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PARTIALLY COMPATIBLE BRANDS AND CONSUMER WELFARE

by

Chien–fu Chou and Oz Shy

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THE FOERDER INSTITUTE FOR ECONOMIC RESEARCH
Faculty of Social Sciences
Tel–Aviv University, Ramat Aviv, Israel.

Partially Compatible Brands and Consumer Welfare*

Chien-fu Chou and Oz Shy

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Abstract

We propose an environment for modelling an industry producing differentiated brands which are partially compatible with each other. We show that when each brand is supported by its brand specific supporting services, a firm may increase the variety of its supporting services and its market share by reducing the degree of compatibility of its machine with other machines' supporting services. However, when a firm is not supported by its brand specific supporting services, it can only gain additional market share when it increases the compatibility of its machine. We also show that consumers benefit when machines become more compatible. However, consumers may become worse off and producers become better off when the products become one hundred percent compatible.

Keywords: Compatibility, Partial Compatibility, Computer Industry, Software Industry

JEL Classification Number: 610, 620

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In recent years with the introduction of personal computers and telecommunication networks, academic economists have realized the importance of product compatibility. In general, products are said to be compatible when their design is coordinated in some way, enabling them to work together.[1] There are three different reasons for why a consumer may prefer to purchase compatible products. In the case where network externalities prevail, an increase in product compatibility increases the network size, see Katz and Shapiro (1985, 1986) and Farrell and Saloner (1985, 1986). Compatibility may increase the variety of systems as in Matutes and Regibeau (19 88) and Economides (1989a). Finally, as in Chou and Shy (1990b), when there are increasing returns to scale in the supporting service industry, compatibility may enlarge the variety of supporting services. Given that consumers' valuation of a brand increases when the brand becomes more compatible with other brands, firms are forced to consider the compatibility of their design. In the case of brand specific supporting services, compatibility affects firms' pricing behavior since their prices affect the number of consumers purchasing the brand and hence the variety of supporting services.

It is often observed that different brands of the same product are only *partially* compatible. For example, not all DOS computers are one hundred percent compatible in the sense that there always exist some software packages which can run on one machine but not on the others. However, economists generally conduct their analyses concentrating only on the cases where brands are either perfectly compatible or completely incompatible.[2] Since compatibility may reduce the competition among firms and therefore may increase prices, a comparison of these two extreme cases may lead to a paradoxical result in which consumers are worse off when firms produce compatible products. The purpose of this paper is to demonstrate that such a comparison is insufficient to conclude whether consumers gain or lose from an increase in compatibility and that models which incorporate partial compatibility are better suited for this welfare analysis. We propose an analytic framework which enables us to define the concept of *variable* degree of compatibility and provide an analysis of the profitability and welfare effects of changing the degree of compatibility.[3]

Our analysis is also useful to explain why not all firms invest in making their machines compatible with the supporting services of the other brands. We show that by unilaterally increasing the degree of compatibility of a machine with the supporting services of the other machines, a firm will reduce the variety of its machine specific supporting services and lose some of its market share. If a firm makes its machine highly compatible with the other's supporting services, its entire supporting service will vanish. This follows from the observation that firms producing supporting services would find it more profitable to produce services which support *both* brands rather than brand specific supporting services.

This note is organized as follows. In section I we set up a model for the computer and software industries and define the concept of variable degree of compatibility. Section I also analyzes the general case where the pieces of hardware have different degrees of compatibility. Section II analyzes the equilibrium profit and welfare levels for all possible degrees of product compatibility for the case that all machines are equally compatible. Section III concludes with a discussion of how firms determine the degree of compatibility of their products.

I. The Environment

Consider a computer industry producing two computer brands named brand A and brand B. We denote by P_i the price of computer brand i, $i = A, B$. Each consumer is endowed with Y dollars to be spent on hardware and software. Denote by E_i the expenditure of a computer i user on software compatible with machine i. Thus, $E_i = Y - P_i$, $i = A, B$. We denote by N_i the total number of software packages which can be run on an i-machine. The service to a system i user, denoted by S_i, is defined as an increasing function of both her expenditure on software and the number of software packages compatible with machine i, $i = A, B$. Formally, let

$$S_i \equiv E_i(N_i)^\theta, \quad \text{where } 0 < \theta < 1 \text{ and } i = A, B. \tag{1}$$

Consumers are uniformly indexed by δ on the interval $[0, 1]$ according to their relative preference towards computer brand A. We define the utility of a consumer type δ as[4]

$$U^\delta \equiv \begin{cases} \delta S_A & \text{if she is an } A\text{-user} \\ (1-\delta) S_B & \text{if she is a } B\text{-user} \end{cases} \tag{2}$$

The number of software packages written specifically for machine i is denoted by n_i, $i = A, B$. The main feature of this model is that the machines can be partially compatible in the sense that in addition to its own software, each machine can also run a selected number of software packages written for its rival machine. Let ρ_i, $0 \leq \rho_i \leq 1$, measure the degree of compatibility of computer i with respect to j's software in the sense that ρ_i measures the proportion of machine j-software which can be run on an i-machine, $i, j = A, B$ and $i \neq j$. Therefore, the total number of software packages available to an i-machine user is equal to

$$N_i = n_i + \rho_i n_j \quad i, j = A, B,\ i \neq j. \tag{3}$$

The consumer who is indifferent between system A and system B is denoted by $\hat{\delta}$ which is found from (2) by solving[5]

$$\hat{\delta} E_A(N_A)^\theta = (1 - \hat{\delta}) E_B(N_B)^\theta. \tag{4}$$

The total number of B-users is given by $\delta_B = \hat{\delta}$, and the total number of A-users is given by $\delta_A = (1 - \hat{\delta})$.

We assume that the total number of software packages written for machine i is equal to the total expenditure spent on i-software by A and B users taking into consideration that the machines are partially compatible with a ρ_i degree of compatibility. In a monopolistically competitive industry with CES preferences, the equilibrium number of firms (software packages) is proportional to the aggregate expenditure, and all software firms charge the same constant price (given equal marginal costs). In our framework, some software firms sell (compatible) software to the two types of users and some sell (incompatible) software to only one type of users. In this case, the analogy to the monopolistic competition zero profit condition is maintained if the software firms only know that there is a probability ρ_i that their products will run on both types of hardware $i = A, B$. There are two justifications for this. First, a firm may design its software at the time where the specification of the computers (or at least of the new generations of computers) are not fully known. Typically, a software firm would work in close association with at least one hardware firm (and be sure of the compatibility of its hardware), but may be uncertain as to the precise hardware design of other computers. Second, one could argue that the model is a simplification of the reality where each of the two hardware firms actually represents a group of (compatible) hardware firms. With this interpretation, it may be reasonable to assume that any software firm can only keep track of the technical developments within one of the two groups.[6]

Observe that an i-user (purchasing n_i software packages designed for the i-machine and $\rho_i n_j$ software packages designed for the j-machine) spends $n_i E_i / N_i$ on i-software and $\rho_i n_j E_i / N_i$ on j-software. Altogether, the total number of software packages written for machine i is proportional to (equal to in the present analysis)

$$n_i = \delta_i \frac{n_i E_i}{N_i} + \delta_j \frac{\rho_j n_i E_j}{N_j}, \quad n_i \geq 0, \;\; i, j = A, B, \; i \neq j. \tag{5}$$

The equations in (5) form a linear simultaneous equation system in $1/N_A$ and $1/N_B$.

First, consider the case where both supporting services industries co-exist. In this case, using Cramer's rule, we have that for $i, j = A, B$ and $i \neq j$,[7,8]

$$N_i = \frac{(1-\rho_A\rho_B)\delta_i E_i}{1-\rho_j} \quad \text{for } 1 - \frac{(1-\rho_j)\delta_j E_j}{\rho_j \delta_i E_i} < \rho_i < 1 - \frac{(1-\rho_j)\delta_j E_j}{\delta_i E_i + (1-\rho_j)\delta_j E_j}. \quad (6)$$

Using (3) and (6), we can solve for the amount of software written specifically for each machine. Thus, for $i, j = A, B$ and $i \neq j$,

$$n_i = \frac{\delta_i Ei}{1-\rho_j} - \frac{\rho_i \delta_j E_j}{1-\rho_i} \quad \text{for } 1 - \frac{(1-\rho_j)\delta_j E_j}{\rho_j \delta_i E_i} < \rho_i < 1 - \frac{(1-\rho_j)\delta_j E_j}{\delta_i E_i + (1-\rho_j)\delta_j E_j}. \quad (7)$$

Substituting (6) into (4), after some manipulations we have that , for $i, j = A, B$ and $i \neq j$,

$$\hat{\delta} = \frac{1}{1 + \left(\frac{1-\rho_A}{1-\rho_B}\right)^{\frac{\theta}{1-\theta}} \left(\frac{E_A}{E_B}\right)^{\frac{1+\theta}{1-\theta}}} \quad \text{for } 1 - \frac{(1-\rho_j)\delta_j E_j}{\rho_j \delta_i E_i} < \rho_i < 1 - \frac{(1-\rho_j)\delta_j E_j}{\delta_i E_i + (1-\rho_j)\delta_j E_j}. \quad (8)$$

It follows from (6) that when ρ_i increases (i-machine can run more of j-software), the total amount of software which can run on the i-machine (N_i) decreases while the total amount of software which can run on j-machine (N_j) increases. The reason for that is rather simple. When, say, machine B becomes less compatible with A-software (ρ_B decreases), fewer A-software packages can be run on the B-machine, implying that less software packages are written for the A-machine (n_A decreases) and that the variety of software written specifically for the B-machine increases (n_B increases), see equation (7). Hence, B's market share increases when machine B becomes less compatible with A-software (see (8)). Therefore, we can state the following proposition.

Proposition 1 *Suppose that both software industries co-exist. Given consumers' expenditures on software (E_A and E_B), and given a degree of compatibility of the j-machine ($\rho_j < 1$), a decrease in the degree of compatibility of the i-machine (a decrease in ρ_i)*

1. *will increase the amount of software usable on the i-machine (N_i),*

2. *will increase the amount of software written specifically for the i-machine* (n_i),

3. *will increase the market share of the firm producing machine i.*

Proposition 1 implies that as long as both software industries co-exist, a computer firm can enlarge its variety of supporting services and can increase its market share by making its machine *less* compatible with the other machine's software. Loosely speaking, reducing the degree of compatibility is a mean for protecting the machine's specific supporting services industry and hence the firm's market share.

In the remainder of the section we consider the second case where the degree of compatibility of machine i is relatively high so that the demand for i-specific software becomes so low so that the i-software industry cannot sustain itself and vanishes. In view of equations (6) and (7),

$$n_i = 0 \text{ and } N_i/\rho_i = n_j = N_j = \delta_i E_i + \delta_j E_j \quad \text{when } \rho_i \geq 1 - \frac{(1-\rho_j)\delta_j E_j}{\delta_i E_i + (1-\rho_j)\delta_j E_j} \tag{9}$$

Hence, by (4) we have that

$$\delta_i = \frac{1}{1 + \rho_i^{-\theta}\left(\frac{E_j}{E_i}\right)}. \tag{10}$$

Thus, we can now state the following.

Proposition 2 *If firm i makes its machine highly compatible with j-software, (the condition in (9) is satisfied), then the software industry supporting the i-machine vanishes. In this case, a further increase in the degree of compatibility of machine i (an increase in* ρ_i*) will increase the number of (j-software) packages which are available to the i-users, thereby increasing the market share of firm i.*

The significance of proposition 2 is that by making machine i highly compatible, the i-software industry disappears, and as revealed in equation (10) i's market share increases with ρ_i. Note that by proposition 1, when the two software industries co-exist, an increase in ρ_i will reduce the market share of firm i. Thus, the fact that the i-software industry vanishes at a certain level of ρ_i is the source of discontinuity in the model in the sense that firm i disconnects from its software industry.

II. The Effects of Varying the Degree of Compatibility

In this section we analyze the effects of an increase in the degree of computer compatibility on the profits of firms and consumers' welfare. With no loss of generality, we assume that machines are produced at zero cost. Thus, the profit of firm i is the price charged by firm i multiplied by firm i's market share. That is, $\Pi_i = P_i\delta_i$. The mechanism of this model is described as follows. The variety of software packages (the number of software firms) adjusts according to consumers' expenditure on software. Computer firms set their prices (hence consumers' expenditure on software) taking into consideration their effects on consumers' choices among systems and the variety of software available for their machines. We define an equilibrium as the pair (P_A^*, P_B^*) so that given $P_j = P_j^*$, P_i^* maximizes Π_i, $i, j = A, B$, $i \neq j$.

In what follows, we restrict our analysis to the case where $\rho_A = \rho_B \equiv \rho$, and consider symmetric equilibria.[9] In this case, equation (8) becomes[10]

$$\hat{\delta} = \begin{cases} \frac{1}{1+\left(\frac{E_A}{E_B}\right)^{\frac{1+\theta}{1-\theta}}} & 0 \leq \rho < 1 \\ \frac{1}{1+\frac{E_A}{E_B}} & \rho = 1 \end{cases} \qquad (11)$$

Therefore, when $\rho_A = \rho_B = \rho$ (the machines have the same degree of compatibility), increasing the degree of compatibility parameter ρ does not affect the location of the marginal consumer and hence the market share of the computer firms. The first order condition for firm i's profit maximization problem, $i = A, B$, yields

$$\frac{E_i}{1-\delta_i} = \begin{cases} \frac{1+\theta}{1-\theta}(Y - E_i) & \text{for } 0 \leq \rho < 1 \\ Y - E_i & \text{for } \rho = 1 \end{cases} \qquad (12)$$

It can be shown, Chou and Shy (1990a), that the two first order conditions can be solved for unique (stable) equilibrium prices. Since the model treats the two systems symmetrically, the unique equilibrium must be symmetric. That is, $\delta_i = 0.5$, $E_A = E_B \equiv E$ and hence $P_A = P_B = Y - E \equiv P$. Using (12), the equilibrium values of software expenditure (E), computer prices (P), computer firm's profit (Π), variety of software available to each user (N), and the service level of each system (S) are given in table 1.

INSERT TABLE 1

Inspecting the profits column in table 1 reveals the following.

Proposition 3 *1. If consumers value software variety ($\theta > 0$), then firms always make higher profit levels when the systems are one hundred percent compatible ($\rho = 1$) compared with any other degree of compatibility ($\rho < 1$). When consumers do not value variety of software ($\theta = 0$), then firms are indifferent between all degrees of compatibility.*

2. As long as the machines are not one hundred percent compatible, varying the degree of compatibility does not have an effect on computer firms' profit.[11]

3. Given that the machines are not one hundred percent compatible, when software variety becomes very important to consumers ($\theta \to 1$), then firms' profit levels approach zero (computer prices converge to marginal costs).

The last item in the proposition can be explained from the fact that when consumers' love for software variety parameter increases, competition among hardware firms increases (demand curves become more elastic) thereby reducing the equilibrium hardware prices.

We now turn to analyzing the effects of changing the degrees of compatibility on consumers' welfare. We find out that consumers are better off with an increase in the degrees of compatibility as long as the machines do not become one hundred percent compatible. This result highlights the importance of constructing models with *variable* degrees of compatibility since a discrete comparison between zero degree of compatibility and one hundred percent degree of compatibility may yield a rather misleading result concluding that consumers are worse off under compatibility. Inspecting the equilibrium values of S in table 1, we can state the following proposition.

Proposition 4 *1. The equilibrium system service levels increase with the degree of compatibility as long as the machines remain partially compatible. That is, $dS/d\rho > 0$ for $\rho < 1$.*

2. However, the service levels are at the lowest levels when the machines are one hundred percent compatible ($\rho = 1$).

Proposition 4 distinguishes between two cases: partial compatibility ($\rho < 1$) and perfect compatibility ($\rho = 1$). When the machines are only partially compatible the price elasticity of demand facing each hardware firm is independent of the degree of compatibility ρ implying that the firms' equilibrium pricing behavior is independent of ρ as long as $\rho < 1$. Thus, consumers with a love for variety can only benefit from an increase in compatibility. Note that as long as $\rho < 1$ there are two software industries producing software for A and B machines. However, a discontinuity occurs when the machines become one hundred percent compatible since when ρ becomes 1 there is only *one* software industry. In this case firms do not have to take into consideration the effect of a price increase on the variety of supporting software. Thus, hardware firms face less elastic demand curves and therefore charge high prices making consumers worse off.

There is a similar way to interpret proposition 4. For each hardware firm, raising its price has essentially two effects. First, it makes its hardware relatively less attractive, inducing some marginal consumers to switch brands. Second, because of both the decrease in market share and the decrease in the software expenditure of its customers, there will be a relative (and absolute) decrease in the variety of software that works on the firm's computer. To the extent that consumers care about software variety, this effect further reduces the market share appropriated by the hardware firm. With perfect compatibility, this second effect disappears so that the firm's incentives to set a higher price are increased.

III. A Discussion

It is observed that most industries produce products which are only partially compatible with each other. For example, most camera brands use different sizes of lenses while using 35mm films. From proposition 3, it is clear that if the computer firms make the decisions on the degrees of compatibility, and if increasing the degrees of compatibility is costless, then firms will choose to produce one hundred percent compatible machines.[12] Next, in a symmetric equilibrium if design costs increase with the degree of compatibility then firms may choose either full compatibility or total incompatibility. This provides some justification for those authors who have focused on these two extreme cases. If the design cost has a minimum for some intermediate value of the degree of compatibility (ρ) partial compatibility may be the optimal choice of the hardware firms.

CHIEN-FU CHOU,
State University of New York at Albany
Albany, NY, U.S.A

OZ SHY
State University of New York at Albany
Albany, NY, U.S.A
and
Tel-Aviv University
Tel-Aviv, Israel

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FOOTNOTES

1. See excellent discussions in Farrell and Saloner (1985, 1987, 1989).

2. Exceptions are the adapters/converters models of Economides (1989b) and Farrell and Saloner (1989).

3. Katz and Shapiro (1985) analyze the effects of increasing in the number of firms producing compatible products on the industrywide output level. They define (industry) partial compatibility as a situation where some firms in the industry produce compatible products and some do not. Here, we define the notion of machine partial compatibility as the percentage of other machine's supporting services that can be used by the machine.

4. This specification of utility does not imply that a consumer indexed by $\delta = 1$ gains a higher utility from system A compared with the consumer indexed by $\delta = 0.9$, since such an interpretation leads to an interpersonal utility comparison.

5. Thus, a consumer indexed by $\delta < \hat{\delta}$ is a B-user while a consumer indexed by $\delta > \hat{\delta}$ is an A-user.

6. We thank the referee for pointing out these arguments. In this case, a firm bears some risk since if the software turns out to be incompatible the firm makes a negative profit. However, the risk is diversified if an investor invests in many software packages.

7. Notice that N_i does not directly depend on E_j. This can be explained as follows. Suppose that B-users' software expenditure increases. That will increase the variety of B software *relative* to A-software. Therefore, A users will reallocate their software expenditure and spend more on B-software and

less on A-software. This will result in an overall reduction in the variety of A-software. In summary, A specific software variety (n_A) decreases while n_B increases such that $N_A = n_A + \rho_A n_B$ does not change.

8. The condition in (6) is obtained from the inequality $n_i > 0$ and (7).

9. For $\rho < 1$, a symmetric equilibrium rules out a boundary solution where one software industry does not exist.

10. The second part of equation (11) follows from (4) by setting $N_A = N_B$ (perfect compatibility).

11. When the degrees of compatibility are not equal this need not be the case.

12. This result is common in the literature on compatibility, see Chou and Shy (1990b), Economides (1989a), and Matutes and Regibeau (1988). Economides (1989b) has cases where partial compatibility is an equilibrium. Matutes and Regibeau (1989) show that entry considerations may induce software firms to produce compatible software.

	E	P	Π	N	S
$0 \le \rho < 1$	$\frac{(1+\theta)Y}{3-\theta}$	$\frac{2(1-\theta)Y}{3-\theta}$	$\frac{(1-\theta)Y}{3-\theta}$	$\frac{(1+\rho)(1+\theta)Y}{2(3-\theta)}$	$\left(\frac{1+\rho}{2}\right)^{\theta}\left(\frac{(1+\theta)Y}{3-\theta}\right)^{1+\theta}$
$\rho = 1$	$\frac{Y}{3}$	$\frac{2Y}{3}$	$\frac{Y}{3}$	$\frac{Y}{3}$	$\left(\frac{Y}{3}\right)^{1+\theta}$

Table 1: The equilibrium values