ABSTRACT

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The strong complementarity between components of a system makes the competition in system markets qualitatively different from those in other markets. When there are multiple types of systems depending on the combinations of the components, there can be several kinds of competition in one system market. The interaction between these competitions and its implication for the market structure are examined in the first two chapters. Chapter 1 finds that the competition in mixed system markets lessens the competition between the original systems. Chapter 1 also finds that relatively low integration and dissolution costs make the competition between the original systems less fierce. Chapter 2 finds that the competition in original systems' retail markets intensifies the competition between the original systems. As a result of the interactions, consumer surplus is the lowest and social welfare is the highest when the mixed system markets are competitive and retail markets are monopolistic.

The last chapter examines how the complementarity between components results in strategic abandoning of market power in system markets. In industries where components have strong complementarity with each other, competition in one component market directly affects competition in the other. In this situation, an integrated manufacturer may want to abandon its duopolistic position in one component market if this leads new entrants to the component market to adopt its other component, and the loss from giving up the duopolistic position in one component market is less than the gains from the increased market share of the other component market. Though both the duopolists may want to choose this strategy, it is also possible that the best response to the rival's strategic abandoning of one component market is to keep the duopolistic position

in both component markets. This is because when the duopolists both give up one component market, market shares for them remain the same as if they kept their duopolistic positions in both component markets. If the costs for making the retained component compatible with the new entrants' components are high, the equilibrium is asymmetric.

MARKET STRUCTURES AND COMPETITION IN SYSTEM MARKETS

by

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PREFACE

A system consists of a set of components, which together provide utility to consumers. A computer is a typical example. This characteristic makes the competition in system markets qualitatively different from those in other markets. When there are multiple types of systems according to the combinations of the components, there can be several kinds of competition in one system market. The interaction between these competitions and its implication for the market structure are examined in the first two chapters. The findings can be an answer to the questions of why TPCIs exist in system markets and how an upstream manufacturer can benefit from adopting a monopolistic retailer. Chapter 1 also analyzes how the costs for integrating components into a system or for breaking a system into components affect the competition in system markets.

Since components of a system have strong complementarity with each other, competition in one component market directly affects competition in the other. Chapter 3 examines how this complementarity affects the competition in system markets and finds that an integrated manufacturer may want to abandon its duopolistic position in one component market. This finding can help us better understand the recent trend in the computer industry towards horizontal competition model where competition is between component manufacturers. The last chapter also finds that in certain situations there can be an asymmetric equilibrium where one duopolistic manufacturer gives up its market power in one component market and its rival retains the market power in both component markets.

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Chapter 1

Why "Third-Party Component Integrators" Exist In System Markets

1.1 Introduction

We see many third-party component integrators (from now on, TPCIs)[1] in system markets[2] such as computers or digital cameras. In computer markets, Dell and Gateway integrate components into a working system. Some components like CD Rom drives, power cables or monitors are provided competitively. Components like CPUs are provided by a monopolist. An interesting fact is that some other components such as RAMs, are provided by system providers, Samsung and Toshiba, who have market power in the component market. In digital camera markets, CCDs, one of the most important parts, are made by only a few companies, Sony, Sanyo and Hitachi. Sony and Sanyo also make and sell their own digital cameras. In camera phone markets, Samsung and Motorola, who sell their own systems, provide their WCDMA chips and CMOS sensors to other camera phone makers. One question of this chapter is why these oligopolistic component manufacturers do not take on the job of integrating and selling the mixed systems. If the manufacturers do the job, they may benefit from internalizing the competition between their original systems and the mixed systems utilizing their components.

This chapter attempts to answer that question, using a model of competition between duopolistic manufacturers of both systems and components. This model is different from the classical upstream-downstream model in that upstream manufacturers are also competing in the downstream markets. In this model, the duopolists' decisions about selling their components jointly determine the structure of the mixed system markets. Considering its profits under each

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[1] TPCIs are intermediaries that buy components from manufacturers and integrate them to produce their own systems. In the computer industry, they are often called VARs (Value Added Retailers).

[2] A system consists of a set of components, which together provide utility to users. When sold separately, the components must be integrated in order to produce utility, by consumers themselves or a third-party integrator, etc.

mixed system market structure, each duopolistic manufacturer decides how to sell its components under no pressure to provide its components competitively.

I find that the duopolistic manufacturers can make more profits when the mixed system markets are competitive. This result is similar to that in the previous literature on vertical externalities.[3] However, the reason is very different. In the previous literature, an upstream monopolist prefers a competitive downstream market, because the competitive market does not introduce a price distortion. If the downstream market is not competitive, then vertical integration of the upstream and the downstream firms is profitable. In this model, however, the duopolistic upstream manufacturers make more profits when the mixed system markets are competitive because competitive mixed system markets bring less fierce competition between the manufacturers' original systems. The manufacturers have fewer incentives to lower prices with the competitive mixed system markets, resulting in higher prices and profits. For a similar reason, the manufacturers make more profits under a competitive mixed system market structure than when each manufacturer has a monopolistic subsidiary for the mixed system market.

An interesting result about consumer surplus comes from this effect of the competition in the mixed system markets on the competition between the manufacturers' original systems. Consumer surplus is lower when the mixed system markets are competitive. This is mainly because the prices for the manufacturers' original systems are higher under the competitive mixed system market structure. However, competitive mixed system markets produce social welfare (joint profits and consumer surplus) highest and closest to the social planner's. The intuition behind this result is that less fierce competition between the manufacturers makes the resulting prices closer to their socially desirable levels.

Another question of this chapter is about the fact that TPCIs, not consumers themselves, take the role of integrating components into mixed systems. This chapter attempts to explain

[3] According to Tirole (1988), a vertical externality arises when any decision made by a downstream retailer that increases his/her demand for the intermediate good increases profits for the upstream manufacturer. Tirole (1988) also gives a brief explanation about the previous literature about this issue.

this fact by assuming that it is costly to integrate components into a system and that this kind of integration costs are less for TPCIs than for consumers. Though the costs can affect firms' marketing practices and competition among them, the previous literature on system markets has not considered this issue. For example, Economides defines "compatible components" as being when "it is feasible for the consumers to integrate them costlessly into a working system."[4] This chapter examines whether and how the costs for component integration affect manufacturers' strategies and market outcomes.

Lower integration costs make the competition between the duopolists less fierce, just as the competitive mixed system markets do. Section 3 presents a detailed explanation of this effect. As well as the integration costs, dissolution costs[5] can also affect the manufacturers' marketing and market competition. This is the case when mixed system integrators have opportunity for arbitrage by purchasing low-priced original systems, breaking them up into components, trading them with other mixed system integrators, and making mixed systems at lower costs. Section 5 considers the effects of this arbitrage behavior on the manufacturers' competition.

Section 2 presents the basic model. The equilibrium prices and profits under each mixed system market structure are analyzed in section 3. Section 4 presents the equilibrium market structure. Analyses of consumer surplus and social welfare are presented in Section 6. Section 7 concludes.

1.2 Model

The basic model is a modified version of the "mix-and-match" model of Matutes and Regibeau (1988). A system is composed of two components, 1 and 2. Two manufacturers, A and B, are producing and selling the components and their own systems. Each component is produced at zero marginal costs, and there are no economies of scope. The components are assumed to be

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[4]Economides (1989), p. 1165.

[5]Dissolution costs are the costs for breaking up a system into components.

compatible with the other manufacturer's matching components.[6] Consequently, there are four possible options for the system: $X_{AA}, X_{BB}, X_{AB}, X_{BA}$.

Consumers are uniformly distributed on the unit square (see Figure 1.1). Manufacturer A is located at the origin, while manufacturer B is located at (1,1). Thus, mixed system X_{AB} is located at (0,1) and X_{BA} at (1,0). A consumer located at the point of coordinates (d_1, d_2) has an ideal component 1 that is d_1 away from manufacturer A's component 1 and an ideal component 2 that is d_2 away from A's component 2. Similarly, the distances between the consumer's ideal point and manufacturer B's components are $1 - d_1$ and $1 - d_2$, respectively. Every consumer is assumed to purchase at most one system. When the components are directly sold to consumers, each consumer purchases the two components in the fixed proportion of one unit of component 1 to each unit of component 2.

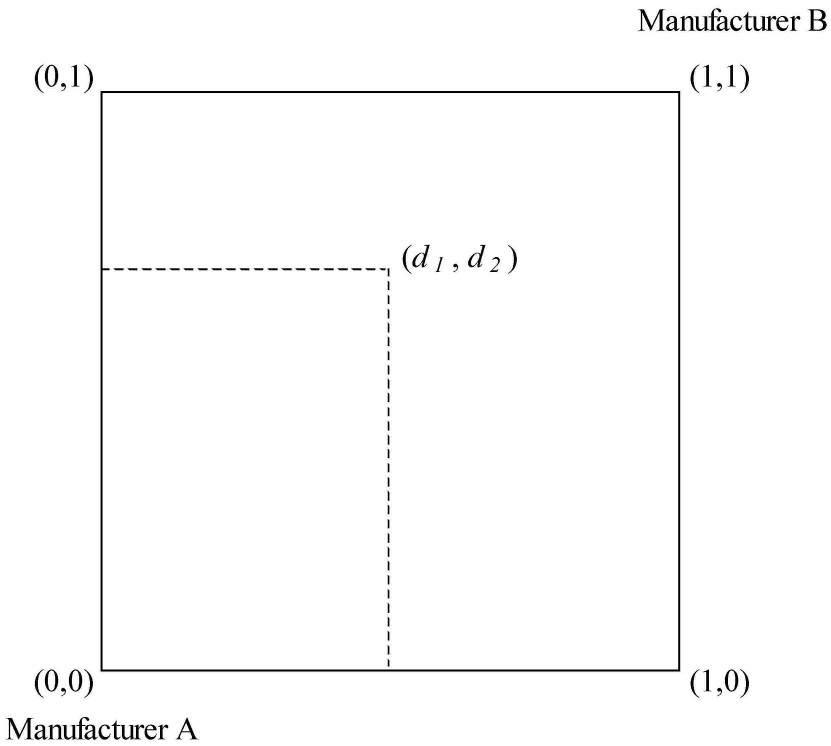

Figure 1.1: Location of Manufacturers and Consumers on the Unit Square

[6]For an analysis of the firms' decision on compatibility, see Matutes and Regibeau (1988).

A consumer buying one unit of system X_{ij} has a surplus of $C - k(d_{1i} + d_{2j}) - P_{ij}$, where C is the reservation price common to all the consumers, and parameter k measures the degree of horizontal product differentiation among the goods. d_{1i} and d_{2j} are the distances of the consumer's ideal components 1 and 2 from system X_{ij}. P_{ij} is the price for the system X_{ij}, including the integration costs when the consumer herself integrates the components into the system. C is assumed to be so high that all markets are covered.

Though all the components are compatible, it is costly to integrate different manufacturers' components into a mixed system. The integration costs for consumers, z_1^I, are higher than the costs for TPCIs or the manufacturers' subsidiaries, z_2^I, reflecting economies of scale. The assumptions on the dissolution costs, z_i^D, are similar. The integration costs can be any positive number theoretically. But, if these costs are bigger than k, the mixed system market vanishes. Since the focus of this chapter is on the structure of mixed system markets, this chapter rules out the case when $z_i^I > k$.[7]

The whole game has three stages. In the first stage, manufacturers A and B simultaneously decide how to sell components. The manufacturers can sell their components to consumers or mixed system integrators such as TPCIs or their own subsidiaries. In the second stage, the two manufacturers announce their system and component prices. If the manufacturers' decisions in the first stage result in no other type of mixed system integrators than consumers, consumers purchase systems or components at the second stage and the game ends. If there are mixed system integrators other than consumers, they decide prices in the third stage. All systems are sold to the public, while the components are sold in the way decided in the first stage. Resale of the components is assumed to not be possible.[8] This possibly unrealistic assumption allows a clearer

[7]The analysis of the cases with no mixed system market will be the same as in Matutes and Regibeau (1988). Unlike z_i^I, there is no upper limit on z_i^D.

[8]Resale of the components between consumers or from consumers to firms are assumed too costly to happen. In addition, the manufacturers may be able to prohibit the firms who bought their components from reselling them.

comparison of the outcomes in each mixed system market structure.

Another scenario for the timing of the game is possible: in the second stage the two manufacturers decide only their component prices and in the final stage all of the system prices are decided. Since the results under this alternative scenario are complex and the two scenarios share many results, this chapter focuses on the above scenario. Appendix A reports the equilibrium under the alternative scenario.

In the first stage, each manufacturer has several ways to sell its components. It can sell its components directly to consumers or TPCIs. There are many potential TPCIs in the industry. If both manufacturers sell their components to all TPCIs, the TPCIs will have a Bertrand competition, pricing their mixed systems at marginal costs that are the sum of the component prices and the integration costs. If the manufacturers decide to sell their components to only one and the same TPCI at each point, the TPCI will have a local monopoly power.

The manufacturers can also establish subsidiaries in the first stage. When a manufacturer builds its own subsidiaries, the manufacturer maximizes the total profits of the vertical structure, the manufacturer itself and its subsidiaries. A manufacturer has two options with regard to establishing subsidiaries: to establish one subsidiary at (1,0) or (0,1), or to establish one subsidiary at both (1,0) and (0,1). Since mixed system integrators face price competition, the manufacturers do not have any incentives to build more than one subsidiary at each point. For a similar reason, a manufacturer with a subsidiary(ies) may want to provide its components exclusively to its own subsidiary(ies). However, a subsidiary needs both manufacturers' components in order to produce mixed systems. This chapter will focus on the case where manufacturers provide their components for all subsidiaries of both manufacturers.[9]

In summary, in the first stage each manufacturer has the following five options: (1) to sell

[9]If the two manufacturers do not sell their components to their rival's subsidiary(ies), there would be no mixed systems, resulting in competition between the two original systems. Similarly, when the manufacturers decide to sell their components to different TPCIs, no TPCIs will be able to produce mixed systems. However, these cases are not the equilibrium because each manufacturer can be better off from changing its own choices about TPCIs.

its components to consumers; (2) to sell its components to one TPCI at each point; (3) to sell its components to all TPCIs at each point; (4) to establish one subsidiary at a point and provide its components for all subsidiaries[10]; (5) to establish one subsidiary at each point and provide its components for all subsidiaries.

1.3 Equilibrium Prices and Profits

This section presents the equilibrium prices and profits in the various mixed system market structures that result from the two manufacturers' decisions in the first stage. For calculation of the equilibrium, a symmetric equilibrium is assumed to exist and symmetry conditions are imposed.[11] If both manufacturers decide to sell their components directly to consumers in the first stage, only consumers will integrate the components into the mixed systems. When the manufacturers decide to sell their components to any TPCIs at each point, there are many TPCIs producing mixed systems X_{AB} and X_{BA}. Since the TPCIs face the Bertrand competition, they will be called competitive TPCIs. On the other hand, if the manufacturers' decisions are to sell the components to the same TPCI at each mixed system market, the TPCI will be the only mixed system provider at each point. This TPCI will be called the locally monopolistic TPCI. When each manufacturer establishes one subsidiary at a point and provides its components for all the subsidiaries, each subsidiary will be the only mixed system provider at each point.[12] We will call these subsidiaries locally monopolistic subsidiaries. If each manufacturer decides to establish a subsidiary at each point and to provide its components to all the subsidiaries, there will be two subsidiaries in each mixed system market. These subsidiaries will be called competitive subsidiaries.

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[10]For example, if manufacturer A establishes a subsidiary at (0,1), it provides its component 1 for its subsidiary and sells its component 2 to manufacturer B's subsidiary.

[11]These equilibrium prices and profits are shown to be valid by numerical computations with the integration costs fixed at values 0, 0.1, 0.2, ... , 1.0.

[12]If both manufacturers establish their subsidiaries at the same point, then no subsidiaries can make mixed systems.

It should be noted that each case has an equilibrium corresponding to competition between two systems only. When the manufacturers set their component prices so high that any unilateral changes in the component prices cannot make the mixed system integration profitable, there remain only the two manufacturers' original systems in the last stage. In essence, these equilibria are the same as in the cases where the manufacturers' decisions in the first stage lead to no mixed system integrators, and are not the focus of this chapter.

1.3.1 Consumers

Let us begin with the case when both manufacturers decide to sell their components directly to consumers in the first stage.[13] In this case, it takes integration costs of z_1^I for a consumer to assemble a mixed system. Since every consumer's reservation price, C, is assumed to be high enough for the whole market to be covered, a consumer at (d_1, d_2) will purchase system X_{AA} when the following inequalities hold:

$$P_{AA} + k(d_1 + d_2) \leq P_{1A} + P_{2B} + z_1^I + k(d_1 + 1 - d_2);$$

$$P_{AA} + k(d_1 + d_2) \leq P_{1B} + P_{2A} + z_1^I + k(1 - d_1 + d_2);$$

$$\text{and } P_{AA} + k(d_1 + d_2) \leq P_{BB} + k(1 - d_1 + 1 - d_2).$$

P_{ii} is the price for system X_{ii}, and P_{1i} and P_{2i} are the prices for manufacturer i's components 1 and 2, respectively. D_{AA}, the resulting demand for system X_{AA}, is $(\frac{z_1^I+k+P_{1A}-P_{AA}+P_{2B}}{2k}) \cdot (\frac{z_1^I+k+P_{2A}-P_{AA}+P_{1B}}{2k}) - \frac{1}{2}[(\frac{z_1^I+k+P_{2A}-P_{AA}+P_{1B}}{2k}) - (\frac{-z_1^I+k-P_{1A}+P_{BB}-P_{2B}}{2k})] \cdot [(\frac{z_1^I+k+P_{1A}-P_{AA}+P_{2B}}{2k}) - (\frac{-z_1^I+k-P_{2A}+P_{BB}-P_{1B}}{2k})]$. D_{BB}, D_{AB} and D_{BB} are defined similarly. $D_{BB} = (1 - \frac{-z_1^I+k-P_{1A}+P_{BB}-P_{2B}}{2k}) \cdot (1 - \frac{-z_1^I+k-P_{2A}+P_{BB}-P_{1B}}{2k}) - \frac{1}{2}[(\frac{z_1^I+k+P_{2A}-P_{AA}+P_{1B}}{2k}) - (\frac{-z_1^I+k-P_{1A}+P_{BB}-P_{2B}}{2k})] \cdot [(\frac{z_1^I+k+P_{1A}-P_{AA}+P_{2B}}{2k}) - (\frac{-z_1^I+k-P_{2A}+P_{BB}-P_{1B}}{2k})]$. $D_{AB} = (1 - \frac{z_1^I+k+P_{1A}-P_{AA}+P_{2B}}{2k}) \cdot (\frac{-z_1^I+k-P_{1A}+P_{BB}-P_{2B}}{2k})$. $D_{BA} = (1 -$

[13]The analysis in this subsection is almost the same as in Matutes and Regibeau (1992) except that the consumers must pay costs for integrating the components.

$\frac{z_1^I+k+P_{2A}-P_{AA}+P_{1B}}{2k}) \cdot (\frac{-z_1^I+k-P_{2A}+P_{BB}-P_{1B}}{2k})$. (See Figure 1.2.)

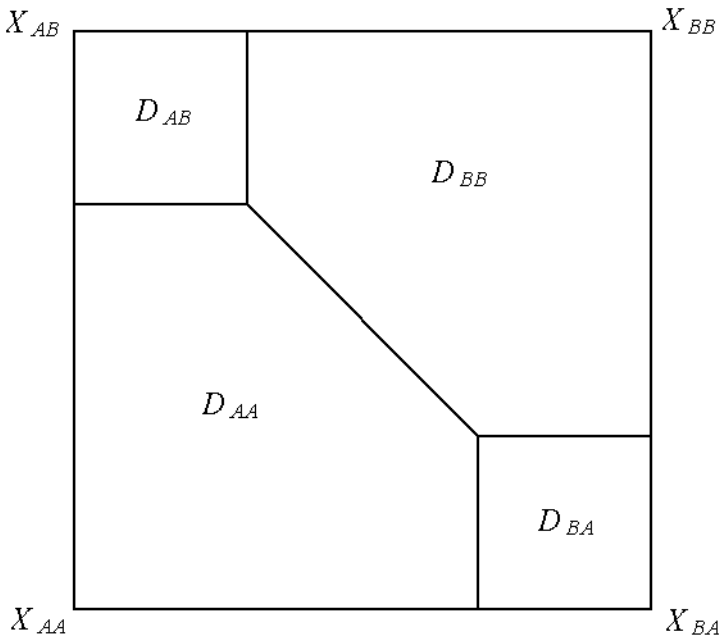

Figure 1.2: Demands for the Systems

Manufacturer A's profit maximization problem is the following:

$$\underset{P_{AA},P_{1A},P_{2A}}{Max} f^A\left(P_{AA}, P_{1A}, P_{2A}; P_{BB}, P_{1B}, P_{2B}\right) = P_{AA}D_{AA} + P_{1A}D_{AB} + P_{2A}D_{BA}.$$

Manufacturer B has a similar profit maximization problem.

As stated earlier, when consumers themselves integrate mixed systems, the game ends at the second stage. The equilibrium system prices and profits can be obtained from the two manufacturers' profit maximization problems and the symmetry conditions of $P_{AA} = P_{BB}$, $P_{1A} = P_{1B}$ and $P_{2A} = P_{2B}$. $P_{AA} = P_{BB} = \frac{4k^2}{3k+z_1^I}$, $P_{1A} = P_{2A} = P_{1B} = P_{2B} = \frac{11k^2-2z_1^Ik-(z_1^I)^2}{4(3k+z_1^I)}$ and $\Pi_{AA} = \Pi_{BB} = \frac{67k^4-8z_1^Ik^3+6(z_1^I)^2k^2-(z_1^I)^4}{32(3k+z_1^I)}$. In addition, $D_{AB} = D_{BA} = \frac{(k-z_1^I)^2}{16k^2}$.

If we compare this equilibrium with the equilibrium in the case where consumers have to choose only from the two manufacturers' original systems, we will find that selling components and systems (mixed bundling) is preferable to the manufacturer over selling only systems (pure bundling). When $0 < z_1^I < k$, the equilibrium pure bundling price k is lower than $\frac{4k^2}{3k+z_1^I}$, and the equilibrium pure bundling profits, $\frac{k}{2}$, are also lower than $\frac{67k^4-8z_1^Ik^3+6(z_1^I)^2k^2-(z_1^I)^4}{32(3k+z_1^I)}$.

Pure bundling gives lower profits to the manufacturers than mixed bundling, because pure bundling intensifies the competition between the two manufacturers. With pure bundling, a decrease in P_{AA}, for example, increases the demand for system X_{AA}, decreasing only the demand for X_{BB}. When the two manufacturers use mixed bundling, the same decrease in P_{AA} decreases not only the demand for X_{BB} but also the demands for X_{AB} and X_{BA} that use manufacturer A's components. Thus, the manufacturers have fewer incentives to lower their prices when they use mixed bundling.

Matutes and Regibeau (1988) find that selling only components (pure component selling) is more preferable to the manufacturers than pure bundling for a similar reason. Anderson and Leruth (1993) show that similar results can be attained using a discrete choice framework.

1.3.2 Competitive TPCIs

When both manufacturers decide to sell their components to all TPCIs at each point in the first stage, there will be many TPCIs producing mixed systems X_{AB} and X_{BA}. Consumer demands are different from those expressed in subsection 3.1, because now consumers only observe system prices not component prices. $D_{AA} = (\frac{k+P_{AB}-P_{AA}}{2k}) \cdot (\frac{k+P_{BA}-P_{AA}}{2k}) - \frac{1}{2}[(\frac{k+P_{BA}-P_{AA}}{2k}) - (\frac{k-P_{AB}+P_{BB}}{2k})] \cdot [(\frac{k+P_{AB}-P_{AA}}{2k}) - (\frac{k-P_{BA}+P_{BB}}{2k})]$. $D_{BB} = (1 - \frac{k-P_{AB}+P_{BB}}{2k}) \cdot (1 - \frac{k-P_{BA}+P_{BB}}{2k}) - \frac{1}{2}[(\frac{k+P_{BA}-P_{AA}}{2k}) - (\frac{k-P_{AB}+P_{BB}}{2k})] \cdot [(\frac{k+P_{AB}-P_{AA}}{2k}) - (\frac{k-P_{BA}+P_{BB}}{2k})]$. $D_{AB} = (1 - \frac{k+P_{AB}-P_{AA}}{2k}) \cdot (\frac{k-P_{AB}+P_{BB}}{2k})$. $D_{BA} = (1 - \frac{k+P_{BA}-P_{AA}}{2k}) \cdot (\frac{k-P_{BA}+P_{BB}}{2k})$.

However, the two manufacturers face the same profit maximization problems as in subsection 3.1, except that z_1^I is replaced by z_2^I. This is because the competitive TPCIs that are competing in prices set their mixed system prices at their marginal costs.[14] Therefore, the equilibrium prices $P_{AA} = P_{BB} = \frac{4k^2}{3k+z_2^I}$ and $P_{1A} = P_{2A} = P_{1B} = P_{2B} = \frac{11k^2-2z_2^Ik-(z_2^I)^2}{4(3k+z_2^I)}$. The profits $\Pi_{AA} = \Pi_{BB} = \frac{67k^4-8z_2^Ik^3+6(z_2^I)^2k^2-(z_2^I)^4}{32(3k+z_2^I)}$ and the demand for mixed systems $D_{AB} = D_{BA} = \frac{(k-z_2^I)^2}{16k^2}$. The

[14] Thus, $P_{AB} = P_{1A} + P_{2B} + z_2^I$ and $P_{BA} = P_{1B} + P_{2A} + z_2^I$ in the last stage.

following proposition compares this equilibrium with the equilibrium in the previous section.

Proposition 1 *When the manufacturers sell their components to competitive TPCIs, the equilibrium original system and component prices, profits and demand for a mixed system are always higher than when the manufacturers sell their components to consumers. The mixed system prices are always lower when the manufacturers sell their components to competitive TPCIs than when the manufacturers sell their components to consumers.*

Proof. The only difference in the equilibrium prices and profits is the magnitude of the integration costs. Since the equilibrium system and component prices, profits and demand for a mixed system are decreasing in the integration costs, the assumption of $z_1^I > z_2^I$ is sufficient to prove the above proposition. The equilibrium mixed system price increases in the integration costs. ■

Higher integration costs lead to lower equilibrium prices because they bring more fierce competition between the manufacturers, just as bundling does. The rise in such costs make the mixed system prices higher, resulting in smaller demand for the mixed systems. The smaller the mixed system markets are, the bigger incentives to cut the prices the manufacturers have. This is because a manufacturer's decrease of its system price will do less harm to its component sales if the mixed system markets are smaller. Meanwhile, the equilibrium mixed system price increases in the integration costs because component prices decrease less rapidly than the integration costs rise.

It is interesting that higher integration costs intensify the competition between the manufacturers even when the manufacturers sell only their components. For a clearer comparison, let us consider the two cases of zero and positive integration costs. Without the integration costs, the market for a manufacturer's original system is contiguous with the markets for mixed systems only. If integration requires positive costs, however, the markets for the manufacturers' original systems border each other. When manufacturer B lowers the price of its component 2, the demands for X_{BB} and X_{AB} will increase (See Figure 1.3.) The shaded areas represent increases in the manufacturer B's component sales, while the area with broad lines show increases in the sales of manufacturer B's systems, that is, both components. Thus, the manufacturers have more incentives to lower their prices when their original systems' markets border each other.

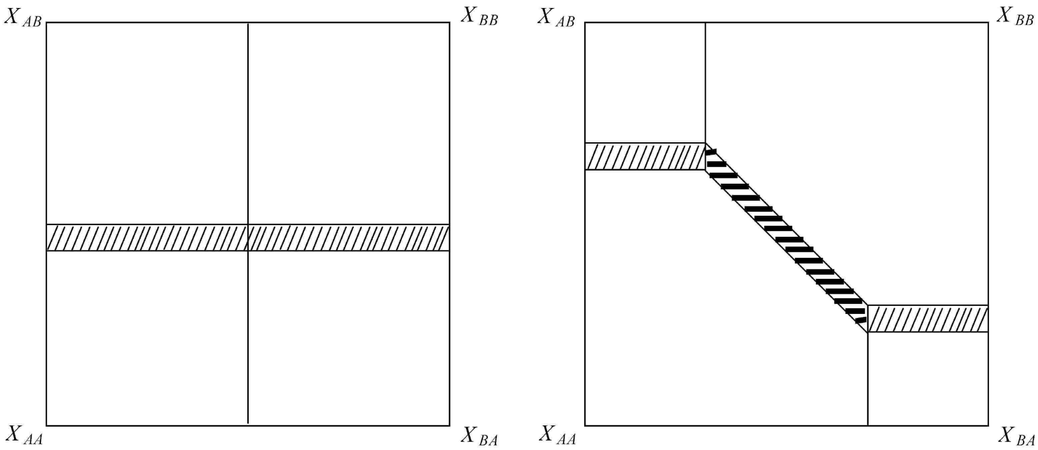

Figure 1.3: Effects of Manufacturer B's Price Decrease When the Integration Costs Are Zero and Positive

1.3.3 Locally monopolistic TPCIs

If the manufacturers' decisions in the first stage are to sell the components to only one and the same TPCI at each point, the TPCIs will be the only mixed system providers. Since the TPCIs have market power, they will choose their mixed system prices maximizing their profits in the third stage. Considering these mixed system prices, the two manufacturers decide their prices in the second stage. The manufacturers' profit functions are similar to those in subsection 3.2.

From the profit maximization problems of the manufacturers and the TPCIs and the symmetry conditions, $P_{AA} = P_{BB} = \frac{6k^2}{5k+z_2^I}$, $P_{1A} = P_{2A} = P_{1B} = P_{2B} = \frac{17k^2-4z_2^I k-(z_2^I)^2}{4(5k+z_2^I)}$ and $P_{AB} = P_{BA} = \frac{28k^2+7z_2^I k+(z_2^I)^2}{3(5k+z_2^I)}$.[15] The profits $\Pi_{AA} = \Pi_{BB} = \frac{221k^4-14z_2^I k^3+12(z_2^I)^2k^2-2(z_2^I)^3k-(z_2^I)^4}{72k^2(5k+z_2^I)}$ and the demand for mixed systems $D_{AB} = D_{BA} = \frac{(k-z_2^I)^2}{36k^2}$. Comparing these results with the equilibrium in subsection 3.2 leads to the following proposition.

Proposition 2 *When the manufacturers sell their components to competitive TPCIs, the equilib-*

[15] Solutions of the FOC's of the locally monopolistic TPCIs' profit maximization problems in the last stage are functions of the prices that are decided in the second stage. The equilibrium prices in the second stage are derived from plugging these functions into the manufacturers' profit functions and solving the resulting FOC's for the original system and component prices.

rium original system and component prices, profits and demand for a mixed system are always higher than when the manufacturers sell their components to monopolistic TPCIs. The mixed system prices are always lower when the manufacturers sell their components to competitive TPCIs than when the manufacturers sell their components to monopolistic TPCIs.

The intuition behind Proposition 2 is similar to that of Proposition 1. The poorer results for the manufacturers when they sell their components to locally monopolistic TPCIs are because of the resulting fiercer competition between themselves. Since the locally monopolistic TPCIs' prices are higher than their costs, they might possibly keep the manufacturers' prices high. However, as the locally monopolistic TPCIs' markets shrink, the manufacturers become more aggressive in their pricing.

1.3.4 Locally monopolistic subsidiaries

When each manufacturer decides to establish one subsidiary at a point and to sell its components to all the subsidiaries, each subsidiary will be the only mixed system provider at each point. In the second stage, the manufacturers decide their original system and component prices simultaneously. In the last stage, the subsidiaries decide their mixed system prices at the same time. Now the manufacturers maximize the total profits of their vertical structures. If manufacturer A's subsidiary locates at (0,1) and B's subsidiary at (1,0), for example, vertical structure A's profit function is

$$f^A\left(P_{AA}, P_{1A}, P_{2A}; P_{BB}, P_{1B}, P_{2B}, P_{AB}, P_{BA}\right) = P_{AA}D_{AA} + (P_{AB} - P_{2B} - z_2^I)D_{AB} + P_{2A}D_{BA}.$$

Manufacturer B's vertical structure has a similar profit function. The demands for systems are defined in the same way as in subsections 3.2 and 3.3.

From the two vertical structures' profit maximization problems and the symmetry conditions, $P_{AA} = P_{BB} = \frac{6k^2}{5k+z_2^I}$, $P_{2A} = P_{2B} = \frac{14k^2-4z_2^I k-(z_2^I)^2}{3(5k+z_2^I)}$ and $P_{AB} = P_{BA} = \frac{79k^2+25z_2^I k+4(z_2^I)^2}{9(5k+z_2^I)}$. Note that a vertical structure is selling only one component to its rival's subsidiary. The profits $\Pi_{AA} = \Pi_{BB} = \frac{2287k^4-280z_2^I k^3+240(z_2^I)^2k^2-40(z_2^I)^3k-20(z_2^I)^4}{729k^2(5k+z_2^I)}$ and the demand for mixed systems

$D_{AB} = D_{BA} = \frac{4(k-z_2^I)^2}{81k^2}$. Comparison of these results with the equilibria in subsections 3.2 and 3.3 are summarized in Proposition 3.

Proposition 3 *The ranking of the equilibrium prices, profits and demand for a mixed system are the following.*

$$\begin{array}{ll} \textit{Mixed System Price}: & P_{AB}{}^{(mono.TPCI)} > P_{AB}{}^{(comp.TPCI)} > P_{AB}{}^{(subsidiaries)} \\ \textit{Component Price}: & P_{2A}{}^{(subsidiaries)} > P_{2A}{}^{(comp.TPCI)} > P_{2A}{}^{(mono.TPCI)} \\ \textit{Original System Price}: & P_{AA}{}^{(comp.TPCI)} > P_{AA}{}^{(subsidiaries)} = P_{AA}{}^{(mono.TPCI)} \\ \textit{Mixed System Demand}: & D_{AB}{}^{(comp.TPCI)} > D_{AB}{}^{(subsidiaries)} > D_{AB}{}^{(mono.TPCI)} \\ \textit{Profits}: & \Pi_{AA}{}^{(comp.TPCI)} > \Pi_{AA}{}^{(subsidiaries)} > \Pi_{AA}{}^{(mono.TPCI)} \end{array}$$

When a vertical structure decides its mixed system price in the last stage, it may have less incentive to lower that price than a TPCI because its lowered mixed system price decreases its original system sales. However, its mixed system price is lower than a TPCI's because the subsidiary's marginal costs (price of a component plus integration costs) is lower than a TPCI's marginal costs (sum of the prices of two components plus integration costs). With higher integration costs, the effect of the difference in marginal costs is smaller.

When the manufacturers or vertical structures decide their component prices in the second stage, they will decide the component prices at the level equating what they earn marginally and what they lose marginally. When they raise their component prices, they earn the increase in the unit price and the increase in the original system sales. On the other hand, they lose some of their component sales. Since the original system sales are more important to them than the component sales,[16] they want the mixed system price at a level where the demand is not elastic. With the convex inverse demand function, $P_{AB} = k + \frac{1}{2}P_{AA} + \frac{1}{2}P_{BB} - \frac{1}{2}\sqrt{(P_{AA})^2 - 2P_{AA}P_{BB} + (P_{BB})^2 + 16k^2 D_{AB}}$, the vertical structures have the largest incentive to raise the component price. In addition, manufacturers selling their components to competitive

[16]The marginal profits from original system sales are higher than the marginal profits from component sales, unless the original system price is lower than the component price. If the component price is higher than the original system price, no mixed system will be sold.

TPCIs have larger incentive to raise the component price than manufacturers selling their components to locally monopolistic TPCIs. Note that locally monopolistic TPCIs' mixed system prices are higher than those of competitive TPCIs because of the markup over the costs.

The decision about the component price is made at the same time with the decision about the original system price. An interesting result is that the original system price of a vertical structure is the same as that of a manufacturer selling its components to locally monopolistic TPCIs, even though the locally monopolistic TPCIs' mixed system markets are smaller than those of the vertical structures. This is because vertical structures raise the component prices so high that their mixed system sales become less attractive. In fact, a manufacturer's markup over the costs for a mixed system is less than its component price and the component price of a manufacturer with locally monopolistic TPCIs. Thus, original system sales are more important to a vertical structure than to a manufacturer with TPCIs, leading to more aggressive original system pricing.

1.3.5 Competitive subsidiaries

If each manufacturer decides to establish a subsidiary at each point and to provide its components for all the subsidiaries, then two subsidiaries will produce each of the mixed systems X_{AB} and X_{BA}. Vertical structure A, manufacturer A and its two subsidiaries, has the following profit function

$$f^A\left(P_{AA}, P_{1A}, P_{2A}; P_{BB}, P_{1B}, P_{2B}, P_{AB}, P_{BA}\right) =$$

$$P_{AA}D_{AA} + (P_{AB} - P_{2B} - z_2^I)\frac{1}{2}D_{AB} + P_{1A}\frac{1}{2}D_{AB} + (P_{BA} - P_{1B} - z_2^I)\frac{1}{2}D_{BA} + P_{2A}\frac{1}{2}D_{AB}.$$

Vertical structure B has a similar profit function. If two subsidiaries, one of manufacturer A and the other of B, exist together at a point, their mixed system prices should be the same. Furthermore, each subsidiary's markup over the costs should be equal to its mother firm's price for the component which is sold to its rival. If the markup is lower than the component price, the subsidiary will raise its mixed system price, making more profits from the component sales. On the other hand, if the markup is higher than the component price, the subsidiary will lower its mixed system price slightly, driving its rival away from the mixed system market. Thus, if two subsidiaries are active, P_{AB} must be equal to $P_{1A} + P_{2B} + z_2^I$, resulting in the same profit function and the same equilibrium as in subsection 3.2 where the manufacturers sell their components to competitive TPCIs.

In the second stage, a manufacturer may want to make its rival's or its own subsidiary withdraw from the mixed system market by changing its original system or component prices. If a manufacturer changes its original system price, it will affect all the mixed system providers equally. Thus, changing the original system price cannot affect the subsidiaries' decisions of whether to exit or to stay. Though changes in the component prices can make the subsidiaries exit, the resulting equilibrium is the same as in subsection 3.2. A more detailed explanation is in the proof of the following proposition.

Proposition 4 *When each manufacturer establishes a subsidiary at each point, the equilibrium is the same as when the manufacturers sell their components to competitive TPCIs.*

Proof. Consider a situation where all the prices are the same as when the manufacturers provide their components to competitive TPCIs. Changes in the component prices can make a subsidiary exit. Suppose manufacturer A increases P_{1A} from P'_{1A} to P''_{1A}. Then, manufacturer B's subsidiary will exit from the market for X_{AB}. Manufacturer A's subsidiary at the mixed system market can increase its markup by the amount of the increase in the component price. What manufacturer A earns are $area\ u \cdot \Delta markup_{mixed}$ and $area\ w \cdot (markup'_{original} - markup'_{mixed})$. Manufacturer A loses its component sales by the amount of the $area\ v$. (See figure 1.4.)

Before the change in P_{1A}, manufacturer A's profits from the market for X_{AB} are $\frac{1}{2}(u + v + w) \cdot markup'_{mixed} + \frac{1}{2}(u + v + w) \cdot P'_{1A}$. Since $markup'_{mixed} = P'_{1A}$, the profits are equal to $(u + v + w) \cdot markup'_{mixed}$. After the change in P_{1A}, the profits are $u \cdot markup''_{mixed} + w \cdot markup'_{original}$. The difference between these two profits are $[u \cdot markup''_{mixed} + w \cdot markup'_{original}] - [(u + v + w) \cdot markup'_{mixed}] = [u \cdot \Delta markup_{mixed} + w \cdot (markup'_{original} - markup'_{mixed})] - [v \cdot markup'_{mixed}]$.

Now consider the situation where both manufacturers sell their components to competitive TPCIs. An increase in P_{1A} from P'_{1A} to P''_{1A} will give manufacturer A the additional profits of

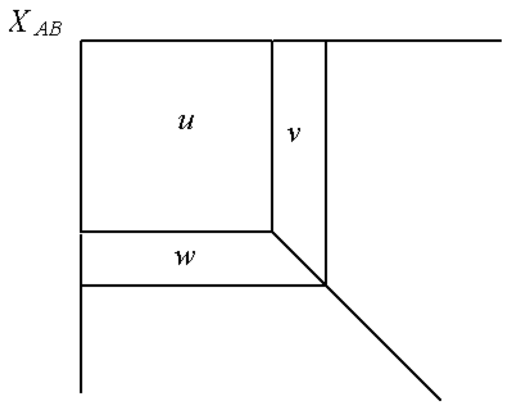

Figure 1.4: When Manufacturer A Raises the Price for Its Component 1

$area\ u \cdot \Delta P_{1A}$ and $area\ w \cdot (markup'_{original} - P'_{1A})$. The loss to manufacturer A is $v \cdot P'_{1A}$ from the decrease in the sales of its component 1. Since $markup'_{mixed} = P'_{1A}$ and $\Delta markup_{mixed} = \Delta P_{1A}$, the earnings in the two situations are the same and the losses in the two situations are also the same. This logic can be applied to the case when the manufacturer lowers its component price. ■

1.4 Equilibrium Market Structure

In this section, we consider the two manufacturers' decisions in the first stage. Up to now, we have seen the equilibria in the cases where the manufacturers' decisions in the first stage are the same. Consideration of the other cases where the manufacturers' decisions are different will complete the payoff matrix that the manufacturers face in the first stage.

		Manufacturer B: providing components for				
		(a) consumers	(b) one TPCI at each point	(c) any TPCIs at each point	(d) two Subsidiaries	(e) four Subsidiaries
A	(a)	(Π^{aa}, Π^{aa})	$(\frac{1}{2}k, \frac{1}{2}k)$	$(\frac{1}{2}k, \frac{1}{2}k)$	$(\frac{1}{2}k, \frac{1}{2}k)$	$(\frac{1}{2}k, \frac{1}{2}k)$
	(b)	$(\frac{1}{2}k, \frac{1}{2}k)$	(Π^{bb}, Π^{bb})	(Π^{bb}, Π^{bb})	$(\frac{1}{2}k, \frac{1}{2}k)$	$(\frac{1}{2}k, \frac{1}{2}k)$
	(c)	$(\frac{1}{2}k, \frac{1}{2}k)$	(Π^{bb}, Π^{bb})	(Π^{cc}, Π^{cc})	$(\frac{1}{2}k, \frac{1}{2}k)$	$(\frac{1}{2}k, \frac{1}{2}k)$
	(d)	$(\frac{1}{2}k, \frac{1}{2}k)$	$(\frac{1}{2}k, \frac{1}{2}k)$	$(\frac{1}{2}k, \frac{1}{2}k)$	(Π^{dd}, Π^{dd})	(Π^{dd}, Π^{dd})
	(e)	$(\frac{1}{2}k, \frac{1}{2}k)$	$(\frac{1}{2}k, \frac{1}{2}k)$	$(\frac{1}{2}k, \frac{1}{2}k)$	(Π^{dd}, Π^{dd})	(Π^{ee}, Π^{ee})

Table 1.1: Matrix of Payoffs to the Manufacturers

If manufacturer A sells its components directly to consumers only and manufacturer B sells to TPCIs, no mixed system can be made. This result is from the assumption of no resale of the components. Consumers can not make mixed systems because they are not provided the components from B. Similarly, TPCIs cannot produce mixed systems without A's components. The market structure in this case is the same as when the manufacturers use pure bundling. A similar logic can be applied to the cases where the manufacturers choose the strategy combinations (a,d) or (a,e).

The results are also the same when manufacturer A sells its components to only one TPCI at each point and manufacturer B sells components to consumers or subsidiaries. However, if A sells its components to only one TPCI at each point and B sells to any TPCIs, the equilibrium is the same as when both manufacturers sell the components to one TPCI.

When the manufacturers choose the strategy combination (d,e), the equilibrium payoffs are the same as when they choose (d,d). If manufacturer A chooses (d) and B chooses (e), then B's subsidiary at (0,1) is not provided A's component 1.

The above analysis and the previous propositions result in the following proposition about the equilibrium of the whole game.

Proposition 5 *The equilibria of the whole game are symmetric. If manufacturer A chooses an action, B's best response is to follow A's action.*

Proof. The equilibrium sets of strategy are (a,a), (b,b), (c,c), (d,d) and (e,e) because $\frac{1}{2}k < \Pi^{aa} < \Pi^{cc} = \Pi^{ee}$ and $\frac{1}{2}k < \Pi^{bb} < \Pi^{dd} < \Pi^{cc} = \Pi^{ee}$ from the propositions 1 to 4. ■

Note that though there are five equilibrium strategy combinations, the best outcomes to the manufacturers are achieved when they choose (c,c) or (e,e). Competition in the mixed system markets gives the manufacturers the highest profits.

1.5 When There Are Intra-firm Trades of Components

In the analysis up to now, the assumption of no resale was applied to all cases including the case where each manufacturer has a subsidiary at each point. It implies that the manufacturers recognize the buyers and prevent them from reselling. Suppose, for example, B cannot prevent the trade of components within vertical structure A (manufacturer A and A's two subsidiaries) and B's original system price is low relative to the sum of its component prices. Since B sells its components to vertical structure A's subsidiaries and its systems to the public, manufacturer A has opportunity for arbitrage by purchasing B's low-priced original systems, breaking them up into components, giving them to its subsidiaries, and making mixed systems at lower costs.

Likewise, TPCIs may have similar opportunity for arbitrage. Up to now, the TPCIs are assumed to be at either (0,1) or (1,0). However, it is also possible that some TPCIs purchase the components from both A and B and sell both mixed systems.[17] These TPCIs can be interpreted to have two branches at each of the points (0,1) and (1,0). Since these TPCIs can also purchase the original systems, they have opportunity for arbitrage.

This section analyzes the equilibrium when this arbitrage behavior is possible. There are three subcases: (1) when each manufacturer decides to establish a subsidiary at each point; (2) when the manufacturers decide to sell their components to any TPCIs who have two branches; and (3) when the manufacturers decide to sell their components to a TPCI who has two branches.

In any subcase, the arbitrage behavior places a constraint on the manufacturers' pricing. If there are no integration or dissolution costs, a system price should be equal to the sum of the component prices. Introduction of the integration and dissolution costs, however, limits the arbitrage behavior, relaxing the constraint on the manufacturers' pricing. As a result, a system's price has only to be in a range around the sum of the component prices. That is, a manufacturer can choose its system price in the range of [sum of the prices of components $- z^D$, sum of the prices of components $+ z^I$][18]. If the price of a system is lower than the sum of the prices of components minus z^D, component integrators will buy systems and break them up into components. If the price of a system is higher than the sum of the component prices plus z^I, component integrators

[17] In reality, many TPCIs sell various systems which include different brands of components.

[18] For a simpler notation, in this section z^I and z^D will be used instead of z_2^I and z_2^D, respectively.

will buy components to make systems at a lower price than the manufacturer.

Therefore, manufacturer A has the following profit maximization problem with two constraints:

$$\underset{P_{AA},P_{1A},P_{2A}}{Max} f^{A}\left(P_{AA},P_{1A},P_{2A};P_{BB},P_{1B},P_{2B},P_{AB},P_{BA}\right)=P_{AA}D_{AA}+P_{1A}D_{AB}+P_{2A}D_{BA}$$

$$s.t.\begin{cases} g_1^A=-P_{AA}+P_{1A}+P_{2A}-z^D\leq 0 \\ g_2^A=P_{AA}-P_{1A}-P_{2A}-z^I\leq 0\end{cases}.$$

Manufacturer B has a similar constrained profit maximization problem.

1.5.1 Competitive TPCIs or competitive subsidiaries

Let us consider the subcase of competitive TPCIs or competitive subsidiaries first. As in subsections 3.2 and 3.5, $P_{AB}=P_{1A}+P_{2B}+z_2^I$ and $P_{BA}=P_{1B}+P_{2A}+z_2^I$. The symmetric equilibrium is derived from the above two constrained profit maximization problems and the symmetry conditions. The following proposition summarizes the equilibrium.

Proposition 6 *When the manufacturers sell their components to competitive TPCIs or competitive subsidiaries with arbitrage constraints on their pricing, The constraints g_1^A and g_1^B bind if $2z^D+z^I<k$. In this case, $P_{AA}^*=P_{BB}^*=\frac{2k^2}{z^D+z^I+k}$ and $P_{1A}^*=P_{2A}^*=P_{1B}^*=P_{2B}^*=\frac{(z^D)^2+z^Dz^I+z^Dk+2k^2}{2(z^D+z^I+k)}$. If $k<2z^D+z^I$, the equilibrium is the same as in subsection 3.2, the case without the arbitrage constraints. The constraints g_2^A and g_2^B never bind.*

Proof. The Kuhn-Tucker conditions for the profit maximization problems should be satisfied simultaneously. In addition, in Nash equilibrium each player takes the rival's prices as given. Therefore, the symmetric Nash equilibrium[19] will satisfy one of the following:

$$\text{(i)} \bigtriangledown f^A(P_A^*;P_B^*)=0, \bigtriangledown f^B(P_B^*;P_A^*)=0 \text{ and } g_1^A(\cdot),g_2^A(\cdot),g_1^B(\cdot),g_2^B(\cdot)<0;$$

[19]From the symmetry assumption, the two manufacturers' decisions satisfy the same one of the conditions.

$$\text{(ii)} \bigtriangledown f^A(P_A^*; P_B^*) + \lambda_1^A \bigtriangledown g_1^A(P_A^*; P_B^*) = 0, \bigtriangledown f^B(P_B^*; P_A^*) + \lambda_1^B \bigtriangledown g_1^B(P_B^*; P_A^*) = 0;$$

$$\text{(iii)} \bigtriangledown f^A(P_A^*; P_B^*) + \lambda_2^A \bigtriangledown g_2^A(P_A^*; P_B^*) = 0, \bigtriangledown f^B(P_B^*; P_A^*) + \lambda_2^B \bigtriangledown g_2^B(P_B^*; P_A^*) = 0.$$

In case (i), the solutions $P_{AA}^* = P_{BB}^* = \frac{4k^2}{3k+z_i^I}$ and $P_{1A}^* = P_{2A}^* = P_{1B}^* = P_{2B}^* = \frac{11k^2-2z^I k-(z^I)^2}{4(3k+z^I)}$ are valid when $g_1^A(\cdot) = -P_{AA}^* + P_{1A}^* + P_{2A}^* - z^D < 0$, that is, $2z^D + z^I > k$. $g_2^A(\cdot) = P_{AA}^* - P_{1A}^* - P_{2A}^* - z^I = -\frac{(z^I+k)}{2}$ is always less than zero. Case (ii) produces the above equilibrium prices and the value of λ_1^A is $\frac{(k-2z^D-z^I)(k-z^D-z^I)}{4k^2}$. When $2z^D + z^I < k$, $\lambda_1^A > 0$. There is no valid solution in case (iii) because $\lambda_2^A = \frac{-2z^I-k}{4k}$ is always negative. ■

1.5.2 Monopolistic TPCI

When the manufacturers sell their components to a TPCI who has two branches, the TPCI has market power in both mixed system markets. This TPCI also has opportunity for arbitrage. If the component prices are too high, the TPCI will buy and dissolve systems to provide the components for its branches. The equilibrium is derived from the profit maximization problems of this TPCI and the manufacturers, and the symmetry conditions.

Proposition 7 *When the manufacturers sell their components to a monopolistic TPCI who has a branch at each point, g_1^A and g_1^B bind if $2z^D + z^I < k$. In this case, $P_{AA}^* = P_{BB}^* = \frac{3k^2}{z^D+z^I+2k}$, $P_{1A}^* = P_{2A}^* = P_{1B}^* = P_{2B}^* = \frac{(z^D)^2+z^D z^I+2z^D k+3k^2}{2(z^D+z^I+2k)}$ and $P_{AB}^* = P_{BA}^* = \frac{11k^2+5(z^D+z^I)k+2(z^D+z^I)^2}{3(z^D+z^I+2k)}$. If $k < 2z^D + z^I$, the equilibrium is the same as in Section 3, the case without the arbitrage constraint. The constraints g_2^A and g_2^B never bind.*

Proof. The equilibrium should satisfy the profit maximization conditions of the locally monopolistic TPCI in addition to the Kuhn-Tucker conditions for the manufacturers' profit maximization problems. Therefore, the symmetric Nash equilibrium will satisfy one of the following:

$$\text{(i)} \bigtriangledown f^A(\cdot) = 0, \bigtriangledown f^B(\cdot) = 0, g_1^A(\cdot), g_2^A(\cdot), g_1^B(\cdot), g_2^B(\cdot) < 0 and \bigtriangledown f^{AB}(\cdot) + \bigtriangledown f^{BA}(\cdot) = 0;$$

$$\text{(ii)} \bigtriangledown f^A(\cdot) + \lambda_1^A \bigtriangledown g_1^A(\cdot) = 0, \bigtriangledown f^B(\cdot) + \lambda_1^B \bigtriangledown g_1^B(\cdot) = 0 \text{ and } \bigtriangledown f^{AB}(\cdot) + \bigtriangledown f^{BA}(\cdot) = 0;$$

(iii) $\bigtriangledown f^A(\cdot) + \lambda_2^A \bigtriangledown g_2^A(\cdot) = 0, \bigtriangledown f^B(\cdot) + \lambda_2^B \bigtriangledown g_2^B(\cdot) = 0$ and $\bigtriangledown f^{AB}(\cdot) + \bigtriangledown f^{BA}(\cdot) = 0$.

In case (i), the solutions $P^*_{AA} = P^*_{BB} = \frac{6k^2}{5k+z^I}$, $P^*_{1A} = P^*_{2A} = P^*_{1B} = P^*_{2B} = \frac{17k^2-4z^Ik-(z^I)^2}{4(5k+z^I)}$ and $P^*_{AB} = P^*_{BA} = \frac{28k^2+7z^Ik+(z^I)^2}{3(5k+z^I)}$ are valid when $g_1^A(\cdot) = -P^*_{AA} + P^*_{1A} + P^*_{2A} - z^D < 0$, that is, $2z^D + z^I > k$. $g_2^A(\cdot) = P^*_{AA} - P^*_{1A} - P^*_{2A} - z^I = -\frac{(z^I+k)}{2}$ is always less than zero. Case (ii) produces the above solutions and the value of λ_1^A is $\frac{(k-2z^D-z^I)(k-z^D-z^I)}{9k^2}$. When $2z^D + z^I < k$, $\lambda_1^A > 0$. There is no valid solution in case (iii) because $\lambda_2^A = \frac{-(k+z^I)}{9k}$ is always negative. ■

1.5.3 Discussion

The equilibrium original system price decreases in the dissolution costs. The equilibrium is at the lower boundary of the arbitrage constraint on the system price. Thus, if the dissolution costs are higher, a manufacturer can cut its system price to a lower level. In other words, the dissolution costs act like a brake on the two manufacturers' price competition.

Also note that the equilibrium prices in the case with a monopolistic TPCI are lower than the prices in the case with competitive TPCIs as long as g_1^A and g_1^B bind. This is from the same logic that is in subsection 3.3. Competition between the manufacturers' original systems becomes fiercer as the locally monopolistic TPCIs' markets shrink.

Binding constraints are more preferable to the manufacturers than unconstrained profit maximization. When $2z^D + z^I < k$, the condition for the arbitrage constraint to bind, the manufacturers enjoy higher profits together with higher equilibrium original system prices. This advantage arises because the arbitrage limits competition between the manufacturers. Zero dissolution costs limit the competition between the manufacturers maximally, letting the equilibrium original system price be exactly twice the equilibrium component price. If the dissolution costs are very high, the constraint is too wide to limit the competition between the manufacturers.

1.6 Consumer Surplus and Social Welfare

This section compares consumer surplus and social welfare, the joint profits and consumer surplus, in each mixed system market structure.

In this model, C, the reservation price common to all the consumers distributed in a unit square, is the maximum value for consumer surplus or social welfare. Since a consumer buying one unit of system X_{ij} has a utility of $C - k(d_{1i} + d_{2j}) - P_{ij}$, consumer surplus decreases in transportation costs and system prices. Figure 1.5 shows consumer surplus under the five mixed system market structures. In this figure, the dissolution costs are assumed to be the same as the integration costs for a simpler calculation. The horizontal axis stands for the value of the integration costs as the ratio over k. The vertical axis represents the amount that is deducted from the maximum consumer surplus, C, also as the ratio over k.

The calculation of consumer surplus shows that competitive TPCIs give the least surplus to the consumers. This surprising result arises because price effects dominate the effects of transportation costs on consumer surplus. Though competitive TPCIs minimize the total transportation costs, the higher system prices thanks to the competition in the mixed system markets leave the least surplus to the consumers. Consumer surplus is highest when monopolistic subsidiaries produce mixed systems. Locally monopolistic TPCIs also give consumers higher surplus than competitive TPCIs. Likewise, intra-firm trades of components are bad news to consumers.

Consumer surplus increases in integration costs because higher integration costs bring fiercer competition between original systems and lower prices. In addition, as the integration costs increase and thus the mixed system markets shrink, the differences in the consumer surplus decrease.

Unlike consumer surplus, social welfare does not depend on the system prices. Social welfare in this model depends only on transportation, integration and dissolution costs. There is a trade-off between these factors. Higher market shares of mixed systems accompany higher integration costs, but also lower transportation costs to consumers. Figure 1.6 compares social welfare in the five mixed system market structures and the social planner's. In this figure also, the dissolution costs are assumed to be the same as the integration costs. The horizontal axis is the same as in Figure 1.5. The vertical axis represents the amount that is deducted from the maximum social welfare, C, as the ratio over k.

Figure 1.6 shows that competitive TPCIs produce social welfare closest to the social plan-

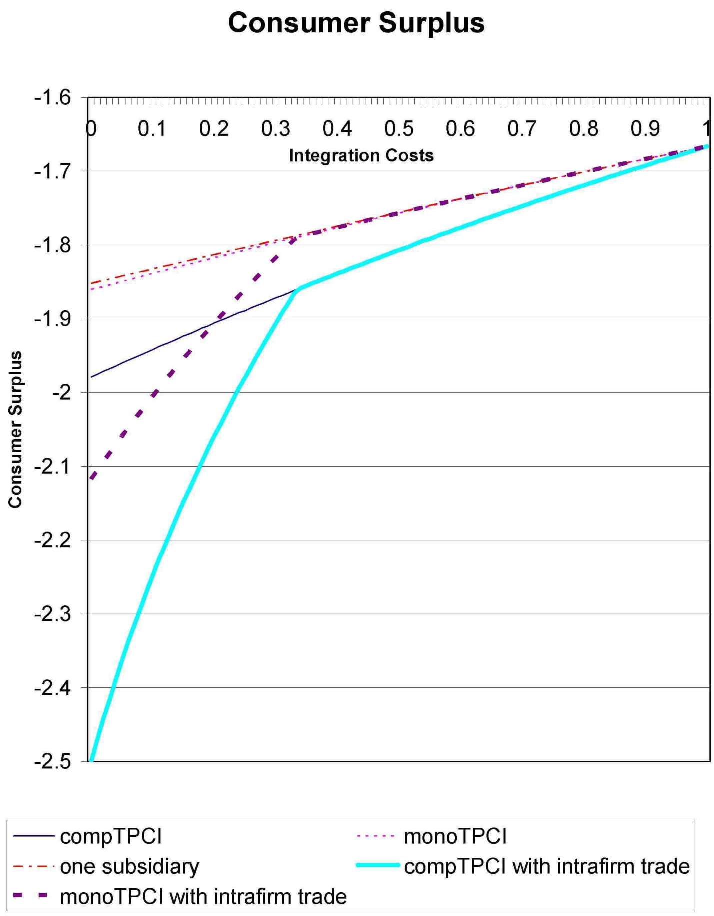

Figure 1.5: Comparison of Consumer Surplus under Each Mixed System Market Structure

ner's[20]. From the social planner's perspective, the only difference between the values of mixed and original systems is the integration costs. For example, when the integration costs are zero, the social planner assigns half of the market to the mixed systems. The competition between the original systems places a lower price to the original systems than their socially desirable level. When the manufacturers' original systems face less fierce competition, the original system price is closer to its socially desirable value. Since the competitive TPCIs give the manufacturers the least fierce competition, they also bring the highest social welfare.

[20]The social planner sets the market for a mixed system market equal to $\frac{(k-z^I)^2}{4k^2}$, producing social welfare equal to $C - [\frac{z^I}{2} + \frac{(z^I)^3}{6k^2} - \frac{(z^I)^2}{2k^2} + \frac{k}{2}]$.

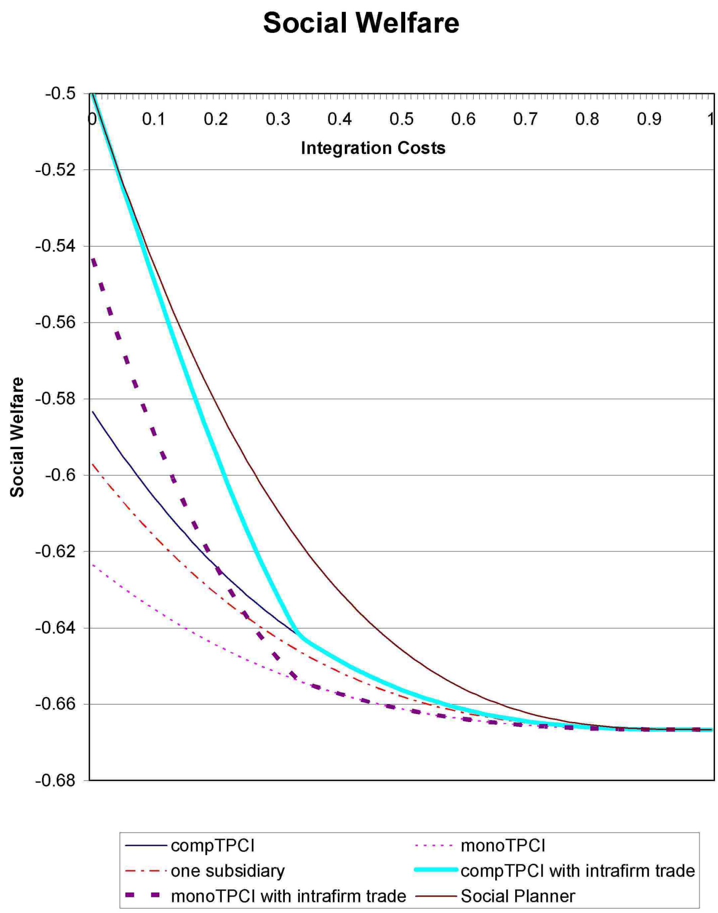

Figure 1.6: Comparison of Social Welfare under Each Mixed System Market Structure

1.7 Conclusion

The following intuitions can summarize the results of this chapter. Manufacturers can benefit from more competition in the mixed system markets, because it lessens the competition between their original systems. In addition, the lower the integration or dissolution costs are, the less fierce the competition between the manufacturers is.

These intuitions make us understand better why "plug and play" technology is valuable to the manufacturers. If all components are "plug and play", there are no integration or dissolution costs. If the manufacturers bring competition in the making of the mixed systems,[21] then they

[21] In this situation, the manufacturers' profits are maximized when they sell their components

will enjoy the minimum level of competition, or, the minimum level of freedom in their pricing. In other words, "plug and play" enables the manufacturers to commit not to use mixed bundling.

In the model of this chapter, the results for the cases with competitive TPCIs and with competitive subsidiaries are the same. This is because the competition in the mixed market is a Bertrand game. A modification of this aspect, such as a Cournot game instead, could shed more light on the relationship between the competition in the mixed system market and the competition in the original system market.

There are many other areas for extension or modification of the model in this chapter. Analysis of N manufacturers' case can be tried. Another interesting extension will introduce new players such as system makers who do not produce all the components. They may have incentives different from the manufacturers of all components or the pure TPCIs. In addition, their introduction will make a more realistic model.

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to consumers, competitive TPCIs or competitive subsidiaries.

Chapter 2

Upstream Manufacturers Selling Components and Bundles for System Markets

2.1 Introduction

This chapter extends the previous chapter's topic, the interaction between competitions in a system market. Competition often brings efficient resource allocation, maximizing social welfare. However, if there are several kinds of competition in a market and a certain competition can soften other kinds of competition, it is unclear which type of competition should be encouraged or not. The previous chapter finds that more competition in the mixed system markets lessens the competition between the duopolists' original systems. The more competition in the mixed system provision gives more profits to the duopolists but less surplus to the consumers.

This chapter extends the previous chapter's analysis, considering the structures of both downstream markets, not only for the mixed systems but also for the manufacturers' original systems. For this objective, the duopolistic manufacturers are assumed not to take part in the downstream markets themselves. Instead they decide the market structure for their original systems. If a manufacturer chooses a retailer to sell its original systems, then the retailer will be a local monopolist. If the manufacturer chooses to sell its bundles to any retailers who want to enter the market for its original systems, then the original system market will be competitive. As in the previous chapter, the two manufacturers' decisions of to whom to sell their components jointly determine the market structure for the mixed systems.

This chapter finds that locally monopolistic retailers bring higher profits to the manufacturers than competitive retailers do. Introduction of a retailer causes the manufacturer to raise its price. This manufacturer's profits will increase proportionally if every consumer has a unit demand and his/her reservation price is high enough. Duopolists competing over consumers located on a line also have this incentive. There are additional benefits to the duopolists from having their own monopolistic retailers, if they are competing over consumers on a sqare. First, the locally monopolistic retailers make the competition between the original systems less fierce. The markups on the bundle prices by the locally monopolistic retailers shorten the border between the original system markets. The shortened border enables the two duopolistic manufacturers keep higher prices. Second, the manufacturers' incentives to cut their bundle prices are fewer relative to their incentives to cut their component prices, because the manufacturers cannot take the full benefits from cutting their bundle prices.

A surprising result comes when a manufacturer chose a locally monopolistic retailer and its rival chose competitive retailers. In this situation, the manufacturer with a locally monopolistic retailer prices its bundle higher than the sum of its component prices. This manufacturer is not aggressive in bundle pricing, while its rival is aggressive because it does not lose the benefits from cutting its bundle price to anyone. These incentives are combined to induce the manufacturer with a locally monopolistic retailer to price its bundle high relative to its component prices, and its rival to price its bundle low relative to its component prices. The rival's bundle price is very close to or even lower than the price of its one component.

Section 2 presents the basic model. The equilibrium prices and profits under each downstream market structure are analyzed in section 3. Section 4 presents the equilibrium downstream market structure. Analyses of consumer surplus and social welfare are presented in Section 5. Section 6 concludes.

2.2 Model

The basic model is the same as in Chapter 1. A system is composed of two components, 1 and 2. Two manufacturers, A and B, are producing the components at zero marginal cost. The components are assumed to be compatible with the other manufacturer's matching components. Consequently, there are four possible options for the system, two original and two mixed systems; $X_{AA}, X_{BB}, X_{AB}, X_{BA}$. Unlike in Chapter 1, the two manufacturers do not sell their systems to consumers. Instead they choose the retailers who will sell their original systems to the consumers. As in Chapter 1, the manufacturers choose the mixed system makers to whom they sell their components.

Assumptions about consumers are the same as in the previous chapters. Consumers are uniformly distributed on the unit square (see Figure 2.1). Four systems are located at the corners. A consumer located at the point of coordinates (d_1, d_2) has an ideal component 1 that is d_1 away from manufacturer A's component 1 and an ideal component 2 that is d_2 away from A's component 2. Similarly, the distances between the consumer's ideal point and manufacturer B's components are $1 - d_1$ and $1 - d_2$, respectively. Every consumer is assumed to purchase at most one system.

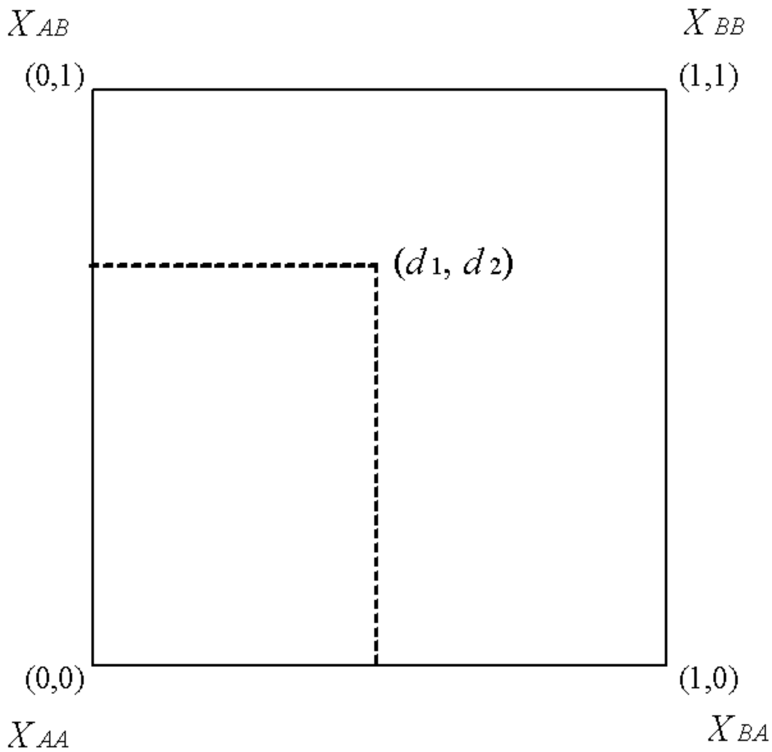

Figure 2.1: Locations of the Four Systems and Consumers on the Unit Square

A consumer buying one unit of system X_{ij} has a surplus of $C - k(d_{1i} + d_{2j}) - P_{ij}$, where C is the reservation price common to all the consumers and parameter k measures the degree of horizontal product differentiation among the goods. d_{1i} and d_{2j} are the distances of the consumer's ideal components 1 and 2 from system X_{ij} and P_{ij} is its price. C is assumed to be high enough for the whole market to be covered by any type of system makers.

To focus on the downstream market structure, consumers are not assumed to be able to integrate components into a system. Also for simplicity, the integration costs are assumed to be zero.[22] Since resale is not allowed, the assumption about the dissolution costs is not needed.

The whole game has three stages as in Chapter 1. In the first stage, manufacturers A and B simultaneously decide to whom to sell their components and bundles. If their decisions create local monopoly, they also decide, in this stage, the fixed fees that are charged to the locally monopolistic retailers and mixed system makers for the market power.[23] In the second stage, the two manufacturers decide their prices for the components and the bundles. Mixed system makers and retailers play a Bertrand game over a unit square in the last stage.

There are many potential mixed system makers and retailers of the original systems in the industry. Thus, in the first stage, each manufacturer has the following four options: (1) to sell its components to any mixed system makers and its bundles to any retailers; (2) to sell its components to any mixed system makers and its bundles to one retailer; (3) to sell its components to one mixed system maker for each X_{AB} and X_{BA} and its bundles to any retailers; (4) to sell its components to one mixed system maker for each X_{AB} and X_{BA} and its bundles to one retailer.

A manufacturer can decide the market structure for its original system. If a manufacturer sells its bundle to many retailers, they will have a Bertrand competition, pricing at the bundle price. Those retailers are called competitive retailers in this chapter. If, instead, a manufacturer sells its bundle to one retailer, it will be a local monopolist.

Unlike for the original system market, a manufacturer's unilateral decision cannot determine the market structure for the mixed systems. Both manufacturers' simultaneous decisions jointly determine the market structure. If both manufacturers sell their components to any mixed system

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[22]Even if it takes positive costs to integrate mixed systems, it does not change the qualitative aspects of the results. The rankings of the payoffs to the manufacturers corresponding to the downstream market structures do not change in the integration costs.

[23]Since a mixed system needs the two manufacturers' components, charging fees to a locally monopolistic mixed system maker becomes a matter of bargaining. This chapter assumes for simplicity that the same fee is charged to a mixed system maker by the two manufacturers. As will be seen below, a locally monopolistic mixed system maker' profits, and so the total fixed fees charged to it, are very small. Thus, any changes in the solution to the bargaining game does not affect the equilibrium of the whole game.

makers, the mixed system makers will price their systems at marginal costs that are the sum of the component prices. These mixed system makers are called competitive mixed system makers. If the manufacturers decide to sell their components to only one and the same maker for each X_{AB} and X_{BA}, the mixed system makers will have local monopoly power.[24] They are called locally monopolistic mixed system makers.

2.3 Equilibrium Prices and Profits

This section presents the equilibrium prices and profits in the various downstream market structures that result from the two manufacturers' decisions in the first stage.[25] Since each manufacturer has four options, there are sixteen continuation games possible. However, several of these subgames share the same equilibrium. For example, if a manufacturer sells its components to monopolistic mixed-system makers while the other manufacturer sells to any mixed-system makers, then the payoffs will be the same as when both manufacturers sell their components to monopolistic mixed-system makers. This is because no one can produce mixed systems with only one manufacturer's components. Thus, the results from (a, c) are the same as (c, c) and the results from (b, d) are the same as (d, d). In addition, the results from (b, c), (d, a) and (d, c) are the same. Therefore, this section will focus the six subgames left which are summarized in the following table. Payoffs pair $(v)^{-1}$ is the payoffs pair (v) with manufacturer A and B's payoffs interchanged.

2.3.1 Competitive Mixed System Makers and Competitive Retailers

Let us begin with the case when both manufacturers sell their components to many mixed system makers and their bundles to any retailers in the first stage. Since every consumer's reservation price, C, is assumed to be high enough for the whole market to be covered, a consumer at (d_1, d_2)

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[24]If the manufacturers decide to sell their components to different mixed system makers, no system maker will be able to produce mixed systems, resulting in competition between the two original systems. As stated in Chapter 2, these cases make the same result as in Matutes and Regibeau (1988) and are not the focus of this paper.

[25]All the equilibrium prices, profits and demands are summarized in Appendix B.

		Manufacturer B			
		a) comp. mixed comp. retailer	b) comp. mixed mono. retailer	c) mono. mixed comp. retailer	d) mono. mixed mono. retailer
A	a)	(i)	(v)	(iii)	(vi)
	b)	$(\text{v})^{-1}$	(ii)	(vi)	(iv)
	c)	(iii)	$(\text{vi})^{-1}$	(iii)	(vi)
	d)	$(\text{vi})^{-1}$	(iv)	$(\text{vi})^{-1}$	(iv)

Table 2.1: Subgames

will purchase system X_{AA} when the following inequalities hold:

$$P_{AA} + k(d_1 + d_2) \leq P_{AB} + k(d_1 + 1 - d_2);$$

$$P_{AA} + k(d_1 + d_2) \leq P_{BA} + k(1 - d_1 + d_2);$$

$$\text{and } P_{AA} + k(d_1 + d_2) \leq P_{BB} + k(1 - d_1 + 1 - d_2).$$

P_{ij} is the price for system X_{ij}. The demand functions are obtained from those inequalities. $D_{AA} = (\frac{k+P_{AB}-P_{AA}}{2k}) \cdot (\frac{k+P_{BA}-P_{AA}}{2k}) - \frac{1}{2}[(\frac{k+P_{BA}-P_{AA}}{2k}) - (\frac{k-P_{AB}+P_{BB}}{2k})] \cdot [(\frac{k+P_{AB}-P_{AA}}{2k}) - (\frac{k-P_{BA}+P_{BB}}{2k})]$; $D_{BB} = (1 - \frac{k-P_{AB}+P_{BB}}{2k}) \cdot (1 - \frac{k-P_{BA}+P_{BB}}{2k}) - \frac{1}{2}[(\frac{k+P_{BA}-P_{AA}}{2k}) - (\frac{k-P_{AB}+P_{BB}}{2k})] \cdot [(\frac{k+P_{AB}-P_{AA}}{2k}) - (\frac{k-P_{BA}+P_{BB}}{2k})]$; $D_{AB} = (1 - \frac{k+P_{AB}-P_{AA}}{2k}) \cdot (\frac{k-P_{AB}+P_{BB}}{2k})$; $D_{BA} = (1 - \frac{k+P_{BA}-P_{AA}}{2k}) \cdot (\frac{k-P_{BA}+P_{BB}}{2k})$. (See Figure 2.2.) Since the competitive mixed system makers and retailers price at their marginal costs, $P_{AA} = R_A$; $P_{BB} = R_B$; $P_{AB} = P_{1A} + P_{2B}$; $P_{BA} = P_{1B} + P_{2A}$, where R_i is manufacturer i's bundle price and P_{1i} and P_{2i} are the prices for manufacturer i's components 1 and 2, respectively.

From this reasoning, the equilibrium system prices and profits can be obtained from the two manufacturers' profit maximization problems. Manufacturer A's profit maximization problem is the following:

$$\underset{R_A, P_{1A}, P_{2A}}{Max} f^A (R_A, P_{1A}, P_{2A}; P_{-A}) = R_A D_{AA} + P_{1A} D_{AB} + P_{2A} D_{BA}.$$

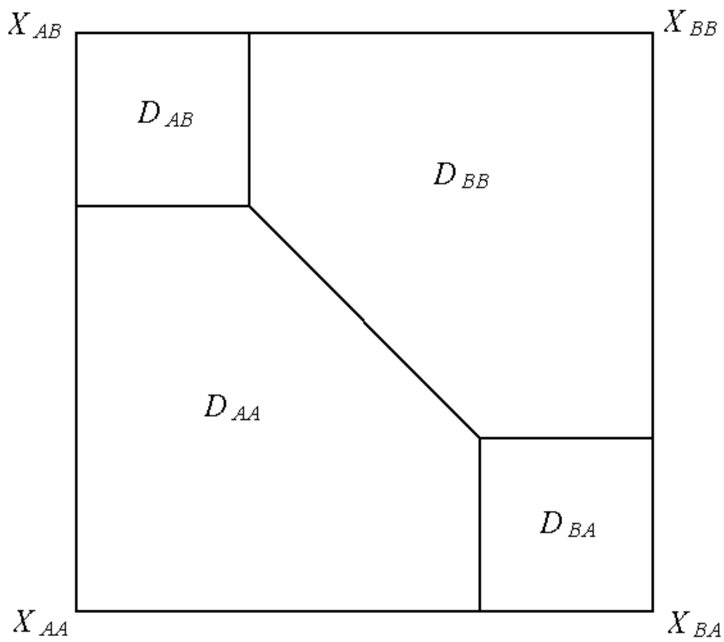

Figure 2.2: Demands for the Systems

Manufacturer B has a similar profit maximization problem.

The resulting equilibrium prices $P_{AA} = P_{BB} = R_A = R_B = 1.333k$ and $P_{1A} = P_{2A} = P_{1B} = P_{2B} = 0.917k$. The profits for the manufacturers $\Pi_{upA} = \Pi_{upB} = 0.698k$ and the demand for mixed systems $D_{AB} = D_{BA} = 0.0625$. The results are the same as in Subsection 1.3.2 of Chapter 1. In that subsection, the two manufacturers sell their systems directly to consumers, selling their components to competitive mixed system makers. Since the competitive retailers' prices are the same as the manufacturers' bundle prices, the results are the same.

2.3.2 Competitive Mixed System Makers and Monopolistic Retailers

This subsection examines the case when each manufacturer sells its components to many mixed system makers and its bundles to one retailer in the first stage. Since the consumers observe only the system prices, the demand functions are the same as in the previous subsection. However, P_{AA} and P_{BB} are decided differently. In the last stage, the two locally monopolistic retailers decide their prices, maximizing their profits, $(P_{AA} - R_A)D_{AA}$ and $(P_{BB} - R_B)D_{BB}$, respectively. Considering the effects on the system prices, the two manufacturers decide their prices in the second stage.

Since the results from solving the last stage's profit maximization problems are too complex to be applied to the equilibrium calculation in the second stage, this essay uses the Implicit Function Theorem.[26] The resulting equilibrium prices $P_{AA} = P_{BB} = 3.111k$. $R_A = R_B = 2.333k$ and $P_{1A} = P_{2A} = P_{1B} = P_{2B} = 1.722k$. The profits for the manufacturers $\Pi_{upA} = \Pi_{upB} = 1.290k$ and for the locally monopolistic retailers $\Pi_{AA} = \Pi_{BB} = 0.302k$. The demand for mixed systems $D_{AB} = D_{BA} = 0.111$.

Compared with the results in the previous subsection, monopolistic retailers give higher profits to the manufacturers than competitive retailers. This advantage is from the less fierce competition between the manufacturers' bundles. Because of the local monopolists' markups, the original system markets shrink, shortening the border between the two markets. Moreover, a manufacturer can not receive the full benefits from cutting its bundle price because its monopolistic retailer will take some parts of the benefits from changing the retail price of the bundle. With the fewer incentives to cut the bundle price, the two manufacturers face a less fierce competition and can charge higher prices. As a result, mixed systems' market share increases to 22% from the 13% that results in the case of competitive mixed system makers and competitive retailers.

2.3.3 Monopolistic Mixed System Makers and Competitive Retailers

If the manufacturers' decisions in the first stage are to sell the components to only one and the same mixed system maker for each X_{AB} and X_{BA}, the system makers will work as local monopolists. They will choose their mixed system prices to maximize their profits, $(P_{ij} - P_{1i} - P_{2j})D_{ij}$, in the third stage. Considering these mixed system prices, the two manufacturers decide their prices in the second stage. The manufacturers' profit functions are the same as in subsection 3.1.

This case shares the same results with Subsection 1.3.3 in Chapter 1 because the competitive retailers' prices are the same as the manufacturers' bundle prices. From the profit maximization problems of the mixed system makers and the manufacturers, $P_{AA} = P_{BB} = R_A = R_B = 1.2k$,

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[26]For a detailed explanation, see Appendix A.1.

$P_{1A} = P_{2A} = P_{1B} = P_{2B} = 0.85k$ and $P_{AB} = P_{BA} = 1.867k$. The profits for the manufacturers $\Pi_{upA} = \Pi_{upB} = 0.614k$ and for the locally monopolistic mixed system makers $\Pi_{AB} = \Pi_{BA} = 0.005k$. The demand for the mixed systems $D_{AB} = D_{BA} = 0.028$.

2.3.4 Monopolistic Mixed System Makers and Monopolistic Retailers

With all the four systems sold by local monopolists, the system prices P_{ij} are decided to maximize $(P_{ij} - P_{1i} - P_{2j})D_{ij}$ and P_{ii} to maximize $(P_{ii} - R_i)D_{ii}$ in the last stage. Considering the effects on these prices, the two manufacturers decide their prices in the second stage.

With the same method as in Subsection 2.3.2, the resulting equilibrium prices $P_{AA} = P_{BB} = 3.050k$. $R_A = R_B = 2.189k$ and $P_{1A} = P_{2A} = P_{1B} = P_{2B} = 1.629k$. The profits for the manufacturers $\Pi_{upA} = \Pi_{upB} = 1.169k$, for the locally monopolistic retailers $\Pi_{AA} = \Pi_{BB} = 0.371k$ and for the locally monopolistic mixed system makers $\Pi_{AB} = \Pi_{AB} = 0.018k$. The demand for mixed systems $D_{AB} = D_{BA} = 0.07$.

Monopolistic retailers give higher profits to the manufacturers than competitive retailers as in Subsection 2.3.2. However, this advantage created by the monopolistic retailers is reduced by the disadvantage created by the monopolistic mixed system makers. This disadvantage is similar to that in Subsection 1.3.3 in the previous chapter. The locally monopolistic mixed system makers' markups make the mixed system markets shrink, lengthening the border between the markets for the manufacturers' original systems. The manufacturers become more aggressive in their pricing, resulting in more fierce competition and lower profits.

2.3.5 Competitive Mixed System Makers and Asymmetric Retailers

This subsection analyzes the case where a manufacturer, say manufacturer A, sells its bundles to a monopolistic retailer and its components to competitive mixed system makers, while the other manufacturer, say manufacturer B, sells its bundles and components to competitive retailers and mixed system makers. In this situation, $P_{BB} = R_B$; $P_{AB} = P_{1A} + P_{2B}$; $P_{BA} = P_{1B} + P_{2A}$ but P_{AA} is decided to maximize $(P_{AA} - R_A)D_{AA}$ in the last stage. Considering the effects on these prices, the two manufacturers decide their prices in the second stage.

Since there are too many equations to solve, a numerical analysis is used to obtain the equilibrium prices.[27] The resulting equilibrium price $P_{AA} = 2.357k$, $P_{BB} = R_B = 2.198k$. $R_A = 1.561k$. $P_{AB} = P_{AB} = 2.720k$ from $P_{1A} = P_{2A} = 0.601k$ and $P_{1B} = P_{2B} = 2.119k$. The profits for the manufacturers $\Pi_{upA} = 0.664k$ and $\Pi_{upB} = 1.380k$ and for the locally monopolistic retailer of X_{AA}, $\Pi_{AA} = 0.292k$. The demands for mixed systems $D_{AB} = D_{BA} = 0.076$, for system X_{AA}, $D_{AA} = 0.367$ and for system X_{BB}, $D_{BB} = 0.481$.

It is surprising that manufacturer A's bundle price, $R_A = 1.561k$ is higher than the sum of its component prices $P_{1A} + P_{2A} = 1.202k$.[28] Manufacturer A is not aggressive in bundle pricing because it can not take the full benefits from cutting its bundle price. On the contrary, manufacturer B is aggressive in its bundle pricing because it does not lose the benefits from cutting its bundle price to anyone. These incentives are combined to result in A's bundle price high relative to its component prices and B's bundle price low relative to its component prices. Manufacturer B's bundle price, $R_B = 2.198k$, is very close to the price of its one component, $P_{1B} = P_{2B} = 2.119k$.

2.3.6 Monopolistic Mixed System Makers and Asymmetric Retailers

This subsection analyzes the case where all players in the last stage are local monopolists except the retailers of X_{BB}. Manufacturer A sells its bundles to a monopolistic retailer and its components to monopolistic mixed system makers, while manufacturer B sells its bundles to competitive retailers and its components to monopolistic mixed system makers. Now, P_{ij} are decided to maximize $(P_{ij} - P_{1i} - P_{2j})D_{ij}$ and P_{AA} to maximize $(P_{AA} - R_A)D_{AA}$. But, $P_{BB} = R_B$. Considering the effects on these prices, the two manufacturers decide their prices in the second stage.

A numerical analysis is used to obtain the equilibrium prices.[29] The resulting equilibrium

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[27] For a detailed explanation, see Appendix C.

[28] It should be noted that manufacturer A receives the fixed fees in addition to the bundle price.

[29] Calculation of the equilibrium also used the method of applying the Implicit Function Theorem. For a detailed explanation, see Appendix C.

price $P_{AA} = 2.301k$, $P_{BB} = R_B = 2.105k$. $R_A = 1.448k$. $P_{AB} = P_{AB} = 2.806k$. $P_{1A} = P_{2A} = 0.509k$ and $P_{1B} = P_{2B} = 2.111k$. The profits for the manufacturers $\Pi_{upA} = 0.594k$ and $\Pi_{upB} = 1.296k$ and for the locally monopolistic retailer of X_{AA}, $\Pi_{AA} = 0.328k$. The profits for the monopolistic mixed system makers, $\Pi_{AB} = \Pi_{BA} = 0.007k$. The demand for mixed systems $D_{AB} = D_{BA} = 0.037$, for system X_{AA}, $D_{AA} = 0.385$ and for system X_{BB}, $D_{BB} = 0.542$.

The results in this case are similar to those in the previous subsection as the results in subsections 3.3 and 3.4 are similar to those in 3.1 and 3.2, respectively. Monopolistic mixed system makers bring more fierce competition between the original systems. The equilibrium prices, profits and demands for mixed systems are lower than with competitive mixed system makers. As in the previous subsection, manufacturer A's bundle price, $R_A = 1.448k$ is higher than the sum of its component prices, $P_{1A} + P_{2A} = 1.018k$. Note that by the introduction of the monopolistic mixed system makers, manufacturer B's market share increases from 48.1% to 54.2%. This is because manufacturer B, with its competitive retailers, can control more easily the consumer price of its original system.

Another interesting result is that manufacturer B's bundle price, $R_B = 2.105k$ is lower than the price of its one component, $P_{1B} = P_{2B} = 2.111k$. It can be an explanation for this surprising result that now manufacturer B is more aggressive in its bundle pricing than with competitive mixed system makers, because some parts of the benefits from cutting its component prices are lost to the locally monopolistic mixed system makers. Compared with the case of competitive mixed system makers, manufacturer B's bundle price is now 4.2% lower, while its component price is 0.4% lower.

However, manufacturer A is still aggressive in its component pricing. Its component price decreases 15.3%, while its bundle price decreases 7.2%. Though manufacturer A loses some parts of the benefits from cutting its component prices like manufacturer B, using component prices to attack B's market is more attractive to A. This is from the asymmetric situation. With higher market share of X_{BB}, the markets for X_{AB} and X_{BA} are rectangles not squares. If manufacturer A cuts its component price, its effect is larger on D_{BB} than on D_{AA}. Since the introduction of the monopolistic mixed system makers increases manufacturer B's market share and manfuacturer B is more aggressive in bundle pricing, the difference in the effects on D_{BB} and D_{AA} is larger, inducing manufacturer A more aggressive in its component pricing.

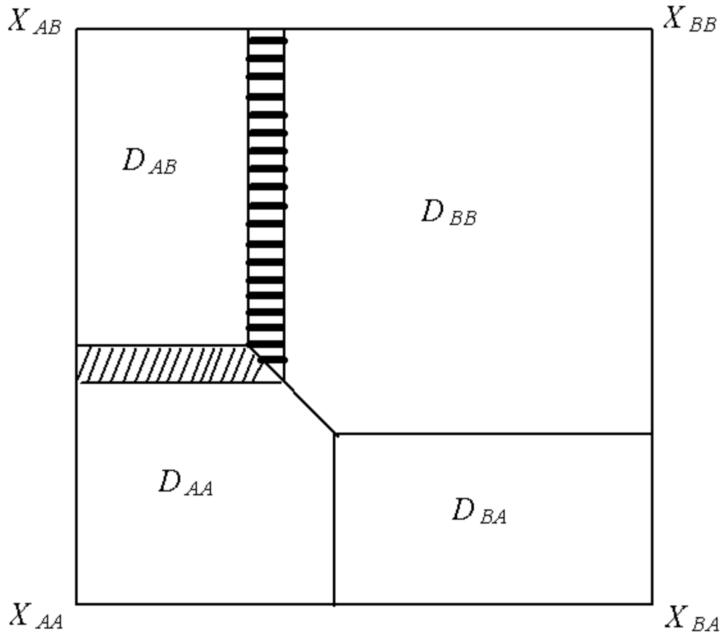

Figure 2.3: Effects of a Decrease in Manufacturer A's Component 1

2.4 Equilibrium Downstream Market Structure

In this section, we consider the two manufacturers' decisions in the first stage. From the analysis up to now, we can fill out the payoff matrix which the two manufacturers face in the first stage. Each payoffs are not only the manufacturer's profits but also include the profits of the monopolistic retailers, if any, and half of the profits of the monopolistic mixed system makers, if any. Each number should be read as a ratio over k.

The pure strategy Nash equilibria, (b,b) and (d,d), can be easily found from the above payoff matrix. The equilibrium downstream market structure requires locally monopolistic retailers whether the mixed system makers are competitive or locally monopolistic. Note that (b,b) is the unique Nash equilibrium that survives the iterated deletion of weakly dominated strategies. (b,b) is also the unique Pareto dominant equilibrium.

		Manufacturer B			
		a) comp. mixed comp. retailer	b) comp. mixed mono. retailer	c) mono. mixed comp. retailer	d) mono. mixed mono. retailer
A	a)	$(0.698, 0.698)$	$(1.380, 0.956)$	$(0.619, 0.619)$	$(1.303, 0.929)$
	b)	$(0.956, 1.380)$	$(1.593, 1.593)$	$(0.929, 1.303)$	$(1.558, 1.558)$
	c)	$(0.619, 0.619)$	$(1.303, 0.929)$	$(0.619, 0.619)$	$(1.303, 0.929)$
	d)	$(0.929, 1.303)$	$(1.558, 1.558)$	$(0.929, 1.303)$	$(1.558, 1.558)$

Table 2.2: Matrix of Payoffs to the Manufacturers

2.5 Consumer Surplus and Social Welfare

This section compares consumer surplus and social welfare, the joint profits and consumer surplus, in each downstream market structure. The table below summarizes the consumer surplus and the social welfare in the six cases of downstream market structure and social planner's.

Downstream Market Structures	CS	SW
Competitive Mixed and Competitive Retailers	$C - 1.979k$	$C - 0.583k$
Competitive Mixed and Monopolistic Retailers	$C - 3.728k$	$C - 0.543k$
Monopolistic Mixed and Competitive Retailers	$C - 1.860k$	$C - 0.623k$
Monopolistic Mixed and Monopolistic Retailers	$C - 3.692k$	$C - 0.576k$
Competitive Mixed and Asymmetric Retailers	$C - 2.914k$	$C - 0.578k$
Monopolistic Mixed and Asymmetric Retailers	$C - 2.857k$	$C - 0.625k$
Social Planner	-	$C - 0.5k$

Table 2.3: Consumer Surplus and Social Welfare in Each Downstream Market Structure

In this model, C, the reservation price common to all the consumers distributed in a unit square, is the maximum value for consumer surplus or social welfare. Since a consumer buying one unit of system X_{ij} has a utility of $C - k(d_{1i} + d_{2j}) - P_{ij}$, consumer surplus decreases in transportation costs and system prices. Consumer surplus is the lowest when the mixed systems are provided competitively and the retailers are locally monopolistic. This is because in this case the two manufacturers can charge the highest prices. For a similar reason, consumer surplus is the highest when the mixed system providers are locally monopolistic and the original system retailers are competitive.

Unlike consumer surplus, social welfare does not depend on the system prices. Social welfare in this model depends only on transportation costs. To minimize these transportation costs, the social planner assigns a quarter of the market to each of the four systems. From the perspective of the social planner, all the four systems are equally valuable. The competition between the bundles places lower prices on the bundles than their socially desirable level. When the manufacturers' bundles face less fierce competition, the bundle price is closer to its socially desirable level. Since the competitive mixed system makers and monopolistic retailers make the competition least fierce, they also bring the highest social welfare.

Note that asymmetric retailers bring lower social welfare even with higher mixed system market shares. Monopolistic mixed system makers and asymmetric retailers result in 7.4% mixed system market share, while monopolistic mixed system makers and competitive retailers result in 5.6% mixed system market share. However, asymmetric retailers with monopolistic mixed system makers bring the lowest social welfare. As stated earlier, the markets for the mixed systems are rectangular. With the linear transportation costs, rectangles are less efficient than squares.

2.6 Conclusion

The results of this chapter can be summarized by the intuition that duopolistic manufacturers can benefit from locally monopolistic retailers of their original systems, because the monopolistic retailers lessen the competition between their original systems.

A crucially important assumption behind these results is that the reservation price common to all the consumers is high enough for the whole market to be covered. It can be a topic for further research to analyze the equilibrium in the cases where the reservation price is not high enough.

There are more areas for modification or extension of the model. A modification of the model by introducing a Cournot game in the downstream markets will be interesting. A more realistic model will introduce integration costs for the mixed system makers and resale of the components.

Chapter 3

Strategic Abandoning of Market Power in System Markets

3.1 Introduction

Creating and defending market power is an important business strategy. This chapter finds, however, that in system markets, it may be profitable for a duopolist to give up its market position in one component market.

To show this strategic abandoning of market power, this chapter models competition between duopolistic manufacturers who produce two complementary components, hardware and software, with many potential hardware providers.[30] In this situation, an integrated manufacturer may want to abandon its duopolistic position in hardware market if this leads new entrants to hardware market to adopt its software, and the loss from giving up the duopolistic position in the hardware market is less than the gains from the increased market share for software. When the potential hardware providers are infinitely many, the integrated manufacturer becomes virtually disintegrated.

Though both the duopolists may want to choose this strategy, it is also possible that the best response to the rival's strategic abandoning of the hardware market is to keep the duopolistic position in both component markets. This is because when the duopolists both give up the hardware market, their software market shares remain the same as if they kept their duopolistic positions in both component markets. If the costs for making their software compatible with the new entrants' hardware are high, the equilibrium is asymmetric.

The manufacturer's incentive to abandon market power can help us to better understand the current horizontal competition model in the computer industry. Competition is between component manufacturers under this horizontal model, while companies make the vast majority of components in-house and sell a complete package to the customer under the traditional vertical integration

[30]The two components are the same in every aspect except that there are many potential providers of one component. Hardware is picked as that component because many hardware providers reflect the actual market structure.

model.[31] It is said that the winners of the horizontal model are the manfuacturers that have a large, and usually dominant, market share within a horizontal layer. For example, Microsoft (MS) is the winner in the operating system layer. According to the findings in this chapter, however, its success depends on the existence of many hardware providers who adopt MS operating system. This research suggests that if MS uses its market power in the OS market to enter and dominate the hardware market, its almost monopolistic status in the OS market could be damaged.[32]

Another interesting question is related to Apple. It cannot be included in the horizontal competition model because it provides most components in house that are not compatible with other companies' components. Considering the dominant status of MS operating systems and IBM compatible computer platforms, it has been questioned why Apple has survived so long. The asymmetric equilibrium found in this chapter can provide an answer to this question. Apple's incompatible systems may be its best strategy against its rivals, MS and many IBM compatible computer platform makers. On the other hand, in this asymmetric equilibrium, MS does not want to enter the hardware market because its entrance may take away its dominant status in the software market.

Section 2 reviews closely related literature. The basic model is presented in Section 3. Section 4 analyzes the equilibrium when the reservation price common to all the consumers is high. Comparative statics are in Section 5. Section 6 suggests some conclusions.

3.2 Literature Review

The most closely related literature with this chapter is Matutes and Regibeau (1988). The model in this chapter is a modified version of their model. Following them, this chapter explicitly modeled

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[31] Yoffie (1997) and Andrew Grove (1993), CEO of Intel, argued that the traditional vertical integration adopted by manufacturers has been replaced by the horizontal model in the computer industry. For related figures, see Appendix D.

[32] Microsoft has been blamed for using its market power in the OS market to enter and dominate other markets for word processing or spread sheet programs. Since hardware also has complementarity with software, it is puzzling why MS does not enter the hardware market.

a system as a set of components instead of treating it as a single good as in Katz and Shapiro (1985) or Farrell and Saloner (1985). Since Matutes and Regibeau's focus was to examine two manufacturers' incentives to produce products compatible with each other, they did not tackle explicitly the issue of component competition versus system competition. In addition, they cannot explain the different structures of the component markets. There is no asymmetric equilibrium of a system provider versus component providers in their model.

Farrell, Monroe and Saloner (1998)'s focus is similar to this chapter's. However, they did not explicitly model the choice of the competition style and so their findings are about biases towards component competition or system competition. In addition, their model does not have an asymmetric equilibrium. They just pointed out that the Apple personal computer was an exception to the general trend towards component competition.

Conner (1995) shares similar insight with this chapter. She examined an innovator's best strategy when there are network externalities. In her model, an innovator invents a technology and then is faced with the decision of how to commercialize it. The innovator may choose either to be the sole seller of the product based on its new technology, or to share that technology with another manufacturer(s) that is invited to produce a clone of the innovator's product. She suggests the innovator may choose to encourage clones of its product when a network externality is present. Though the basic insight is similar to this chapter's, this chapter analyzes the issue in the system market, and thus, the manufacturers have different incentives to give up their market positions. Moreover, in her model, clone products should be modeled to be inferior compared to the original in order for the cloning strategy to be profitable.

Farrell and Gallini (1988) analyze the same issue as Conner (1995), that is, the new product monopolist's incentive to license its technology, although they are different in spirit. When consumers incur setup costs, the monopolist may face "a dynamic consistency problem: the monopolist cannot guarantee low future prices once customers have incurred those costs." Then, second-sourcing can be used as a way to make a commitment to competition in the future. "The technology is given away but with a lag," while the technology is given away but with a deterioration in Conner (1995). As is the case with Conner's model, this model cannot be directly applied to the case of duopolists. However, incorporating the dynamic consistency problem into the duopolists' competition in system markets will be an interesting research topic.

Nalebuff (2000) uses a model similar to this chapter, to show a contrary insight: a firm that sells a bundle of complementary products will have a substantial advantage over rivals who sell the component products individually. However, his model cannot explain why MS does not enter the hardware market, even though hardware also has complementarity with software. A combined model of Nalebuff (2000) and this chapter may explain that a duopolist will benefit by bundling a subset of the components with the help of many providers of the component excluded from the bundle.

3.3 Model

A system is composed of two components, hardware and software. Each component is produced at zero marginal cost (MC), and there are no economies of scope. Though there are infinitely many potential hardware manufacturers along the line [0,1],[33] only two manufacturers, A and B, can produce both the components. Since an incompatible hardware is useless to the consumer, the two manufacturers can determine the market structure.

Consumers are uniformly distributed on the unit square (see Figure 3.1), where manufacturer A is located at the origin, while manufacturer B is located at (1,1). Every consumer can mix and match any components costlessly, only if they are compatible. A consumer located at (d_1, d_2) has his/her ideal first component that is d_1 away from manufacturer A's first component and his/her ideal second component that is d_2 away from A's second component. Similarly, the distances between the consumer's preferred point and manufacturer B's components are $1 - d_1$ and $1 - d_2$,

[33]Another possible interpretation is assuming that the two incumbent manufacturers can publicize their hardware technology, instead of assuming many potential hardware manufacturers. If any manufacturer makes public its hardware technology to make its own clones, new entrants may enter the hardware market and decide their location at any point between [0,1]. It can be thought of as a modified extension of Conner (1995)'s model to the case of duopolists.

respectively.

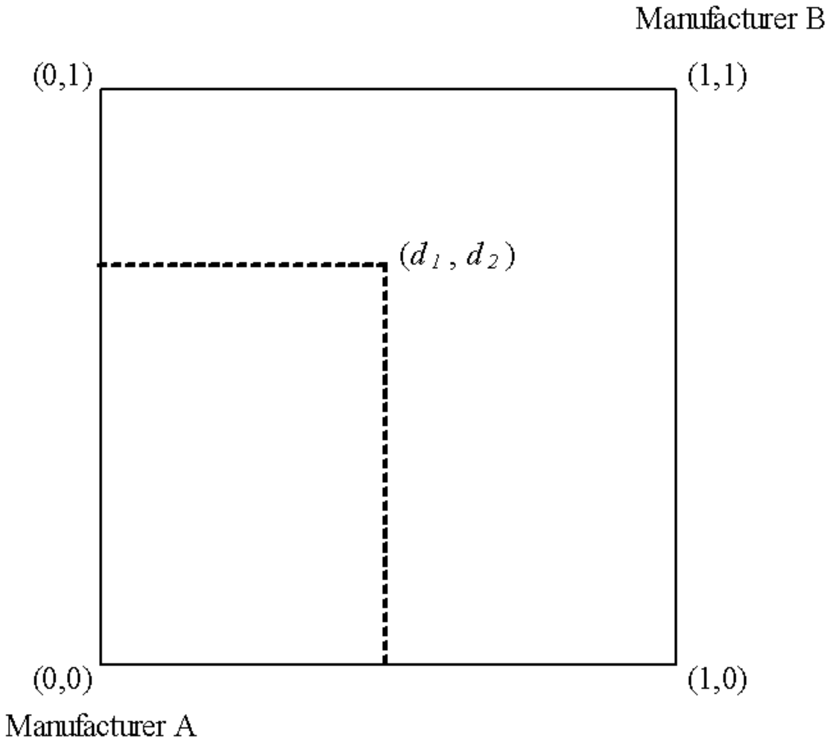

Figure 3.1: Locations of Manufacturers and Consumers on the Unit Square

A consumer buying one unit of system X_{ij} has a surplus of $C - k(d_{1i} + d_{2j}) - P_{ij}$, where C is the reservation price common to all the consumers and parameter k measures the degree of horizontal product differentiation between the two manufacturers' goods. d_{ij} is the distance between the consumer's ideal i^{th} component and firm j's. P_{ij} is the total price of the system composed of component 1 by firm i and component 2 by firm j. Each consumer buys the two components in the fixed proportion of one unit of good 1 and each unit of good 2. Every consumer purchases at most one unit of the system.

The whole game is a three-stage game. In the first stage of the game, each manufacturer decides whether to be the producer of its own proprietary systems or the provider of software compatible with every hardware. In the following stage, each manufacturer announce its price. If no manufacturer decided to make its software compatible, the game ends. If any manufacturer chose to provide compatible software, then there will be a Bertrand game among new entrants in the third stage.

It is costly to make software to be compatible with hardware. This model assumes that the incumbent manufacturer pays fixed costs, F, to make their software compatible with the new entrants to the hardware market. The new entrants to the hardware market are ready to produce their hardware, without any additional costs.[34]

3.4 Equilibrium When C Is High

The equilibrium depends on the level of the reservation price C relative to the product differentiation parameter k. This section considers the case when C is big enough for the whole market to be covered.

3.4.1 Equilibrium Prices and Profits When Both Manufacturers Sell Incompatible Systems

Let's first consider the case when the two manufacturers sell incompatible systems.[35] A consumer located at (d_1, d_2) will purchase the system from manufacturer A rather than from manufacturer B if $P_A + k(d_1 + d_2) P_B + k(2 - d_2)$, where P_i is the price of manufacturer i's system. For $P_A \geq P_B$, the manufacturers' profits are:

$$\Pi_A = \frac{1}{2} P_A \cdot [1 + \frac{P_B - P_A}{2k}]^2,$$

$$\Pi_B = P_B \cdot [1 - \frac{1}{2}(1 + \frac{P_B - P_A}{2k})^2].$$

Maximizing profits with respect to P_A and P_B respectively yields $P_i^* = k$, and thus $\Pi_i = \frac{1}{2}k$. The two manufacturers have the same market share of $\frac{1}{2}$. (See Figure 3.2.) This is valid

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[34]If some costs are assumed for the entrance to the hardware market, the number of entrants will be limited. Though this is a more realistic assumption, infinitely many hardware providers were assumed because both may reach similar results and infinitely many hardware providers make the equilibrium calculation much simpler.

[35]It is exactly the same as the " direct competitors' case" in the Matutes-Regibeau model.

solution as long as the whole market is served at equilibrium prices, i.e., as long as $C - P_i^* - k \geq 0$, or $C \geq 2k$.

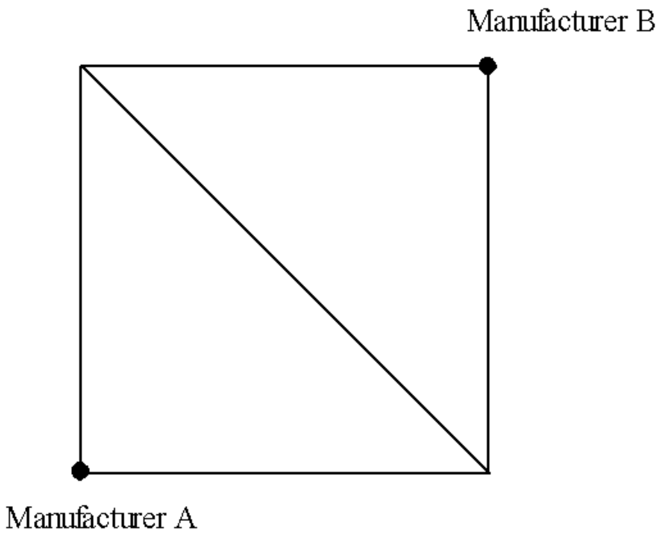

Figure 3.2: Equilibrium Market Configuration When Both Manufacturers Sell Incompatible Systems

3.4.2 Equilibrium Prices and Profits When Only One Manufacturer Sells Compatible Software

When manufacturer A chose to give up profits from its hardware component market and to make its software compatible with every other hardware, all the consumers of software A are able to choose their ideal hardware. In addition, every new entrant's hardware price will be the marginal cost that is zero.[36] Thus, a consumer located at (d_1, d_2) will purchase the system of manufacturer A's software and a new entrant's hardware rather than of manufacturer B, if $P_{AS} + k \cdot d_2 \leq P_B + k(2 - d_1 - d_2)$, where P_{AS} is the price of manufacturer A's software. The manufacturers' profits are:

$$\Pi_{AS} = P_{AS} \int_0^1 \frac{2k - kd_1 - P_{AS} + P_B}{2k} \mathrm{d}d_1 - F,$$

$$\Pi_B = P_B \left(1 - \int_0^1 \frac{2k - kd_1 - P_{AS} + P_B}{2k} \mathrm{d}d_1\right).$$

[36]For a proof, see Appendix E.

Maximizing profits with respect to P_{AS} and P_B yields $P_{AS}^* = \frac{7}{6}k$ and $P_B^* = \frac{5}{6}k$, and $\Pi_{AS} = \frac{49}{72}k - F$ and $\Pi_B = \frac{25}{72}k$, respectively. Manufacturer A's market share is $\frac{7}{12}$ and Manufacturer B's $\frac{5}{12}$. (See Figure 3.3.) As in the previous subsection, these equilibrium prices are valid as long as $C \geq 2k$.

Note that manufacturer A's price is higher than B's price even though A's market share is bigger than B's. The increased variety of hardware enables manufacturer A to enjoy both high price and bigger market share. As another result, absent the fixed cost F, the sum of both manufacturers' profits is greater than k, the total profits when there are only manufacturer A and B's systems.

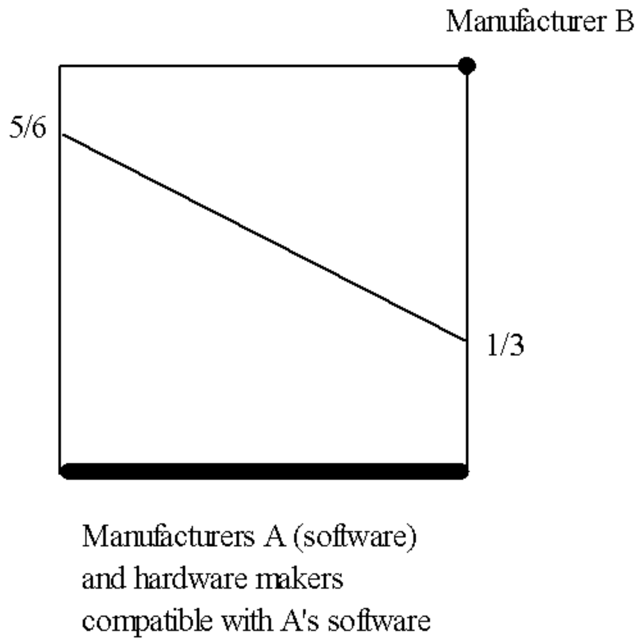

Figure 3.3: Equilibrium Market Configuration When Only One Manufacturer Sells Compatible Software

3.4.3 Equilibrium Prices and Profits When Both Manufacturers Sell Compatible Software

If both manufacturers make their software compatible with every hardware, each consumer can purchase his/her ideal hardware type without any related costs. In this case also, every new entrant's hardware price will be the zero marginal cost. A consumer located at (d_1, d_2) will be indifferent between the software of manufacturer A and B if $P_{AS} + k \cdot d_2 = P_{BS} + k(1 - d_2)$. This case boils down to a typical Hotelling game. Solving this game results in $P_i^* = k$, and $\Pi_i = \frac{1}{2}k - F$. The two manufacturers have the same market share of $\frac{1}{2}$. (See Figure 3.4.) This solution is valid as long as $C - P_i^* - k \geq 0$, or $C \geq 2k$.

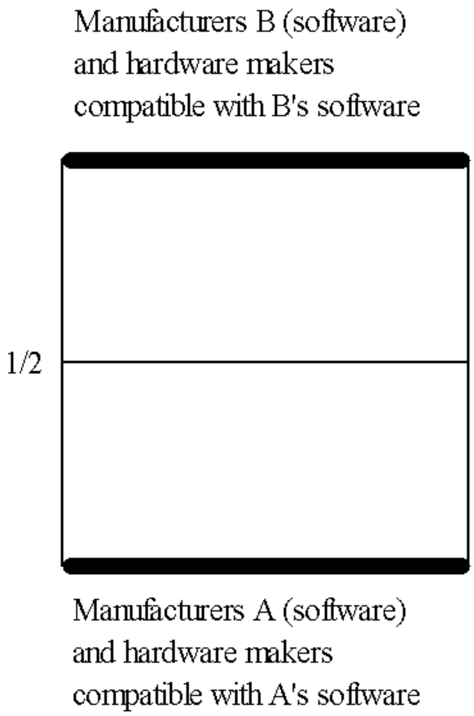

Figure 3.4: Equilibrium Market Configuration When Both Manufacturers Sell Compatible Software

3.4.4 Equilibrium of the Whole Game

The analysis up to now shows that the two manufacturers will face the payoff matrix below in the first stage.

		Manufacturer B	
		Compatible Software	Incompatible System
Manufacturer A	Compatible Software	$(\frac{1}{2}k - F, \frac{1}{2}k - F)$	$(\frac{49}{72}k - F, \frac{25}{72}k)$
	Incompatible System	$(\frac{25}{72}k, \frac{49}{72}k - F)$	$(\frac{1}{2}k, \frac{1}{2}k)$

Table 3.1: Matrix of Payoffs to the Manufacturers

The equilibrium of the whole game depends on the relative magnitude of F. When $F > \frac{13}{72}k$, both manufacturers will not give up their hardware markets. If $\frac{11}{72}k < F < \frac{13}{72}k$, only one manufacturer will make its software compatible with every hardware. With F less than $\frac{11}{72}k$, both manufacturers will choose to sell compatible software. There are no mixed strategy equilibria when $F > \frac{13}{72}k$, since " Compatible Software" strategy is strictly dominated. F less than $\frac{11}{72}k$ also makes " Incompatible System" strategy strictly dominated. When $\frac{11}{72}k < F < \frac{13}{72}k$, a mixed strategy equilibrium exists and the related probability is $\frac{13}{2}k - 36\frac{F}{k}$. The higher the magnitude of F within this range, the less probability will be given to the " Compatible Software" strategy.

The strategy of making its software compatible with every hardware has costs and benefits. One of the costs is the lost profits from giving up its own hardware market. The other costs are the fixed costs F. The benefits are from the increased demands for its software. The equilibrium depends on the relative magnitude of these costs and benefits.

3.5 Consumer Surplus and Social Welfare

This section compares consumer surplus and social welfare, the joint profits and consumer surplus, in each case. The table below summarizes the consumer surplus and the social welfare in the three cases.

	CS	SW
Both Incompatible Systems[37]	$C - \frac{5}{3}k$	$C - \frac{2}{3}k - F$
Asymmetric Case[38]	$C - \frac{53}{36}k$	$C - \frac{4}{9}k - F$
Both Compatible Software[39]	$C - \frac{5}{4}k$	$C - \frac{1}{4}k - F$

Table 3.2: Consumer Surplus and Social Welfare in Each Case

Prediction of the results is not difficult. The introduction of infinitely many hardware makers make the consumer surplus higher. Though the software provider in the asymmetric case charges a high price, that effect is less than the effect of the infinitely many hardware types. The ranking of the social welfare is the same.

3.6 Comparative statics

This section considers the changes in the equilibrium when the reservation price, C, is not high enough for the whole market to be covered. There are two sub-cases: (1) C is so low that each manufacturer's market does not touch the other's; (2) C is in intermediate levels.

3.6.1 Equilibrium When C is Very Low

If C is so low that each manufacturer's market does not touch the other's, each manufacturer will behave as a local monopolist.

Let's consider the case where each manufacturer provides incompatible system. Manufacturer A will serve the consumers whose utility from purchasing A's system, $C - k(d_1 + d_2) - P_A$, is greater than or equal to zero. Maximizing $\Pi_A = P_A \cdot \frac{1}{2}\left(\frac{C-P_A}{k}\right)^2$ with respect to P_A yields $P_A^* = \frac{1}{3}C$ and $\Pi_A = \frac{2C^3}{27k^2}$. This is a valid solution if the manufacturers' markets do not overlap at the equilibrium prices, i.e. if $C - k - \frac{1}{3}C < 0$ or $C < \frac{3}{2}k$.

Otherwise, if each manufacturer makes its software compatible with every hardware, its software will be sold to the consumers whose utility $C - k \cdot d_2 - P_{AS} \geq 0$. Maximizing $\Pi_{AS} = P_{AS} \cdot \left(\frac{C-P_{AS}}{k}\right) - F$ with respect to P_{AS} yields $P_{AS}^* = \frac{1}{2}C$, and $\Pi_{AS} = \frac{C^2}{4k} - F$ when C is less than or equal to $2k$. This solution is valid as long as the manufacturers' markets do not touch each other's, i.e. $C - \frac{1}{2}k - \frac{1}{2}C < 0$ or $C < k$.

Note that when C is sufficiently low, there is no asymmetric equilibrium to the whole game such that one manufacturer provides incompatible system and the other manufacturer provides compatible software. This is because if C is less than or equal to k, the two manufacturers behave like monopolists. Since the two manufacturers are symmetric, both manufacturers will make the same choice concerning compatibility.

Since low C does not bring about an asymmetric equilibrium, the relative magnitude of F decides the changes in the equilibrium when C increases. Suppose, for example, that $\frac{11}{72}k < F < \frac{13}{72}k$. In this case, the manufacturers will choose to provide incompatible systems when C is very low.[40] However, these manufacturers' choices will make an asymmetric equilibrium when C is greater than $2k$.[41] Thus, higher market demands[42] can result in asymmetric equilibrium between the two manufacturers, while they choose incompatible systems when market demands are low. If $F > \frac{13}{72}k$, on the contrary, the two manufacturers will choose to provide incompatible systems regardless of the values for C.

3.6.2 Equilibrium When C is in Intermediate Levels

In this case, the two manufacturers will set the price so that consumer surplus is zero on the market boundary. The range of C is $\frac{2}{3}k < C < 2k$ for the manufacturers of incompatible systems. Each manufacturer will price $P_i = 2C - 2k - P_j$ so that $P_i^* = C - k$ and $\Pi_i = \frac{1}{2}(C-k)$.[43]

The range of C for the manufacturers of compatible software is $k < C < \frac{3}{2}k$. Each manufacturer will set its price, $P_i^* = C - \frac{1}{2}k$ so that $\Pi_i = \frac{1}{2}(C - \frac{1}{2}k) - F$.[44] The table below summarizes the equilibrium prices and profits according to the value of C relative to k.

3.7 Conclusion

This chapter has considered whether and when it is profitable for a duopolist in system markets to give up its market position. In industries where components have strong complementarity with each other, an integrated manufacturer may want to abandon its duopolistic position in one component

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[40] Absent the fixed costs F, compatibility makes more profits since $\frac{C^2}{4k} > \frac{2C^3}{27k^2}$ with C less than or equal to k. However, $F > \frac{11}{72}k$ is too big for the local monopolists to prefer compatibility on net.

[41] From Section 3.4, we know that the equilibrium is asymmetric for $\frac{11}{72}k < F < \frac{13}{72}k$.

[42] In this model, the magnitude of C relative to k is the only exogenous variable which decides market demands.

[43] The equilibrium described here is the symmetric one. There are also continuum of asymmetric equilibria. These asymmetric equilibria result from the fact that the two manufacturers are at the kink point of the demand curve in this situation. As often occurs, there can exist multiple equilibria.

[44] There are also a continuum of asymmetric equilibria.

	Both incompatible systems		Both compatible software	
	Price	Profits	Price	Profits
$C < k$	$\frac{1}{3}C$	$\frac{2C^3}{27k^2}$	$\frac{1}{2}C$	$\frac{C^2}{4k} - F$
$K < C < \frac{3}{2}k$			$C - \frac{1}{2}k$	$\frac{1}{2}\ (C - \frac{1}{2}k) - F$
$\frac{3}{2}k < C < 2k$	$C - k$	$\frac{1}{2}(C - k)$		
$2k < C$	k	$\frac{1}{2}k$	k	$\frac{1}{2}k - F$

Table 3.3: Equilibrium Prices and Profits When C Is Not High

market if this leads new entrants to the component market to adopt its other component, and the loss from giving up the duopolistic position in one component market is less than the gains from the increased market share of the other component market.

Another main finding is the asymmetric equilibrium in which one duopolist gives up its market power in one component market and the other duopolist retains its market powers in both component markets. This asymmetric equilibrium can be summarized as the competition over a unit square between a firm at a point and firms on a line. A firm at a point can survive in spite of pressures from firms on a line, a set of infinitely many points, because they are competing in a square with positive transportation costs.

There are various areas for modification or extension of the model in this chapter. An interesting one will be a combined model of Nalebuff (2000) and this chapter. It will be able to explain the issue of the merits of bundling versus the merits of strategic abandoning of market power in some component markets.

Appendix A

When All System Prices Are Set Later Than Component Prices

Under this alternative scenario, four system prices, two for original and two for mixed systems, are decided in the last stage. However, solving four simultaneous equations for the four prices is not easy. For example, Mathematica 4.1 is not able to do this calculation. This difficulty is from the fact that the symmetry condition should not be imposed on the FOC's in the last stage. The Implicit Function Theorem enables us to go around this problem. The following subsection describes the methods used in the equilibrium calculation. Subsection 8.2 reports the results.

A.1 Methods in calculating the equilibrium

Consider the case with locally monopolistic TPCIs first. In the last stage, FOC's for the profit maximization problems will be the following:

$$\frac{\partial \Pi^A}{\partial P_{AA}} = f^A(P^*_{AA}, P^*_{A1}, P^*_{A2}, P^*_{BB}, P^*_{B1}, P^*_{B2}, P^*_{AB}, P^*_{BA}) = 0$$

$$\frac{\partial \Pi^B}{\partial P_{BB}} = f^B(P^*_{AA}, P^*_{A1}, P^*_{A2}, P^*_{BB}, P^*_{B1}, P^*_{B2}, P^*_{AB}, P^*_{BA}) = 0$$

$$\frac{\partial \Pi^{AB}}{\partial P_{AB}} = f^{AB}(P^*_{AA}, P^*_{A1}, P^*_{A2}, P^*_{BB}, P^*_{B1}, P^*_{B2}, P^*_{AB}, P^*_{BA}) = 0$$

$$\frac{\partial \Pi^{BA}}{\partial P_{BA}} = f^{BA}(P^*_{AA}, P^*_{A1}, P^*_{A2}, P^*_{BB}, P^*_{B1}, P^*_{B2}, P^*_{AB}, P^*_{BA}) = 0$$

Let y denote $(P_{AA}, P_{BB}, P_{AB}, P_{BA})$ and x denote $(P_{A1}, P_{A2}, P_{B1}, P_{B2})$. If the 4×4 matrix $\frac{\partial F}{\partial y}$ evaluated at (x^*, y^*) is nonsingular, there exist functions $P_{AA} = P_{AA}(x)$, $P_{BB} = P_{BB}(x)$, $P_{AB} = P_{AB}(x)$, $P_{BA} = P_{BA}(x)$ defined on a ball ß about x^*. Furthermore, we can compute $\frac{\partial y}{\partial x}$ at (x^*, y^*) by totally differentiating the above equations and solving the resulting system.

In the second stage, manufacturer A's FOC's will be the following:

$$\frac{d\Pi^A}{dP_{A1}} = \frac{\partial P_{AA}}{\partial P_{A1}} \cdot \frac{\partial \Pi^A}{\partial P_{AA}} + \frac{\partial P_{BB}}{\partial P_{A1}} \cdot \frac{\partial \Pi^A}{\partial P_{BB}} + \frac{\partial P_{AB}}{\partial P_{A1}} \cdot \frac{\partial \Pi^A}{\partial P_{AB}} + \frac{\partial P_{BA}}{\partial P_{A1}} \cdot \frac{\partial \Pi^A}{\partial P_{BA}} + \frac{\partial \Pi^A}{\partial P_{A1}} = 0 \text{ and}$$

$$\frac{d\Pi^A}{dP_{A2}} = \frac{\partial P_{AA}}{\partial P_{A2}} \cdot \frac{\partial \Pi^A}{\partial P_{AA}} + \frac{\partial P_{BB}}{\partial P_{A2}} \cdot \frac{\partial \Pi^A}{\partial P_{BB}} + \frac{\partial P_{AB}}{\partial P_{A2}} \cdot \frac{\partial \Pi^A}{\partial P_{AB}} + \frac{\partial P_{BA}}{\partial P_{A2}} \cdot \frac{\partial \Pi^A}{\partial P_{BA}} + \frac{\partial \Pi^A}{\partial P_{A2}} = 0,$$

which are evaluated at (x^*, y^*). Manufacturer B's problem is similar. Thus, there are four equations and eight variables. With the symmetry conditions, the four equations are the same. Since the FOC's in the last stage should also be satisfied on the equilibrium path, solving the FOC's in the second and last stages will produce the equilibrium prices and profits. Now, imposing symmetry conditions on the FOC's in the last stage does not pose any problems. The resulting solutions might include Nash equilibria which are not SPNE. However, the resulting solutions should include SPNE.

There are multiple solutions to the above simultaneous equations. The equilibrium prices and profits reported in the next subsection are the unique ones that survive the following tests:

(1) Excluding complex numbers;

(2) Applying SOC's at the last stage;

(3) Removing the solutions that make the market share of a mixed system vanish to zero or negative.

A.2 Equilibrium prices, profits and welfare when all system prices are set in the last stage

Original System Prices:

$P_{AA}{}^{(comp.TPCI)} > P_{AA}^{(subsidiaries)} > P_{AA}{}^{(mono.TPCI)}$ for $0.12k \leq z^I \leq 0.97k$

$P_{AA}{}^{(subsidiaries)} > P_{AA}{}^{(comp.TPCI)} > P_{AA}{}^{(mono.TPCI)}$, $z^I \leq 0.11k$ or $z^I \geq 0.98k$

However, $P_{AA}{}^{(comp.TPCI)} \doteq P_{AA}^{(subsidiaries)}$ for $0 \leq z^I \leq k$

Mixed System Prices:

$P_{AB}{}^{(mono.TPCI)} > P_{AB}{}^{(subsidiaries)} > P_{AB}{}^{(comp.TPCI)}$

Component Price:

$P_{1A}{}^{(comp.TPCI)} > P_{1A}{}^{(subsidiaries)} > P_{1A}{}^{(mono.TPCI)}$

Demand for a Mixed System:

$D_{AB}{}^{(comp.TPCI)} > D_{AB}{}^{(subsidiaries)} > D_{AB}{}^{(mono.TPCI)}$

Profits:

$\Pi_{AA}{}^{(comp.TPCI)} > \Pi_{AA}{}^{(subsidiaries)} > \Pi_{AA}{}^{(mono.TPCI)}$, $z^I \leq 0.62k$ or $z^I \geq 0.98k$

$\Pi_{AA}{}^{(subsidiaries)} > \Pi_{AA}{}^{(comp.TPCI)} > \Pi_{AA}{}^{(mono.TPCI)}$ for $0.63k \leq z^I \leq 0.97k$

However, $\Pi_{AA}{}^{(comp.TPCI)} \doteq \Pi_{AA}{}^{(subsidiaries)}$ for $0 \leq z^I \leq k$

Consumer Surplus:

$CS^{(mono.TPCI)} > CS^{(subsidiaries)} \doteq CS^{(comp.TPCI)}$

Social Welfare:

$SW^{(comp.TPCI)} > SW^{(subsidiaries)} > SW^{(mono.TPCI)}$ for $0 \leq z^I \leq 0.67k$

$SW^{(mono.TPCI)} > SW^{(subsidiaries)} > SW^{(comp.TPCI)}$ for $0.68k \leq z^I \leq k$

When $0.98k \leq z^I$, the competition between two manufacturers with monopolistic TPCIs is the same as the competition between two incompatible systems. As in Section 3, higher integration costs or local monopoly in providing mixed system prices make the competition between original systems fiercer, resulting in lower original system prices.

Appendix B

Summary of the Equilibrium in Chapter 2

(i) competitive mixed system makers and competitive retailers
(ii) competitive mixed system makers and monopolistic retailers
(iii) monopolistic mixed system makers and competitive retailers
(iv) monopolistic mixed system makers and monopolistic retailers
(v) competitive mixed system makers and asymmetric retailers
(vi) monopolistic mixed system makers and asymmetric retailers

	(i)	(ii)	(iii)	(iv)	(v)	(vi)
System Prices						
P_{AA}	$1.333k$	$3.111k$	$1.200k$	$3.050k$	$2.357k$	$2.301k$
P_{BB}	$1.333k$	$3.111k$	$1.200k$	$3.050k$	$2.198k$	$2.105k$
$P_{AB} = P_{BA}$	$1.833k$	$3.444k$	$1.867k$	$3.522k$	$2.720k$	$2.806k$
Component Prices						
A	$0.917k$	$1.722k$	$0.850k$	$1.629k$	$0.601k$	$0.509k$
B	$0.917k$	$1.722k$	$0.850k$	$1.629k$	$2.119k$	$2.111k$
Bundle Prices						
A	$1.333k$	$2.333k$	$1.200k$	$2.189k$	$1.561k$	$1.448k$
B	$1.333k$	$2.333k$	$1.200k$	$2.189k$	$2.198k$	$2.105k$
Profits						
Π_{upA}	$0.698k$	$1.290k$	$0.614k$	$1.169k$	$0.664k$	$0.594k$
Π_{upB}	$0.698k$	$1.290k$	$0.614k$	$1.169k$	$1.380k$	$1.296k$
Π_{AA}	0	$0.302k$	0	$0.371k$	$0.292k$	$0.328k$
$\Pi_{AB} = \Pi_{BA}$	0	0	$0.005k$	$0.018k$	0	$0.007k$
Demands						
D_{AA}	$0.437k$	$0.389k$	$0.472k$	$0.430k$	$0.367k$	$0.385k$
D_{BB}	$0.437k$	$0.389k$	$0.472k$	$0.430k$	$0.481k$	$0.542k$
$D_{AB} = D_{BA}$	$0.063k$	$0.111k$	$0.028k$	$0.070k$	$0.076k$	$0.037k$
CS*	$-1.979k$	$-3.728k$	$-1.860k$	$-3.692k$	$-2.914k$	$-2.857k$
SW*	$-0.583k$	$-0.543k$	$-0.623k$	$-0.576k$	$-0.578k$	$-0.625k$

* The numbers for CS and SW are deductions from C.

Table B.1: Summary of the Equilibrium in Chapter 2

Appendix C

Numerical Equilibrium Calculation in Cases of Asymmetric Retailers

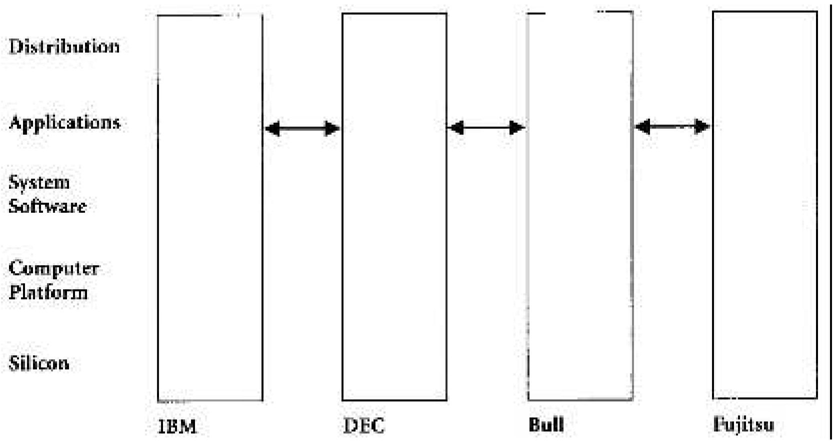
To calculate the equilibrium in the case of asymmetric retailers, "FindRoot" command in Mathematica 4.1 is used to obtain the solutions for the FOC's in the second stage. Various starting points are tested because "FindRoot" stops when it finds one solution. $14,112$ sets of the starting points are tested in the case of competitive mixed system makers and asymmetric retailers: 6 points ($2.3k \sim 4.8k$ by $0.5k$) for P_{AA}; 7 points ($1.5k \sim 4.5k$) for R_A; 8 points ($0.6k \sim 4.1k$) for P_{1A} and P_{2A}; 7 points ($2.1k \sim 5.1k$) for R_B; 6 points ($2.1k \sim 4.6k$) for P_{1B} and P_{2B}. In the case of monopolistic mixed system makers and asymmetric retailers, $63,504$ sets of the starting points are tested: 6 points ($2.3k \sim 4.8k$ by $0.5k$) for P_{AA}; 6 points ($2.8k \sim 5.3k$) for P_{AB} and P_{BA}; 7 points ($1.4k \sim 4.4k$) for R_A; 7 points ($0.5k \sim 3.5k$) for P_{1A} and P_{2A}; 6 points ($2.1k \sim 4.6k$) for R_B; 6 points ($2.1k \sim 4.6k$) for P_{1B} and P_{2B}. The equilibrium prices in Subsections 3.3.5 and 3.3.6 are the only sets of the solutions that survive the following tests: (1) excluding complex or negative numbers; (2) applying SOC's at the last stage; (3) removing the solutions that make any system's market share to be negative.

"FindMinimum" command, a gradient-based optimization tool, is used to check whether the solutions obtained above are correct. In the case of competitive mixed system makers and asymmetric retailers, "FindMinimum" is used to seek for the local minimum of each manufacturer's profit function, given the other manufacturer's prices. Since the minimum found by "FindMinimum" is not guaranteed to be a global one, $1,331$ sets of the starting points are tested: 11 points ($0 \sim 5.0k$ by $0.5k$) for each R_i, P_{1i} and P_{2i}. In addition, "NMinimize" with "RandomSearch" Method, a numerical tool for global optimization, is used to check the validity of the solutions. The optimum values and optimizing prices found by these two methods are the same as the equilibrium profits and prices obtained above. However, in the case of monopolistic mixed system makers and asymmetric retailers, "FindMinimum" and "NMinimize" are not used since the explicit solutions for P_{AA}, P_{AB} and P_{BA} are not obtained.

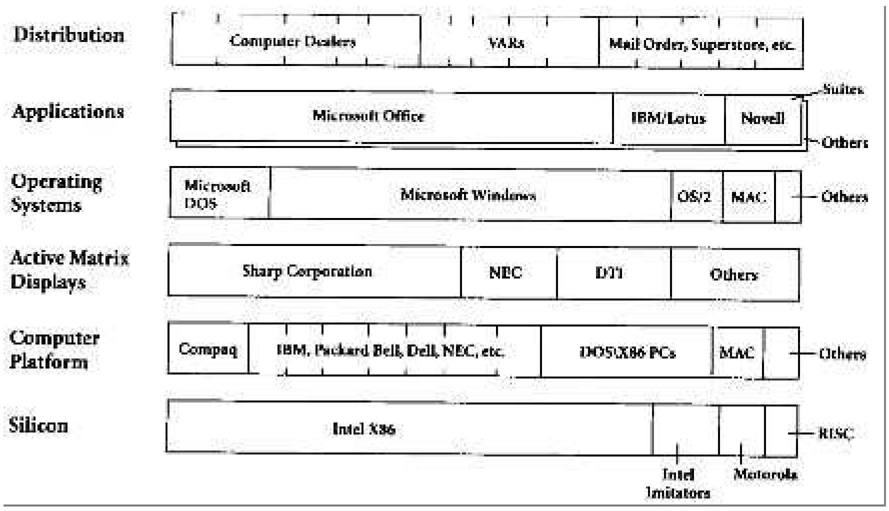
Appendix D

"Old" and "New" Market Structures in Computer Industry

A. The "old" computer industry[45]:



B. The 1995 computer industry[46]:



[45]Adapted from Intel documents and The Economist. Cited again from Yoffie (1997).

[46]Adapted from Intel documents; The Economist; and Department of Defense, Building U.S. Capabilities in Flat Panel Displays (October 1994). Cited again from Yoffie (1997).

Appendix E

Pricing of New Entrants to the Hardware Market

Proposition 8 *When a manufacturer chooses to make its software compatible with every other hardware, every new entrant's hardware price should go to the marginal cost. (Necessary Condition)*

Proof:

Suppose a situation where a hardware maker makes positive profits by pricing $P_i > MC$ and $Q_i(P_i) > 0$. In this situation, if a new hardware maker comes in to hardware maker i's market and sets its price equal to P_i, it will also make positive profits. Therefore, in equilibrium, $(P_i - MC) \cdot Q_i(P_i)$ should go to zero for every i.

There are seven possibilities:

(1) $P_i \to MC$, $Q_i(P_i) > 0$ for every i;

(2) $P_i > MC$, $Q_i(P_i) \to 0$ for every i;

(3) $P_i \to MC$, $Q_i(P_i) \to 0$ for every i;

(4) $P_i \to MC$, $Q_i(P_i) > 0$ for some i's, and $P_i > MC$, $Q_i(P_i) \to 0$ for the others;

(5) $P_i \to MC$, $Q_i(P_i) > 0$ for some i's, and $P_i \to MC$, $Q_i(P_i) \to 0$ for the others;

(6) $P_i > MC$, $Q_i(P_i) \to 0$ for some i's, and $P_i \to MC$, $Q_i(P_i) \to 0$ for the others.

(7) $P_i \to MC$, $Q_i(P_i) > 0$ for some i's, $P_i > MC$, $Q_i(P_i) \to 0$ for other i's, and $P_i \to MC$, $Q_i(P_i) \to 0$ for the others.

Consider a situation where a hardware maker prices at MC and its demand is strictly greater than zero. Since the hardware maker's demand is continuous, if it raises its price, it will get positive profits. Thus (1), (4), (5) and (7) cannot be an equilibrium.

Consider the second situation where $P_i > MC$, $Q_i(P_i) \to 0$ for every i. In that situation a hardware maker can steal its neighbor hardware makers' markets by lowering its price and get positive profits. Hence, case (2) cannot be an equilibrium, either.

Case (6) has various sub-cases. If, in some sub-cases, hardware makers in an area price strictly higher than MC, those sub-cases cannot be an equilibrium for the same reason as in case (2).

The rest is cases (3) and (6) which does not have any areas where all the hardware makers price over MC.

Proposition 9 *When a manufacturer chooses to make its software compatible with every other hardware, every new entrant's hardware price will be equal to the marginal cost. (Existence)*

Proof:

Suppose that all the real numbers between 0 and 1 are occupied and every hardware maker prices at MC. This situation clearly satisfies the necessary condition. In this situation, any hardware maker does not have an incentive to move its location because all the places are occupied already. In addition, if the other hardware makers price at MC, hardware maker i should price at MC. Otherwise, it will lose its market to its neighbors. This case corresponds to case (3).

Suppose that all the real numbers between 0 and 1 are occupied and every hardware maker prices at MC except one hardware maker, say the hardware maker at $\frac{1}{2}$. This hardware maker at $\frac{1}{2}$ has zero market share because of its higher price. In this situation, the other hardware makers do not want to move to the point $\frac{1}{2}$ or raise their prices. The hardware maker at $\frac{1}{2}$ does not want to move or change its price, either. If it lowers its price to MC, it will get some market share but its profits are still zero. This corresponds to case (6). Similar reasoning can be applied to the situation where countably many hardware makers enter the market.

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