the utility level of a consumer of relative type δ. Thus,

$$U^\delta = \begin{cases} (1+\epsilon)(1-\delta)E_A k^\theta (\rho_A E_A + \rho_B E_B)^\theta & \text{if } \delta \text{ is an } A\text{-user} \\ \delta E_B k^\theta (\rho_A E_A + \rho_B E_B)^\theta & \text{if } \delta \text{ is a } B\text{-user} \end{cases} \tag{7}$$

Since ρ_A is the equilibrium number of consumers who purchase A-systems and since consumers are indexed according to a decreasing preference towards A-systems, the consumer with a relative index $\delta = \rho_A$ represents the consumer who is indifferent between purchasing systems A or B. Thus, ρ_A can be found by solving $(1+\epsilon)(1-$

[5]Equation (6) can be obtained as the equilibrium number of software firms when the software industry consists of monopolistically competitive firms with a constant marginal cost and a constant markup pricing policy. In Chou and Shy (1989a,b) we showed that k is inversely related to the software development cost and to the degree of substitution amongst software packages.

$\rho_A)E_A = \rho_A E_B$.[6] Hence,

$$\rho_A = \frac{1}{1+(1+\epsilon)^{-1}\left(\frac{E_B}{E_A}\right)} = \frac{1}{1+(1+\epsilon)^{-1}\left(\frac{I-P_B}{I-P_A}\right)}. \tag{8}$$

2.4 The profit of computer firms

The profit of each firm depends on the market share which in turn depends on computer prices. Since ρ_A is the number of consumers purchasing A-systems, equation (8) is also the market demand function for A- computers. Hence, the market demand function for B-computers can be calculated from (8) by observing that $\rho_B = (1-\rho_A)$. The profit of a computer firm i is the product of the price and its market share. Hence,

$$\Pi_A = P_A\rho_A = \frac{P_A}{1+(1+\epsilon)^{-1}\left(\frac{E_B}{E_A}\right)} = \frac{P_A}{1+(1+\epsilon)^{-1}\left(\frac{I-P_B}{I-P_A}\right)} \tag{9}$$

$$\Pi_B = P_B\rho_B = \frac{P_B}{1+(1+\epsilon)\left(\frac{E_A}{E_B}\right)} = \frac{P_B}{1+(1+\epsilon)\left(\frac{I-P_A}{I-P_B}\right)}$$

2.5 Equilibrium market shares

In this model, consumers observe the prices of computers (P_A and P_B) and the variety of available software packages (μ), and determine which system to buy. The number of software firms μ is determined in a monopolistically competitive equilibrium in the software industry (see equation (6)). Each computer firm takes the price charged by its opponent as given and chooses a price to maximize its profit taking into account the effects on consumers' choice of systems and the software industry. All these effects are summarized in (9). A computer industry equilibrium is a pair $\{P_A, P_B\}$ such that for a given P_j, P_i maximizes Π_i, $i = A, B$ and $i \neq j$.

[6]The last equation is obtained by equating the utility of consumer $\delta = \rho_A$ when he is an A-user to his utility level when he is a B- user.

Differentiating (9) with respect to P_A and P_B respectively, after some manipulations we have that

$$E_A+(1+\epsilon)(E_A)^2(E_B)^{-1}-P_A=0 \quad \text{and} \quad E_B+(1+\epsilon)^{-1}(E_B)^2(E_A)^{-1}-P_B=0. \quad (10)$$

Equations (10) determine a unique pair of $\{P_A, P_B\}$ that constitutes a unique Nash equilibrium, see Chou and Shy (1989a). It is easy to show that the two price strategies are strategically complements, see Bulow et al. (1985). That is, the firms' reaction functions are upward sloping. Using (8), we can rewrite (10) as

$$\rho_B = \frac{E_A}{P_A}, \quad \text{and} \quad \rho_A = \frac{E_B}{P_B}. \quad (11)$$

Equations (11) show that each computer firm sets its price so that the ratio of software expenditure to price is equal to the market share of its opponent. Thus, a high computer price corresponds to a high equilibrium market share maintained by the computer firm.

2.6 Network effects

We now analyze the effect of a change in the distribution parameter ϵ on the system service (S_A) enjoyed by an A user. Differentiating (10) with respect to ϵ, using Cramer's Rule and (11), we obtain

$$(1+\epsilon)(det)\frac{dP_A}{d\epsilon} = 3P_A - I = E_A\left(\frac{2}{\rho_B}-1\right) > 0, \quad \text{and} \quad (12)$$

$$(1+\epsilon)(det)\frac{dP_B}{d\epsilon} = I - 3P_B = -E_B\left(\frac{2}{\rho_A}-1\right) < 0,$$

where $det = 4/(\rho_A\rho_B) - 1 > 0$. Equations (12) show that the price of an A-computer increases and the price of a B-computer decreases when there is an increase in the relative number of A-oriented consumers. Notice that an A-oriented consumer (a consumer indexed by a low z) need not be an A-user. However, the following proposition shows that an increase in the number of A-oriented consumers (an increase in ϵ) increases the equilibrium total number of system A users and decreases the number of B users.

Proposition 1 *The market share of the A-computer firm increases with an increase in the relative number of A-oriented consumers. That is,* $d\rho_A/d\epsilon > 0$.

Proof: By (12), $dP_B/d\epsilon < 0$ and therefore $dE_B/d\epsilon > 0$. Hence, $d[E_B/P_B]/d\epsilon > 0$ and the proposition follows from (11). *Q.E.D.*

We now analyze the effects of changing the distribution of preferences on the variety of software packages. Proposition 1 shows that the market share of the A-computer firm is larger when there are more A-oriented consumers. In particular when there are more A-oriented consumers than B- oriented consumers ($\epsilon > 0$), a further increase in the relative number of A-oriented consumers increases A's monopoly power (decreases B's monopoly power) resulting in a higher price of A-computers (a lower price of B-computers) and therefore reduces the software expenditure of each A-user (increase the software expenditure of B-users). Since there are relatively more A-users, ($\rho_A > \rho_B$), there will be an overall decrease in the expenditure on software and hence a decrease in the variety of software packages. Similarly, when there are more B-oriented consumers ($\epsilon < 0$), a further increase in the number of B-oriented consumers (a decrease in ϵ) will result in a decrease in the variety of software packages. Thus, when the two computer firms have equal market shares, the variety of software reaches the highest level since the competition between computer firms is the most intense (computer prices are the lowest). Also observe that since consumers have fixed budgets to spend on hardware and software, there is a negative relationship between the amount of profit collected by computer firms and consumers' software expenditure and hence the variety of software. Thus, the sum of profits of computer firms ($\Pi_A + \Pi_B$) is at the lowest level when the variety of software is at the highest level. Therefore, we can state the following proposition.

A formal proof is given in the appendix.

Proposition 2 *The sum of the computer firms' profit is at the lowest level and the variety of software packages is at the highest level when consumers are symmetrically distributed ($\epsilon = 0$). Also, the sum of profits is increasing and the variety of software is decreasing when the distribution of consumers becomes more asymmetric. Formally, $sign[d(\Pi_A + \Pi_B)/d\epsilon] = -sign(d\mu/d\epsilon) = sign(\epsilon)$.*

It follows from proposition 2 and (12) that when $\epsilon \geq 0$, a further increase in the relative number of A-oriented consumers (an increase in ϵ) will increase P_A and reduce the variety of software μ. Therefore, by (1) we have that the welfare of A-users (measured by S_A) will be reduced. Thus, the following proposition demonstrates the possibility of negative network effects.

Proposition 3 *When the distribution of consumers is biased towards A-systems, a further increase in the relative number of A-oriented consumers will reduce the welfare of existing A-users. Formally, $dS_A/d\epsilon < 0$ for $\epsilon \geq 0$.*

When the distribution of consumers is biased towards B-users ($\epsilon < 0$), then an increase in ϵ will increase the price of A-systems and the variety of software thereby generating two opposing welfare effects. It can be shown that the variety of software and the welfare of an A-user (S_A) approach zero when the relative number of A-oriented consumers declines to zero ($\epsilon \to -1$).[7] Figure 2 shows the welfare level of an A-user (S_A) as a function of population distribution parameter ϵ.

INSERT FIGURE 2

When ϵ is sufficiently small (most consumers are B-oriented), a small increase in the relative number of A-oriented consumers (an increase in ϵ) will increase S_A. This

[7]Observe that (10) implies that as $\epsilon \to -1$, $E_A \to P_A$. Therefore by (11), $\rho_B \to 1$ and hence $\rho_A \to 0$ and also $E_B \to 0$. That is, A's market share (ρ_A) and the expenditure on B- systems (E_B) approach zero. Hence, by (6) $\mu \to 0$, and by (1) $S_A \to 0$.

is the case of positive network effects. In addition, there exists an $\epsilon^* < 0$ in which the welfare of an A-user is maximized. For $\epsilon > \epsilon^*$, a further increase in the relative number of A-users will reduce the welfare of A-users since the welfare loss from the increase in the price of A-computers dominates the welfare gains from the increase in software variety. Also, note that for $-1 < \epsilon < \epsilon^*$, B-users are always better of with an increase in ϵ since the price of B-computers declines and the software variety increases.

3. Incompatible Systems

In the previous section we analyzed the case where the two computers run the same software. We now analyze the polar case when the two systems are incompatible and use only machine specific software packages. In the compatibility case of the previous section, the results concerning the possibility of negative network effects is independent of the degree of importance of software variety (θ). However, in this section we show that when the systems are incompatible, the parameter θ does affect the possibility of realizing negative network effects.

We assume that there are two independent software industries producing machine specific software packages. The number of software packages supporting machine i is denoted by μ_i, $i = A, B$. The service of a system i for an i-user is now given by

$$S_i = E_i(\mu_i)^\theta, \quad 0 < \theta < 1, \quad i = A, B. \tag{13}$$

The restriction of θ to be less than 1 is needed to ensure well defined reaction functions of the two computer firms. Following the same arguments preceding (6), we can assume that the variety of software compatible with system i is given by

$$\mu_i \equiv k\rho_i E_i = k\rho_i(I - P_i), \quad i = A, B, \quad k > 0. \tag{14}$$

Here, since machines are incompatible, the variety of machine i software packages is proportional to the expenditure on system i software only. Substituting (14) into

(13) and then into (5), we obtain the utility level of type δ consumer. Thus,

$$U^{\delta} = \begin{cases} k^{\theta}(1+\epsilon)(1-\delta)(I-P_A)^{1+\theta}(\rho_A)^{\theta} & \text{if consumer } \delta \text{ is an } A\text{-user} \\ k^{\theta}\delta(I-P_B)^{1+\theta}(\rho_B)^{\theta} & \text{if consumer } \delta \text{ is a } B\text{-user.} \end{cases} \tag{15}$$

Similar to the compatibility case, we can show that in equilibrium

$$\rho_A = \frac{1}{1+\phi^{-1}\left(\frac{E_B}{E_A}\right)^{\beta}}, \quad \text{where } \phi \equiv (1+\epsilon)^{1/(1-\theta)} \quad \text{and} \quad \beta \equiv \frac{1+\theta}{1-\theta}. \tag{16}$$

Hence, the profit of each computer firm is given by

$$\Pi_A = P_A\rho_A = \frac{P_A}{1+\phi^{-1}\left(\frac{E_B}{E_A}\right)^{\beta}} \quad \text{and} \quad \Pi_B = P_B\rho_B = \frac{P_B}{1+\phi\left(\frac{E_A}{E_B}\right)^{\beta}}. \tag{17}$$

Differentiating (17) with respect to P_A and P_B respectively, after some manipulations we have that

$$E_A + \phi(E_A)^{1+\beta}(E_B)^{-\beta} - \beta P_A = 0, \quad \text{and} \quad E_B + \phi(E_B)^{1+\beta}(E_A)^{-\beta} - \beta P_B = 0. \tag{18}$$

Equations (18) determine a pair of $\{P_A, P_B\}$ which constitutes a unique Nash equilibrium. The analog to (11) is given by

$$\beta\rho_B = \frac{E_A}{P_A} \quad \text{and} \quad \beta\rho_A = \frac{E_B}{P_B}. \tag{19}$$

We now analyze the effect of changing the distribution parameter ϵ on the service of system A (S_A) enjoyed by A users. Differentiating (18) with respect to ϵ and using Cramer's Rule, we obtain

$$(1+\epsilon)(det)\frac{dP_A}{d\epsilon} = (2\beta+1+\theta)P_A - (1+\theta)I = E_A\left[\frac{2}{\rho_B} - 1 - \theta\right] > 0, \quad \text{and} \tag{20}$$

$$(1+\epsilon)(det)\frac{dP_B}{d\epsilon} = (1+\theta)I - (2\beta+1+\theta)P_B = -E_B\left[\frac{2}{\rho_A} - 1 - \theta\right] < 0,$$

where $det = 4/(\rho_A\rho_B) - (1+\theta)^2 > 0$. Similar to proposition 1, we can state the following.

Proposition 4 *The market share of the A-computer firm increases with an increase in the number of A-oriented consumers. That is,* $d\rho_A/d\epsilon > 0$.

When the relative number of A-oriented consumers increases, both the price and the number of users of A-computers (P_A and ρ_A) increase. Therefore, an individual A-user's expenditure on software declines. Thus, the aggregate expenditure on A-software (and hence the variety of A-software) may decrease or increase. However, if initially consumers are uniformly distributed ($\epsilon = 0$), then an increase in the relative number of A-oriented consumers will increase the variety of A-software (μ_A).[8]

We now analyze the effects of changing ϵ on the welfare of an A-user. Even if the variety of A-software increases, the welfare of an A-user may still decline if there is a substantial increase in the price of A-computers. We now show that this is indeed the case when the variety of software is less important to consumers (θ is low meaning also that software packages are close substitutes). Thus, the following proposition demonstrates the possibility of negative network effects for the case of incompatible systems. For the following proposition we restrict the analysis to the case where consumers are initially uniformly distributed ($\epsilon = 0$). The proof is given in the appendix.

Proposition 5 *Given that consumers are uniformly distributed* ($\epsilon = 0$)*, there exists a* θ^*, $0 < \theta^* < 1$, *such that for every* $\theta < \theta^*$ *an increase in the relative number of A-oriented consumers (an increase in* ϵ*) will make all A users worse off and all B users better off. That is,* $dS_A/d\epsilon < 0$ *and* $dS_B/d\epsilon > 0$.

Proposition 5 can be explained as follows. An increase in the number of A-users will cause an increase in the price of A-computers, and in addition will increase the variety of A-software. When the degree of software substitution is high (variety is

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[8]Using (14), (19), and (20), it can be shown that when $\epsilon = 0$, $d\mu_A/d\epsilon$ is proportional to $dP_A/d\epsilon > 0$.

not important, θ is low) then the welfare gains from an increase in software variety is dominated by the welfare loss due to an increase in the price of A-computers. This is the case of negative network effects. The case of positive network effects occurs when the degree of software substitution is low (variety is important, θ is high). In this case, the variety effect dominates the price effect. Another way of looking at this is to observe that when the variety of software is important to consumers (θ is high), an increase in a computer's price has a large impact on a user's welfare because of the reduction in the variety of software. Thus, when θ is high the demand (16) becomes more elastic, thereby reducing the possibility of negative network effects.

4. A Comparison of Compatible and Incompatible Systems

In this section we compare an environment with compatible systems to an environment with incompatible systems. First, we ask whether firms find it profitable to produce compatible machines. Then, we ask whether consumers are better off when the machines are compatible. When consumers are uniformly distributed ($\epsilon = 0$), the equilibria are symmetric. Therefore, denote by P^c (P^{inc}) the symmetric equilibrium computer price when the machines are compatible (incompatible), respectively. Solving (10) and (18) for the case of $\epsilon = 0$, we have that

$$P^c = \frac{2I}{3} \quad \text{and} \quad P^{inc} = \frac{2(1-\theta)I}{3-\theta}. \tag{21}$$

In a symmetric equilibrium each firm has one half of the market ($\rho_A = \rho_B = 1/2$). Therefore, the profit of firm i is equal to $P_i/2$. From (21) we find that $P^c > P^{inc}$. Hence, we can state the following proposition.[9]

Proposition 6 *When consumers are uniformly distributed, both firms earn a higher profit when they produce compatible machines compared with producing incompatible*

[9]Computer simulations show that proposition 6 can be generalized to asymmetric distribution cases where $\epsilon \neq 0$. The results are available from the authors.

machines.

Proposition 6 can be explained as follows. When machines are compatible, the effect of an increase in the price of a computer on the variety of software is less significant compared with the case where the two computers are incompatible. Thus, when the machines are compatible, the price set by a computer firm has a smaller effect on market shares. Comparing (8) to (16) reveals that the demand facing a computer firm is less elastic when the two computers are compatible compared with the case when they are incompatible.

Finally, a consumer facing compatible systems enjoys a larger variety of supporting software. Hence, if the computer market is competitive, consumers are necessarily better off with compatible systems. However, under an oligopolistic computer market structure proposition 6 shows that computer firms charge higher prices when the systems are compatible. Hence, if the computer market is non-competitive, consumers are not necessarily better off with compatible systems. For the case of a duopoly we can state the following.

Proposition 7 *In a duopoly world, when consumers are uniformly distributed, consumers are better off with incompatible systems. That is, the service levels S_A and S_B are higher when the systems are incompatible compared with the case where the systems are compatible.*

Proposition 7 is rather surprising.[10] What happens here is that the competition between the computer firms intensifies when the two systems are incompatible. This can be easily explained from the fact that a computer demand curve under compatibility is less elastic than a computer demand curve under incompatibility. When the two systems are compatible, firms maintain high monopoly power and charge

[10]The negative benefits of compatibility can be mitigated somewhat if we assume users' network externalities and/or pirating of software, or when consumers' ranking of the two systems changes when the systems become compatible or incompatible.

high prices. Hence, although consumers enjoy a larger variety of software, they are worse off with compatible systems.[11]

5. Conclusion

We are able to demonstrate that consumers do not always benefit from an increase in the number of consumers purchasing the same brand. Although it is well known that a non-competitive firm may increase its price in the face of a growing demand, it is not clear whether consumers who can *freely* switch to a competing system can always gain from an increase in the number of users purchasing the same brand. In this paper, we provide a testable hypothesis that negative network effects are more likely to occur when machines are compatible or, in the case of incompatible systems, when the degree of substitution in the consumption of brand specific supporting services is high. It should be pointed out that, with monopolistically competitive software industries, the possibility of negative network effects can not arise if the computer industry is competitive since computer firms charge only marginal cost prices which do not vary with the number of consumers and the variety of supporting services, see Chou and Shy (1990). In fact, symmetric monopolistic competition models with a single differentiated products industry *a la* Dixit and Stiglitz (1977) always generate positive network effects. However, in our case of non-competitive computer market with heterogeneous consumers, it is possible that consumers may end up being worse off when more consumers purchase the same brand.

Finally, in this paper we assume a monopolistic competition market structure in the software industries thereby ruling out the strategic role software firms can play in

[11]Computer simulations show that proposition 7 can be generalized to the asymmetric distribution cases except in the extreme cases where a computer firm has a very low equilibrium market share and at the same time the variety is very important to consumers (θ is high). In these cases, if computers become compatible, the substantial increase in the variety of software makes the customers of the smaller company better off.

influencing the behavior of computer firms and consumers. Such an analysis is more complex since in this case software firms affect the market share of each computer firm by varying the amount of software packages written for each machine.

APPENDIX

Proof of Proposition 2: In order to show that $\Pi_A + \Pi_B$ is minimized at $\epsilon = 0$, it is sufficient to show that $d(\Pi_A + \Pi_B)/d\epsilon$ has the same sign as ϵ. Observe that $\Pi_A + \Pi_B = \rho_A P_A + \rho_B P_B$. Therefore,

$$\frac{d(\Pi_A + \Pi_B)}{d\epsilon} = (P_A - P_B)\frac{d\rho_A}{d\epsilon} + \rho_A \frac{d(P_A + P_B)}{d\epsilon} - (\rho_A - \rho_B)\frac{dP_B}{d\epsilon}. \tag{22}$$

In what follows, we will show that each term in (22) has the same sign as ϵ. From (12) we have that $\text{sign}(P_A - P_B) = \text{sign}(\epsilon)$ since $P_A = P_B$ when $\epsilon = 0$. Also by (12), $\text{sign}(d(P_A + P_B)/d\epsilon) = \text{sign}(P_A - P_B) = \text{sign}(\epsilon)$. By proposition 1 (using $P_A = P_B$ when $\epsilon = 0$ and $\rho_A - \rho_B = 2\rho_A - 1$), $\text{sign}(\rho_A - \rho_B) = \text{sign}(\epsilon)$. To see that μ is maximized at $\epsilon = 0$, observe that (6) implies that $\mu = k(I - \Pi_A - \Pi_B)$. *Q.E.D.*

Proof of Proposition 5: For $\epsilon = 0$, we have a symmetric equilibrium where $\rho_A = \rho_B = 1/2$ and $P_A = P_B$. From (18) we find that $P_i = 2(1-\theta)I/(3-\theta)$, $i = A, B$. Substituting these results into the total derivative of (13) with respect to ϵ, we have that $\text{sign}(dS_A/d\epsilon) = \text{sign}(\theta^2 + 3\theta - 2)$. It is easy to verify that the sign is positive for $\theta > \theta^* \equiv (\sqrt{17} - 3)/2$. *Q.E.D.*

Proof of Proposition 7: Denote by S_A^c and S_A^{inc} the welfare of an A-user under compatible and incompatible systems, respectively. Using (6), (14) and (21), evaluating (1) and (13) yields $S_A^c = (I/3)^{1+\theta}$, and $S_A^{inc} = 2^{-\theta}[(1-\theta)I/(3-\theta)]^{1+\theta}$. Define $f(\theta) \equiv S_A^{inc} - S_A^c$. Observe that $f(0) = 0$ and that $f'(\theta) > 0$ for $0 < \theta < 1$. Therefore, $f(\theta) > 0$ for $0 < \theta < 1$. *Q.E.D.*

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FIGURE 1

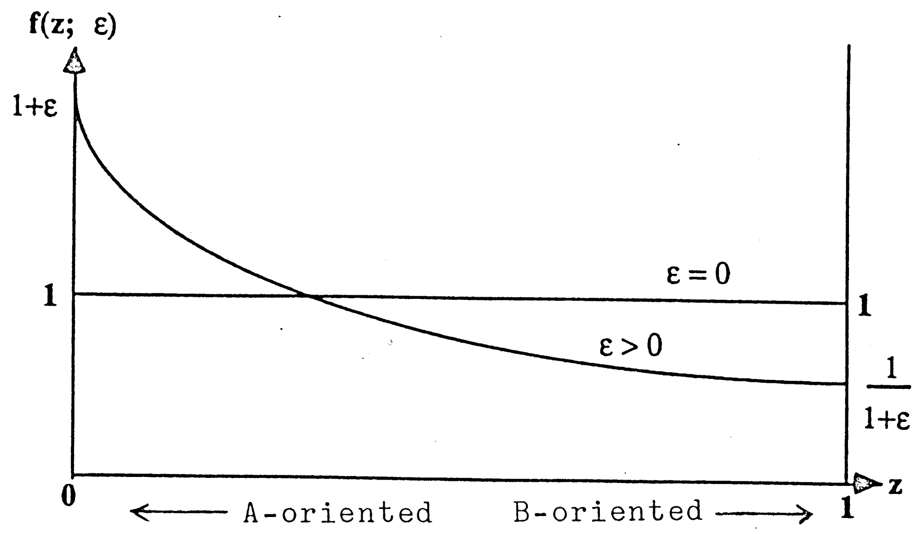

FIGURE 2