Discussion Paper No. 935

MULTIPRODUCT COMPETITION IN VERTICALLY RELATED INDUSTRIES

Shohei Yoshida

May 2015

The Institute of Social and Economic Research
Osaka University
6-1 Mihogaoka, Ibaraki, Osaka 567-0047, Japan

Multiproduct competition in vertically related industries*

Shohei Yoshida†
Graduate School of Economics, Osaka University

May 10, 2015

Abstract

The paper investigates how competition between two multiproduct downstream firms in vertical relationships affects horizontal relationships: competitor collaboration and performance difference. When the upstream market consists of exclusive suppliers, the efficient firm may have incentive for technology transfer *without any payment* to its less efficient rival, which can be a credible device of the efficient firm to enlarge its more profitable product. Moreover, such technology transfer enhances both consumer surplus and social welfare. The inefficient downstream firm may earn more than the efficient firm under upstream markets with exclusive suppliers and with discriminatory monopolist.

Keywords: Multiproduct firm, Technology transfer, Vertical relationship, Competitor collaboration, Firm performance

JEL Classification Numbers: L14, L24, L41

---

*I am especially grateful to Noriaki Matsushima for his valuable advice. I would also like to thank Makoto Hanazono, Shinji Hasegawa, Takeshi Ikeda, Ikuo Ishibashi, Junichiro Ishida, Akio Kawasaki and Takao Ohkawa, the conference participants at the Japanese Economic Association (Doshisha University), and the seminar participants at Kobe University, Kwansei Gakuin University, Nagoya University and Osaka University for their very useful comments. All remaining errors are my own.

†Address: 1-7 Machikaneyama, Toyonaka, Osaka 560-0043, Japan. E-mail: pge031ys@student.econ.osaka-u.ac.jp.

1 Introduction

In the modern economy, the overwhelming majority of large enterprises has two features: they are multiproduct firms (MPFs) (e.g. Bailey and Friedlaender, 1982) and they have vertical business relations.[1] Needless to say, automobile manufactures produce several varieties of automobile, mini car, passenger car, sports car, and so on. Moreover, almost all of them also sell several varieties of passenger car. To do so, automobile manufacturers purchase steel, tires, and a number of parts produced by their suppliers. Buyer-supplier relationships are crucial for firm's performance especially in automobile industry. Previous researches in management have found a positive relationship between cooperative inter-firm relations and the performance of manufactures and suppliers (Cusumano and Takeishi, 1991; Helper and Sako, 1994; Dyer, 1996).[2] This implies that vertical relationships significantly affect many strategic decisions of downstream firms, which determine these firms' performances.[3]

As well as vertical relationships, horizontal relationships such as competitor collaboration among automobile manufacturers are widely observed and also would have a great influence on the firms' performances. Cooperative relationships among manufactures take various forms such as partial equity ownership, joint research/production, OEM, license, etc.[4] Such competitor collaboration is still controversial. Economists and policymakers dealing with antitrust and regulatory issues have recognized that conventional wisdom on single-product firms does not always apply to MPFs.[5] We therefore investigate how competition between MPFs in vertical relationships affects horizontal relationships such as competitor collaborations or firms' performances.

[1] Bernard et al. (2010) show good evidence for the importance of MPFs. Investigating firms in the U.S., they show that MPFs are present in all industries and produce 87% of total output. They think of firms producing a single-product as those whose range of products falls within a single five-digit SIC category. Multiproduct firms, on the other hand, are those whose product range is wide enough to span several five-digit SIC categories. In fact, some firms would produce several varieties of product which are classified into the same category. In a sense, almost all firms must be MPFs.

[2] Some studies show that cooperative relationships in Japan outperform their U.S. counterparts (Nishiguchi, 1994; Dyer, 1996) and the buyer-supplier relationship in Japan has several distinctive features (Morita, 2001). First, a large manufacture typically owns partial shareholding of their suppliers. Second, suppliers make investments that are customized to their purchaser. Third, the relationship is long-term and stable.

[3] It is well-known in economics literature that vertical structure has a great influence on behaviors of firms (e.g., DeGraba, 1990; Mukherjee and Pennings, 2011).

[4] For example, partial ownership between Renault and Nissan, joint research between GM and Honda, Toyota and Ford, joint production between GM and Toyota, Mitsubishi and Nissan, OEM among Nissan, Mazda, Suzuki and Mitsubishi.

[5] Theoretical studies point out the importance of studies on MPFs for a long time (e.g. Bailey and Friedlaender, 1982; Brander and Eaton, 1984). For a decade, a number of studies have been made not only in industrial organization (e.g., Johnson and Myatt, 2003, 2006) but also in other fields of economics such as international trade (e.g., Eckel and Neary, 2010; Bernard et al., 2011).

We consider several types of vertically related industry where duopolists produce two varieties of final product. The product that can be produced at a lower cost is called core product, and the other is called non-core product. Downstream firms require common input (or labor) in order to produce both of products. They have different technologies for one of the products with respect to efficiency. The present setup yields several new results. First, when an upstream market consists of exclusive suppliers, an efficient firm may have incentive for technology transfer, which improves an inefficient firm's technology for producing the non-core product, without any payment. Second, such technology transfer enhances both consumer surplus and social welfare. Finally, an inefficient firm may earn more than an efficient firm under some types of upstream structures.[6]

The effect of the technology transfer on profits of downstream MPFs can be decomposed into the two effects: the *production shift effect* and *input price effect*. The first effect makes MPFs modify their output portfolios of the two products.[7] A reduction in a firm's marginal cost of a product increases the output of the product, but decreases its competitor's output of the same product. This is the standard business-stealing effect. Furthermore it also makes the firm decrease its output of the substitute product to avoid cannibalization. This allows its competitor to expand the other product. To summarize, when a firm improves efficiency of a product, the business-stealing effect directly hurts its competitor whereas the latter effect benefits it. Thus the technology transfer has direct and indirect effects on profits of downstream firms, with both effects working in the opposite directions.

The input price effect works through the upstream market. The technology transfer also affects the pricing of upstream firms. A firm-specific supplier utilizes its input price for extracting rents from its trading downstream firm. The technology transfer reduces the total output and input demand of the efficient firm, while it increases those of the inefficient firm. It thus decreases the input price of the efficient firm and increases that of the inefficient one. The technology transfer benefits the efficient firm through the lower input price. From the view point of the inefficient firm, the technology transfer reduces *ex post* marginal cost of the product but increases that of the other product due to the increase of the input price. Consequently, it accelerates the production shift between the two products.

One may wonder why we consider whether firms transfer its knowledge or technical know-how

[6]Sen and Stamatopoulos (2015) consider a Cournot duopoly with strategic delegation, where quantities of firms are chosen by their managers and shows a similar result.

[7]Lin and Zhou (2013) point out this effect.

without any payment. Generally, explicit knowledge can be transferred through licensing and contracting since it is verifiable. Contrary to such transfer, codification of tacit knowledge is difficult and such knowledge is unverifiable. Hence, licenses and contracts play, at best, the limited role in the transfer of tacit knowledge (Mowery, 1983, p354).[8] Moreover, this allows us to isolate the strategic effects of technology transfer from other incentives by licensing payments.

In some industries, technology transfer without direct compensation indeed occurs through strategic alliances or joint production ventures.[9] Morita et al. (2010) investigate into collaborations among firms. They take a survey, and observe 88 cases in which a firm transfers its technology without direct compensation. Especially, 59% of the technology transfers are performed between firms without partial equity ownerships. In the automobile industry, we can find some cases: the joint production ventures between Nissan and Mitsubishi (NMKV), GM and Toyota (NUMMI) and the strategic alliance between Ford and Mazda.[10] We here give the particulars of the first case. In 2013, Nissan and Mitsubishi began the joint production of mini cars at the NMKV in Japan. Nissan had not produced mini car in person before, and therefore Nissan purchased it from Mitsubishi, Suzuki and Mazda by OEM. Since Mitsubishi has superior technology for mini car, the joint production would involve technology transfers.

Our results suggest some implications for both policymakers and managers. The result on the technology transfer tells us the effect of competitor collaborations on social welfare. Firms often use complex collaborations to achieve a goal (e.g., profit maximization). Antitrust agencies had viewed competitor collaborations as only collusive behaviors. However, in 1993, the National Cooperative Research Act of 1984 was amended to the National Cooperative Research and Production Act of 1993 (NCRPA) so that firms can engage in joint production. Furthermore, the Antitrust Guidelines for Collaborations Among Competitors in 2000 proclaims that "the Federal Trade Commission (FTC) and the U.S. Department of Justice (DOJ) regard such collaborations as often being not only benign

[8]A joint venture is viewed as a mechanism to transfer knowledge that cannot be done by licensing (Kogut, 1988). For further details of contractual difficulties in transferring tacit knowledge, see also Ghosh and Morita (2012).

[9]Employees frequently give technical information to colleagues in other firms, including direct competitors (Schrader, 1991). In the literature on international economics, technology spillovers through FDI have been explored extensively. See Lin and Saggi (1999) and Ishikawa and Horiuchi (2012).

[10]Creane and Konishi (2009) argue that the joint production between GM and Toyota involves technology transfers. They provide the large cases of joint production. Ghosh and Morita (2012) also provide the rich cases for knowledge transfers.

but procompetitive."[11] In the last three decades, the federal antitrust agencies indeed have come to admit competitor collaborations. However, the welfare effect of such collaboration is still controversial. Several recent studies obtain different implications on joint production with technology transfer or know-how disclosure. For instance, joint production as a device to predate non-recipient firms harms consumer surplus but enhances social welfare (Creane and Konishi, 2009).[12] It is true that economists usually define social welfare as the object function of the social planner, but policy makers often regard consumer surplus as a proper measure. In contrast to previous studies, as the joint production certainly raises not only consumer surplus but also social welfare in our paper, our result would promote such joint production.

Patent protection is one of the most important problems for managers. Our first result may imply, however, that some technology spillovers are welcome.[13] In other words, mangers do not have to strive to protect their technological information for non-core products. Furthermore, the result on the profit of MPFs also provides some implications for managers. In the real economy, MPFs face the constraint on selecting the distribution of the management resource, such as R&D, advertisement and human resources. Our result implies that there exist some situations when firms should not invest their resource in less profitable segment.

Several recent studies have raised instances where technology transfer or know-how disclosure without direct compensation can increase profit of technologically superior firm. Creane and Konishi (2009) consider an asymmetric oligopoly model with entry or exit, and show technology transfer without any compensation can be profitable when it works as a type of predation or deterrence. Matsushima and Ogawa (2012) examine incentive of knowledge disclosure for MPFs. They provide the view of know-how disclosure which induces some firms to change their plans for location or specialized products. In those papers, technology transfer drives some rivals out of market or affects decisions for entrants. The primary difference with our model is that we restrict a situation where neither entry nor exit occurs. Milliou and Petrakis (2012) show that a vertically integrated firm can

[11] Potential efficiencies from the collaborations may be attained through a variety of contractual arrangements, including joint ventures, trade or professional associations, licensing arrangements, or strategic alliances, etc.

[12] The effect of know-how disclosure on consumer surplus is positive while that on social welfare is ambiguous (Matsushima and Ogawa, 2012).

[13] Suzuki (1993) analyzes the effects of technological diffusion among and within vertical keiretsu groups in the Japanese electrical machinery industry, and find that positive R&D spillovers, which stem from the R&D activities of other keiretsu groups. It is remarkable that there are the spillovers between core firms of competing keiretsu groups.

choose to fully disclose its knowledge to its downstream rival. In their paper, the technology transfer intensifies downstream competition but expands downstream market size, which increases the wholesale revenue of the vertically integrated firm. Ghosh and Morita (2012) examine technology transfer among competitors with a partial equity ownership, and show an equity alliance may induce the technology transfer. In contrast, our model does not include any direct elements such as PEO or wholesale revenue, which increase the profit of technologically advanced firm. Matsushima and Zhao (2015) examine a bilateral duopoly market in which each downstream firm has outside options and upstream firms can engage in cost reduction and generate technological spillover. They find that each upstream firm has incentive to voluntarily generate the spillover to its upstream rival. As well as our paper, they also point out the importance of linkage between vertical relationship and technology transfer. However, the mechanism of their paper is clearly different from ours since it stems from the existence of outside options.

Our study is also in line with the vast literature on technology licensing. However, few studies examine the impacts of technology licensing on MPFs. Except for analyzing single-product firms, one of the related works is Mukherjee and Pennings (2011), who examine the effects of the unionization structure (viz., decentralized and centralized unions) on incentive for licensing. They show the incentive for licensing is stronger under decentralized unions than centralized. A similar input price effect of licensing in their paper also works in our setting. A notable difference is that in our model technology transfer without payment can indeed occur, while such license never occurs in their model.

The rest of this paper is organized as follows. Section 2 sets up our model and obtains a preliminary result on a property of multiproduct firms. Section 3 analyzes incentive for technology transfer under vertical relationship. Section 4 analyzes alternative scenarios in upstream market. Section 5 offers some concluding remarks. All proofs of the results and derivations of the equilibrium outcomes in the extension models are provided in the Appendices.

2 Model and downstream competition: Preliminary result

2.1 Model

We first characterize downstream market, and then introduce the timing of the game. We follow the model of Lin and Zhou (2013) without R&D investment.[14] The downstream market is composed of two multiproduct firms, named $D1$ and $D2$, which produce two types of final product, goods A and B. The inverse demand functions are specified as

$$p_k = v - (q_{1k} + q_{2k}) - \gamma(q_{1l} + q_{2l}) \quad k, l \in \{A, B\}, \; k \neq l, \tag{1}$$

where p_k is the price of good k, q_{ik} shows the quantity of good k by downstream firm $i \in \{1, 2\}$, and v is a positive demand parameter. The parameter $\gamma \in [0, 1)$ reflects the substitution between goods A and B.

Downstream firms require one unit of common input, e.g., raw material, which is commonly used for goods A and B, to produce one unit of final goods. Each firm has different transformation technologies for each good. Therefore the per unit production cost of good k of downstream firm i, c_{ik}, is denoted by

$$c_{ik} = w_i + z_{ik}, \tag{2}$$

where w_i is the input price for Di, which is determined in an upstream market. z_{ik} is the efficiency measure of a downstream firm and shows the technological level for good k of Di.[15] We can also interpret the production technology of the downstream firms as requiring two inputs, one is produced in the upstream market and the other is supplied by a competitive sector. They have an uneven technological level of input from the competitive sector. One product that the firms can produce at a lower cost is called core product and the other one is called non-core product. We assume that good A is the core product, and technological gap between firms is present only in the technology for the non-core product.[16] We refer to $D1$ ($D2$) as the efficient (inefficient) firm. To summarize, we assume $z_{2B} \geq z_{1B} > z_{iA}$ and z_{iA} is normalized to zero for simplicity.

[14] Lin and Zhou (2013) investigate the R&D portfolio choices of multiproduct firms without vertical relationships.

[15] We obtain qualitatively similar results under the assumption that $c_{ik} = z_{ik}w_i$, where $z_{ik} > 0$, which is employed in Mukherjee and Pennings (2011).

[16] All of the results we present are equally true in the case where $D1$ is efficient in both technologies. Moreover, we can also show that a quality advantage, which is reflected by demand parameters, rather than a cost advantage, will lead to essentially the same result. See the discussion in Lin and Zhou (2013, p.88).

The timing of the game is as follows. The model has two stages: in the first stage, input prices are determined in the upstream market. We specify how the input prices are determined in Section 3. In the second stage, observing the input prices, the downstream firms engage in Cournot competition. In what follows, we are looking for subgame perfect equilibria. Note that the decision of technology transfer is not included in the game. We analyze whether the firms have incentives for technology transfer by comparative statics.

2.2 Downstream competition

In this subsection, we examine an important property of MPFs. In the second stage, given the input price(s), each downstream firm chooses its quantity pair (q_{iA}, q_{iB}) in the final good market. Each firm's problem in this stage can be written as

$$\max_{(q_{iA},q_{iB})} \pi_{Di} = (p_A - c_{iA})q_{iA} + (p_B - c_{iB})q_{iB}. \tag{3}$$

The first-order conditions for profit maximization of D_i are as follows.

$$\frac{\partial \pi_{Di}}{\partial q_{ik}} = (p_k - c_{ik}) - q_{ik} \underbrace{-\gamma q_{il}}_{\text{negative effects}} = 0. \tag{4}$$

The last term captures *cannibalization effects*, which are present only for MPFs. That is, an increase in quantity of one good reduces not only the price of the good but also that of the other one, so that it discourages itself from producing the other one.

It is evident that a decrease in a firm's marginal cost of a product increases its output of that product, but decreases its competitor's output of the same product. The standard business-stealing effect also works as well as for single-product firms. What is unique about MPFs is that the firm also reduces its output of the substitute product to mitigate within-firm cannibalization, which allows its competitor to expand the substitute product. Note that the above property is deeply related to our results.

Assuming interior solutions exist, the equilibrium quantities are obtained as

$$q_{ik} = \frac{(1-\gamma)v - 2c_{ik} + c_{jk} + 2\gamma c_{il} - \gamma c_{jl}}{3(1-\gamma^2)}. \tag{5}$$

From (5), we certainly confirm the property mentioned above. This leads to the equilibrium profit of each downstream firm,

$$\pi_{Di} = \frac{(v - 2c_{iA} + c_{jA})^2 - 2\gamma(v - 2c_{iA} + c_{jA})(v - 2c_{iB} + c_{jB}) + (v - 2c_{iB} + c_{jB})^2}{9(1-\gamma^2)}.$$

3 How does upstream structure affect technology transfer?

In this section, we examine how upstream structure affects technology transfer in a vertically related industry. The structure of the upstream market is the important element in this paper. We consider five types of vertical structure: the upstream market consists of (I) competitive suppliers, (Ⅱ) two upstream firms, named $U1$ and $U2$, which exclusively supply its input for $D1$ and $D2$ respectively, (Ⅲ) a monopolist employing uniform pricing, (Ⅳ) upstream market consists of a monopolist employing discriminatory pricing, and (V) exclusive suppliers for $D1$ and $D2$, respectively, and common suppliers, which supply its input for both $D1$ and $D2$. For simplicity, upstream firm(s) produces at no costs. We consider the relationship between input supplier(s) and final goods producers, although this model is suitable for much more general application. For example, the model can be applied to the relationship between labor unions and firms.

Figure 1 summarizes the structure of the model (the last case is introduced in Section 4). We first analyze the case (I).

[Figure 1 about here]

3.1 Competitive suppliers: Benchmark

Consider a competitive upstream market where the input price is zero. We can interpret this case as a multiproduct duopoly model without vertical structure. We then introduce vertical structures and show our main results in the next subsection.

In the benchmark case, the equilibrium quantity of each firm and price are solved as (substitute $z_{iA} = 0$ when $k = A$)

$$q_{ik}^C = \frac{(1-\gamma)v - 2z_{ik} + z_{jk} + 2\gamma z_{il} - \gamma z_{jl}}{3(1-\gamma^2)}, \tag{6}$$

and

$$p_k^C = \frac{1}{3}(v + z_{ik} + z_{jk}). \tag{7}$$

We then obtain the equilibrium profit of each firm:

$$\pi_{Di}^{C} = \frac{v^2 - 2\gamma v(v - 2z_{iB} + z_{jB}) + (v - 2z_{iB} + z_{jB})^2}{9(1-\gamma^2)}. \tag{8}$$

The conditions that the interior solutions indeed exist are

$$q_{ik}^{C} > 0 \Leftrightarrow \gamma < \frac{v - 2z_{ik} + z_{jk}}{v - 2z_{il} + z_{jl}} \equiv \overline{\gamma}_{ik}^{C}. \tag{9}$$

Hereafter, we restrict our attention to the case where both downstream firms provide both products.

We examine the incentive for the efficient firm to transfer its technology. The technology transfer improves the $D2$'s efficiency for the non-core product, but does not affect the technology for the core product. In words, the technology is valuable for the non-core product but can not be applied to the core one.[17] Consider a situation that the technology transfer yields no direct compensation for $D1$. Therefore the firms agree to the technology transfer if a technology improvement for the non-core product of $D2$ increases not only the profit of $D2$ but also that of $D1$. From (8), we obtain $d\pi_{D1}/dz_{2B} > 0$, which implies,

Proposition 1 *When the upstream market is competitive, the efficient firm has no incentive for the technology transfer to the inefficient firm.*

The technology transfer has two effects, which work oppositely. A decrease in the $D2$'s marginal cost of good B discourages $D1$ from producing good B. On the other hand, it causes that $D2$ produces good A less whereas good B more. Since $D2$ shifts its production from goods A to B, $D1$ can produce good A aggressively. In this case, the former effect dominates the latter, and hence the technology transfer is not profitable for $D1$.

We are also interested in the relationship between the profits of the downstream firms. Comparing them, we have

Proposition 2 *When the upstream market is competitive, the efficient firm always earns more profit than the inefficient firm.*

[17] This is an important assumption for the technology transfer. However, we would obtain qualitatively similar results if the technology is available for the core product but the availability is sufficiently low.

From (6), $D2$ produces good A more than $D1$ and good B less. $D2$ benefits from the higher marginal cost of good B, because it works as a commitment device to produce the core product aggressively. However this force is not strong enough to compensate for the disadvantage in efficiency.

3.2 Exclusive suppliers

In this subsection, we examine the case where the upstream market is composed of two firms which supply its input to the downstream firm exclusively.[18]

Each upstream firm simultaneously decides its input price so as to maximize its own profit.[19] Each upstream firm's problem can be written as

$$\max_{w_i} \pi_{Ui} = w_i Q_i(w_1, w_2),$$

where $Q_i \equiv q_{iA} + q_{iB}$.[20] The first-order condition for the upstream firm i is

$$\frac{\partial \pi_{Ui}}{\partial w_i} = w_i \frac{-4}{3(1+\gamma)} + Q_i(w_1, w_2) = 0. \tag{10}$$

The reaction function of upstream firm i is

$$w_i = \frac{1}{8}(2v - 2z_{iB} + z_{jB} + 2w_j). \tag{11}$$

Equation (11) implies that the input prices are strategic complements. The equilibrium input prices are obtained as

$$w_i^E = \frac{1}{30}(10v - 7z_{iB} + 2z_{jB}). \tag{12}$$

We get that $dw_i^E/dz_{iB} < 0$, and $dw_j^E/dz_{iB} > 0$. This implies

Lemma 1 *When the upstream market consists of exclusive suppliers, as the efficiency of downstream firm i increases, the input price of upstream firm i (j) increases (decreases).*

[18]According to Nobeoka (1996), Nissan bought fuel filters from Tsuchiya Seisakusho, while Mitsubishi bought it from Nippon Denso and Tokyoroki. With respect to fuel filters, Tsuchiya Seisakusho was the exclusive supplier for Nissan and Nippon Denso and Tokyoroki were those for Mitsubishi. In 2014, Nissan buys some engine cooling and air-conditioning system products from MAHLE berh Japan while Mitsubishi does not, which is another example for the exclusive supplier.

[19]This setting means the contract is take-it-or-leave-it offer. Some readers would think that the bargaining power of suppliers is relatively weak in reality. However, Ahmadjian and Oxley (2013) indicate that the profitabilities of Japanese auto suppliers are not lower than those of Japanese auto assemblers in terms of ROA (Table 2 in their paper), which implies that auto suppliers are not always relatively weak to their trading assemblers.

[20]We assume that the upstream firms determine their input prices such that the downstream firms can produce both of the final goods. Since the downstream firms are MPFs, their input demand functions are kinked. Therefore, we must check not only the local optimality (i.e., first-order condition) but also the global optimality (i.e., deviations "beyond" the kinked point). The calculations are described in the appendix.

An efficiency improvement of Di's non-core product raises the profitability of the firm. This leads to a higher input price by its exclusive supplier. On the other hand, Dj decreases its total quantity. The downward shift of input demand decreases the input price.

The equilibrium quantity and price are obtained as

$$q_{ik}^E = \frac{20(1-\gamma)v - 4(11+4\gamma)z_{ik} + (19+11\gamma)z_{jk} + 4(4+11\gamma)z_{il} - (11+19\gamma)z_{jl}}{90(1-\gamma^2)}, \tag{13}$$

$$p_k^E = \frac{1}{18}(10v + 5z_{1k} + 5z_{2k} - z_{1l} - z_{2l}). \tag{14}$$

This leads to the equilibrium profits of the firms:

$$\pi_{Di}^E = \frac{(20v+16z_{iB}-11z_{jB})^2 - 2\gamma(20v+16z_{iB}-11z_{jB})(20v-44z_{iB}+19z_{jB}) + (20v-44z_{iB}+19z_{jB})^2}{9\cdot 30^2(1-\gamma^2)} \tag{15}$$

and

$$\pi_{Ui}^E = \frac{(10v - 7z_{iB} + 2z_{jB})^2}{15\cdot 45(1+\gamma)}. \tag{16}$$

The conditions for the interior solutions, $q_{ik}^E > 0$, are

$$\gamma < \frac{20v - 44z_{ik} + 19z_{jk} + 16z_{il} - 11z_{jl}}{20v + 16z_{ik} - 11z_{jk} - 44z_{il} + 19z_{jl}} \equiv \overline{\gamma}_{ik}^E. \tag{17}$$

We also have to check whether the upstream firms have no incentive to deviate from the their input prices. Let $\overline{\gamma}_d^E$ be the upperbound of γ, and we can show that the condition $\gamma < \overline{\gamma}_d^E$ assures the upstream firms do not deviate.[21] Hence, the condition for the equilibrium is $\gamma < \min\{\overline{\gamma}_{ik}^E, \overline{\gamma}_d^E\}$.

We now turn to the central issue of this section, namely the incentive for the technology transfer in the vertical relationship.

Proposition 3 *When the upstream market consists of exclusive suppliers, the efficient firm may have the incentive for the technology transfer to the inefficient firm and the inefficient firm may accept the offer. Formally for $v > \hat{v}^E$, π_{Di}^E is decreasing in z_{2B} if and only if $\gamma \in (\underline{\gamma}_{\pi 1}^E, \overline{\gamma}_{\pi 2}^E)$ where $\underline{\gamma}_{\pi 1}^E$ and $\overline{\gamma}_{\pi 2}^E$ are the threshold values of γ such that $d\pi_{Di}^E/dz_{2B} = 0$ respectively.*[22]

[21] We derive the threshold values $\overline{\gamma}_d$ for each upstream structure in Appendix B.

[22] It might be possible to define the condition for the technology transfer as when there exists $z'_{2B} \in [z_{1B}, z_{2B})$ such that $\pi_{Di}(v, z_{1B}, z'_{2B}, \gamma) > \pi_{Di}(v, z_{1B}, z_{2B}, \gamma)$ for $i = 1, 2$. Our definition is sufficient for the other. Moreover, that is suitable when the cost reductions of the technology transfer are uncertain in advance.

The technology transfer has the two notable effects. An efficiency improvement for good B of $D2$ increases (decreases) the quantity of good B (A) from $D2$, whereas decreases (increases) that of good B (A) from $D1$ - what we call the "production shift effect." In addition, the technological improvement also induces a lower (higher) input price for $D1$ ($D2$) - what we call the "input price effect." Therefore, $D1$ can produce the core product aggressively, and purchase cheaper inputs from its exclusive supplier. In turn, although $D2$ can not produce good A aggressively, and besides must purchase more expensive inputs, it can produce good B more owing to the lower *ex post* marginal cost of good B. When the condition in Proposition 3 is satisfied, the benefit can be large enough to compensate for the loss for both firms, and consequently the technology transfer can indeed occur. The firms can utilize the technology transfer as a credible device for the "output specialization."

Figure 2 illustrates an example for the proposition above. When z_{2B} is sufficiently low, a decrease in z_{2B} increases both firms' profits. The detail of the conditions is shown in Figure 3. For the technology transfer, γ plays an important role for the condition. That is, γ deeply affects the degree of the production shift effect. Equation (13) shows how the technology transfer modifies their production portfolios. Clearly, the difference between z_{1B} and z_{2B} is also important. When the difference between z_{1B} and z_{2B} is relatively large, the $D1$'s quantity of good A is small while that of good B is large. Suppose that the technology transfer decreases z_{2B}, it yields an decrease in the price of good B and the $D1$'s quantity of good B, resulting in the large loss for $D1$.[23]

[Figures 2 and 3 about here]

When competing firms intend to perform cooperative behaviors such as technology transfer, antitrust authority must beware that it does not have anti-competitive effects.

Proposition 4 *If the technology transfer benefits both downstream firms, then it always enhances both consumer surplus and social welfare.*

How does efficiency of firms affect consumer surplus or social welfare? It is well know that making an inefficient firm more efficient can reduce welfare (Lahiri and Ono, 1988). The intuition of their

[23] Marjit (1990) also shows that technology licensing with fixed fees is likely to occur between firms which are reasonably close in terms of their initial technologies.

result is as follows. A cost reduction in a relatively less efficient firm results in an increase in the total output, which clearly enhances consumer surplus. The cost reduction, however, shifts production from the more efficient firms to the less efficient one, so that producer surplus may fall. Although the latter negative effect also exists in our model, the technology transfer benefits both downstream firms. Hence, the effect to producer surplus is also positive. The technology transfer indeed occurs only if it enhances both consumer surplus and social welfare.

We turn to another interest: which firm can outperform? Comparing the profits of the downstream firms, we get the following:

Proposition 5 *When the upstream market consists of exclusive suppliers, the inefficient firm may earn more profit than that of the efficient firm. Formally for $v > \underline{v}^E$, $\pi^E_{D2} > \pi^E_{D1}$ if and only if $\gamma \in (\underline{\gamma}^E, \overline{\gamma}^E_d)$ where $\underline{\gamma}^E$ is the threshold value of γ such that $\pi^E_{D2} = \pi^E_{D1}$.*

The intuition behind the result is as follows. There exist two positive effects of the inefficiency on the technology for good B in this case. First, by Lemma 1, thanks to its inefficiency, the inefficient firm can purchase its input cheaper than the efficient rival. Since the input is used for both good A and B commonly, the non-core segment of $D2$ serves to indirectly subsidize its core segment.[24] In addition, the inefficient technology for the non-core product works as a commitment device to expand the core one. For the reason above, this counterintuitive result may occur in our model.

Figures 2 and 4 illustrate examples for the proposition. Note that when z_{2B} or γ are sufficiently high, the profit of the inefficient firm exceeds that of the efficient firm. The detail of the conditions is shown in Figure 5. The figure shows that when γ is large, in other words, when the production shift effect works strongly, the inefficient firm outperforms the efficient rival. The difference between z_{1B} and z_{2B} is also important. When γ is relatively small (e.g., $\gamma = 0.6$), the condition requires the difference between z_{1B} and z_{2B} is relatively large. This means when the production shift effect is weak, $D2$ needs less inefficient technology to outperform its rival because both the commitment effect to expand the core product and the input price effect must work strongly.

[Figures 4 and 5 about here]

[24] This effect is also emphasized in the accounting literature. Due to the latent cross-subsidization effect, firms which sell multiple markets can understate the value added by less profitability market (Arya and Mittendorf, 2011).

4 Extensions of the model

So far, we have shown that the technology transfer may occur under the upstream market with the exclusive suppliers. As shown in this section, the technology transfer does not occur when an upstream market is composed of a monopolist, but occurs when many suppliers, which are introduced in Section 4. The result on the profit is also obtained under an upstream market with discriminatory monopolist and many suppliers. Table 1 summarizes the results of this paper.

Table 1. Summary of the Results

Upstream structures	Competitive Suppliers	Exclusive Suppliers	Uniform Pricing Monopolist	Discriminatory Monopolist	Many Suppliers
Technology transfer	×	○	×	×	○
Inefficient firm outperforms	×	○	×	○	○

Consider now the upstream market consists of a monopolist. The following two subsections investigate two kinds of upstream market, that with the monopolist employing uniform pricing and that with the monopolist employing discriminatory pricing. The timing structure of the game is the same in the previous section. Main purpose in the following two subsections is to show the technology transfer does not occur in the markets with upstream monopolists. Subsection 4.3 examines an extended model, named "many suppliers", which is composed of both exclusive and common suppliers.

4.1 Monopolist employing uniform pricing

In this subsection, we consider the case where the upstream monopolist, M, sets a same input price to both downstream firms. The outcome in the second stage is the same as that in the last section. In the first stage the upstream monopolist faces the problem:

$$\max_{w} \pi_M = w \sum_{i\in\{1,2\}} \sum_{k\in\{A,B\}} q_{ik}. \tag{18}$$

The equilibrium input price is obtained as

$$w^{MU} = \frac{1}{8}(4v - z_{1B} - z_{2B}). \tag{19}$$

We thus get the following lemma.

Lemma 2 *When the upstream monopolist employs uniform pricing, as the efficiency in good B increases, the input price increases.*

An efficiency improvement in a good increases the quantity of the good and decreases that of the other. Since the increase in quantity of the good exceeds the decrease in quantity of the others, the total input demand shifts upward so that the input price goes up.

We obtain the equilibrium profits of the firms:

$$\pi_{Di}^{MU} = \frac{(4v + z_{iB} + z_{jB})^2 - 2\gamma(4v + z_{iB} + z_{jB})(4v - 15z_{iB} + 9z_{jB}) + (4v - 15z_{iB} + 9z_{jB})^2}{9 \cdot 8^2(1-\gamma^2)}, \tag{20}$$

$$\pi_{M}^{MU} = \frac{(4v - z_{1B} - z_{2B})^2}{48(1+\gamma)}, \tag{21}$$

where the condition for the equilibrium is $\gamma < \min\{\overline{\gamma}_{ik}^{MU}, \overline{\gamma}_{d}^{MU}\}$.

We are interested in the incentive for the technology transfer and conclude that it never occurs in this case.

Proposition 6 *When the upstream monopolist employs uniform pricing, the efficient firm has no incentive for the technology transfer to the inefficient firm.*

The intuition behind this proposition is similar to that in Proposition 1. There is an additional negative effect for the efficient firm through input price. As Lemma 2 shows, the technology transfer yields a higher input price for both downstream firms. This interferes with an expansion in good A of the efficient firm directly. The negative effect therefore dominates the positive effect from an expansion in the core product.

We turn to the next question: which firm will get a higher profit. Comparing the profits of the downstream firms, we get

Proposition 7 *When the upstream monopolist employs uniform pricing, the efficient firm always earns a higher profit than that of the inefficient firm.*

Proposition 7 is parallel to Proposition 2. Under uniform pricing, the difference in efficiency affects only competition in the final good market. Hence, the intuition in Proposition 2 can be also applied to this case.

4.2 Monopolist employing discriminatory pricing

We next analyze the case where the upstream market consists of the monopolist employing discriminatory pricing.

In the first stage the upstream monopolist faces the problem:

$$\max_{(w_1,w_2)} \pi_M = w_1 Q_1(w_1, w_2) + w_2 Q_2(w_1, w_2), \tag{22}$$

where $Q_i \equiv \sum_{k\in\{A,B\}} q_{ik}$. The equilibrium input prices are

$$w_i^{MD} = \frac{1}{4}(2v - z_{iB}). \tag{23}$$

Lemma 3 *When the upstream monopolist employs discriminatory pricing, an efficiency improvement of a downstream firm increases its input price but has no effect on the input price of the other downstream firm.*

An efficiency improvement of Di shifts the input demand of Di (Dj) upward (downward). Therefore the input price for Di (Dj) increases (decreases). However, since the pricing for downstream firms is complement, there is another effect which works oppositely toward the input demand effects above. For the input price of Dj, two effects are canceled out, and consequently the Di's efficiency improvement has no impact on the Dj's input price.

We obtain the equilibrium profits of the firms:

$$\pi_{Di}^{MD} = \frac{(2v + 2z_{iB} - z_{jB})^2 - 2\gamma(2v + 2z_{iB} - z_{jB})(2v - 6z_{iB} + 3z_{jB}) + (2v - 6z_{iB} + 3z_{jB})^2}{9 \cdot 4^2(1-\gamma^2)}, \tag{24}$$

and

$$\pi_M^{MD} = \frac{(2v - z_{1B})^2 + (2v - z_{2B})^2 + (z_{2B} - z_{1B})^2}{24(1+\gamma)}, \tag{25}$$

where the condition for the equilibrium is $\gamma < \min\{\bar{\gamma}_{ik}^{MD}, \bar{\gamma}_d^{MD}\}$.

We first compare the input prices under uniform pricing and under discriminatory pricing.

Lemma 4 *When the upstream monopolist employs discriminatory pricing, it sets a higher (lower) input price to the (in)efficient firm than when it employs uniform pricing. That is* $w_1^{MD} > w^{MU} > w_2^{MD}$.

Since the *ex ante* profitability of the efficient firm is higher than that of the less efficient one, the monopolist sets a higher input price for the efficient firm in order to exploit it when using price discrimination.

We check whether the efficient firm has incentive for the technology transfer or not.

Proposition 8 *When the upstream monopolist employs discriminatory pricing, the efficient firm has no incentive for the technology transfer to the inefficient firm.*

In this case, the technology transfer also raises the input price for the inefficient firm. However it does not decrease input price for the efficient firm. The positive effects can not be large enough to compensate for the loss from giving up the dominance in *ex ante* efficiency.

We next examine which firm can outperform its rival. Comparing the profits of the downstream firms, we then have

Proposition 9 *When the upstream monopolist employs discriminatory pricing, the inefficient firm may earn a higher profit than that of the efficient firm. Formally for* $v > \underline{v}^{MD}$, $\pi_{D2}^{MD} > \pi_{D1}^{MD}$ *if and only if* $\gamma \in (\underline{\gamma}^{MD}, \overline{\gamma}_d^{MD})$ *where* $\underline{\gamma}^{MD}$ *is the threshold value of* γ *such that* $\pi_{D2}^{MD} = \pi_{D1}^{MD}$.

We can also apply the intuition behind Proposition 5. Figures 6 and 7 illustrate the numerical examples of Proposition 9 and the detail of the conditions is shown in Figure 8. Figure 6 also shows that the more inefficient the inefficient firm becomes, the more profit both firms get. This observation is similar to Lemma 1 in Arya and Mittendorf (2010), which shows a multi-market firm may lose by an increase in a market size.

[Figures 6 and 7 and 8 about here]

4.3 Many suppliers

We complete this section by discussing what happens if the model is extended to an upstream market with many suppliers. Consider an industry where both $D1$ and $D2$ trade with n_E exclusive suppliers respectively, and n_C firms supply to both $D1$ and $D2$. Hereafter, we call the latter "common suppliers." Figure 9 summarizes the structure of the extended model. Note that when $n_E = 1$ and $n_C = 0$, this model is reduced to the model in the subsection 3.2 and when $n_E = 0$ and $n_C = 1$, it is also reduced to the model with the uniform pricing monopolist.

[Figure 9 about here]

The technologies of the downstream firms are modified as follows. The downstream firms require one unit of $n_C + n_E$ kinds of input, which is commonly used for goods A and B, to produce one unit of final goods. Therefore the per unit production cost of good k of downstream firm i, c_{ik}, is denoted by

$$c_{ik} = \sum_{s=1}^{n_C} w_{cs} + \sum_{h=1}^{n_E} w_{ih} + z_{ik} \qquad s \in \{1, ..., n_C\},\ h \in \{1, ..., n_E\}, \tag{26}$$

where w_{cs} is the input price of common supplier s, w_{ih} is that of downstream firm i's exclusive supplier h and z_{ik} is an efficiency measure.

The timing of the game is as follows. In the first stage, the common suppliers and the exclusive suppliers simultaneously decide their input prices. In the second stage, observing the input prices, the downstream firms engage in Cournot competition.

The profits of the common supplier s and the exclusive supplier ih are respectively

$$\pi_{Ucs} = w_{cs}(Q_1 + Q_2), \qquad \pi_{Uih} = w_{ih}Q_i. \tag{27}$$

In the first stage, each upstream firm maximizes its own profit above. After some calculations, the equilibrium input prices are obtained as

$$w_{cs} = \frac{4v - z_{1B} - z_{2B}}{2(2n_C + n_E + 2)}, \tag{28}$$

and

$$w_{ih} = \frac{2(3n_E + 2)v - (3n_C + 3n_E + 4)z_{iB} + (3n_C + 2)z_{jB}}{2(3n_E + 2)(2n_C + n_E + 2)}. \tag{29}$$

Substituting the input prices into the outcome in the second stage, we can obtain the equilibrium profits of the downstream firms. Figures 10 and 11 provide some numerical examples of the relationship between the profits of the downstream firms and z_{2B}. As the figures indicate, when z_{2B} is sufficiently low, the technology transfer benefits both firms. When z_{2B} is sufficiently high, the profit of the inefficient firm exceeds that of the efficient one. We conclude that the results in the exclusive suppliers case also hold in the industry with more complex vertical relationship.

[Figures 10 and 11 about here]

5 Concluding remarks

This paper explores the impact of competition between multiproduct firms in vertical relationships on horizontal relationships: technology transfers between competitors and a difference in firms' performances. To this end, we develop a multiproduct Cournot model with a vertical structure and examine incentive for the technology transfer without any payment. We find that when the upstream market consists of exclusive suppliers or many suppliers, the technology transfer may benefit both downstream firms. Such technology transfer enhances both consumer surplus and social welfare. In addition, an inefficient downstream firm may outperform its efficient rival.

Since cost structures of MPFs influence their output portfolios, an MPF with advanced technology will have incentive to utilize the technology transfer so as to modify the output portfolio in its favor. For the recipient MPF, although such technology transfer shifts its output from more profitable good to less profitable one, the profit may indeed increase. This is because the positive effect from the efficiency improvement of the recipient product can dominate the negative effects from the modification on the output portfolio and the increase in its input price.

The policy implications of our result are as follows. FTC or DOJ recognize that consumers may benefit from competitor collaborations in various ways. However, the welfare effect of competitor collaborations such as joint production is still controversial. Creane and Konishi (2009), for example, show that the joint production, which includes technology transfer, also has a positive effect on social welfare while the market price rises up. In general, cooperative agreements that tend to raise prices or to reduce output are challenged by the agencies as *per se* illegal, while agreements not challenged as *per se* illegal are analyzed as the rule of reason to determine their overall competitive effects. Therefore, based on Creane and Konishi's (2009) result, we can not conclude joint productions should be promoted. In contrast to their research, the joint production in our model certainly raises not only consumer surplus but also social welfare. Our result may justify some approvals for joint production agreements by antitrust agencies.

The overall point that we want to emphasize is that making an analysis of MPFs suggests a number of possibly important and certainly interesting economic consequences. We believe that this paper provides a new insight into competition among MPFs.

Appendix A: The equilibrium when upstream market with monopolist

A.1 The equilibrium when monopolist employing uniform pricing

The first-order conditions is

$$\frac{d\pi_M}{dw} = w\frac{-4}{3(1+\gamma)} + \sum_{i\in\{1,2\}}\sum_{k\in\{A,B\}} q_{ik} = 0. \tag{30}$$

The equilibrium input price is obtained as

$$w^{MU} = \frac{1}{8}(4v - z_{1B} - z_{2B}). \tag{31}$$

The equilibrium quantity and price are obtained as

$$q_{ik}^{MU} = \frac{4(1-\gamma)v - (15+\gamma)z_{ik} + (9-\gamma)z_{jk} + (1+15\gamma)z_{il} - (9\gamma-1)z_{jl}}{24(1-\gamma^2)} \tag{32}$$

and

$$p_k^{MU} = \frac{1}{12}(8v + 3z_{1k} + 3z_{2k} - z_{1l} - z_{2l}). \tag{33}$$

This leads to the equilibrium profits:

$$\pi_{Di}^{MU} = \frac{(4v + z_{iB} + z_{jB})^2 - 2\gamma(4v + z_{iB} + z_{jB})(4v - 15z_{iB} + 9z_{jB}) + (4v - 15z_{iB} + 9z_{jB})^2}{9\cdot 8^2(1-\gamma^2)}, \tag{34}$$

$$\pi_M^{MU} = \frac{(4v - z_{1B} - z_{2B})^2}{48(1+\gamma)}. \tag{35}$$

The conditions that the interior solutions indeed exist, $q_{ik}^{MU} > 0$, are

$$\gamma < \frac{4v - 15z_{ik} + 9z_{jk} + z_{il} + z_{jl}}{4v - 15z_{il} + 9z_{jl} + z_{ik} + z_{jk}} \equiv \overline{\gamma}_{ik}^{MU}. \tag{36}$$

We also have to derive the condition the upstream firm has no incentive for changing its equilibrium input price, and the condition is $\gamma < \overline{\gamma}_d^{MU}$ (see Appendix B). Hence, the condition for the equilibrium is $\gamma < \min\{\overline{\gamma}_{ik}^{MU}, \overline{\gamma}_d^{MU}\}$.

A.2 The equilibrium when monopolist employing discriminatory pricing

The first-order conditions are

$$\frac{\partial\pi_M}{\partial w_i} = w_i\frac{-4}{3(1+\gamma)} + Q_i(w_i, w_j) + w_j\frac{2}{3(1+\gamma)} = 0. \tag{37}$$

The equilibrium input prices are

$$w_i^{MD} = \frac{1}{4}(2v - z_{iB}). \tag{38}$$

The equilibrium quantities and prices are

$$q_{ik}^{MD} = \frac{2(1-\gamma)v - 2(3+\gamma)z_{ik} + (3+\gamma)z_{jk} + 2(1+3\gamma)z_{il} - (1+3\gamma)z_{jl}}{12(1-\gamma^2)} \tag{39}$$

and

$$p_k^{MD} = \frac{1}{12}(8v + 3z_{1k} + 3z_{2k} - z_{1l} - z_{2l}). \tag{40}$$

This leads to the equilibrium profits:

$$\pi_{Di}^{MD} = \frac{(2v + 2z_{iB} - z_{jB})^2 - 2\gamma(2v + 2z_{iB} - z_{jB})(2v - 6z_{iB} + 3z_{jB}) + (2v - 6z_{iB} + 3z_{jB})^2}{9 \cdot 4^2(1-\gamma^2)}, \tag{41}$$

and

$$\pi_M^{MD} = \frac{(2v - z_{1B})^2 + (2v - z_{2B})^2 + (z_{2B} - z_{1B})^2}{24(1+\gamma)}. \tag{42}$$

The conditions that the interior solutions indeed exist, $q_{ik}^{MD} > 0$, are

$$\gamma < \frac{2v - 6z_{ik} + 3z_{jk} + 2z_{il} - z_{jl}}{2v - 6z_{il} + 3z_{jl} + 2z_{ik} - z_{jk}} \equiv \overline{\gamma}_{ik}^{MD}. \tag{43}$$

We also have to derive the condition that the upstream firm has no incentive for deviation to the other price (see Appendix B). Hence, the condition for the equilibrium is $\gamma < \min\{\overline{\gamma}_{ik}^{MD}, \overline{\gamma}_d^{MD}\}$.

Appendix B: Conditions that upstream firms do not deviate

So far, we assume that the upstream firms determine their input prices such that the downstream firm can produce both of the final goods. Since the downstream firms are MPFs, their input demand functions are kinked. The upstream firms under the kinked input demand may find the deviation beyond the kinked point profitable. In this section, we derive the conditions that such deviations are unprofitable for them.

In the case of exclusive suppliers, given the input price of $U1$, $U2$ faces the following problem,

$$\max_{w_2} \; w_2 q_{2A}|_{w_1 = w_1^E} \;\; s.t \;\; q_{2B}|_{w_1 = w_1^E} \leq 0.$$[25]

[25] We check whether $U2$ deviate or not, because $U2$ tends to deviate than $U1$.

The problem reflects the possibility that $U2$ may find another price profitable by giving up the input demand from the non-core product. Define π^E_{U2d} as the solution above, and therefore the no deviation condition for the exclusive supplier is $\pi^E_{U2} > \pi^E_{U2d}$, or

$$\gamma < \frac{320v(5v + 2z_{1B} - 7z_{2B}) + 289z_{1B}^2 - 1348z_{1B}z_{2B} + 1684z_{2B}^2 - 120\sqrt{2}(2z_{2B} - z_{1B})(10v + 2z_{1B} - 7z_{2B})}{80v(20v - 7z_{1B} + 2z_{2B}) - 401z_{1B}^2 + 1772z_{1B}z_{2B} - 1796z_{2B}^2} \equiv \overline{\gamma}^E_d. \tag{44}$$

Similarly, the no deviation conditions for monopolist employing uniform pricing and discriminating pricing are, respectively,

$$\gamma < \frac{12v(v + z_{1B} - 2z_{2B}) + (7z_{2B} - 5z_{1B})(z_{1B} + z_{2B}) - 2\sqrt{3}(2z_{2B} - z_{1B})(4v - z_{1B} - z_{2B})}{12v^2 - (z_{1B} + z_{2B})^2} \equiv \overline{\gamma}^{MU}_d \tag{45}$$

and

$$\gamma < \frac{v(20v - 34z_{2B} + 14z_{1B}) + (27z_{2B}^2 - 21z_{1B}z_{2B} + 3z_{1B}^2) - 2\sqrt{69}(2v - z_{2B})(2z_{2B} - z_{1B})}{v(20v + 22z_{2B} - 14z_{1B}) - (25z_{2B}^2 - 13z_{1B}z_{2B} + z_{1B}^2)} \equiv \overline{\gamma}^{MD}_d. \tag{46}$$

Appendix C: Proofs

Proof of Proposition 1:

Differentiating π^C_{D1} with respect to z_{2B}, we have

$$\frac{d\pi^C_{D1}}{dz_{2B}} < 0 \Leftrightarrow \gamma > \frac{v - 2z_{1B} + z_{2B}}{v}.$$

This violates the interior solution condition, $q_{1B} > 0$. ■

Proof of Proposition 2:

We first show $\min\{\overline{\gamma}^C_{1A}, \overline{\gamma}^C_{1B}, \overline{\gamma}^C_{2A}, \overline{\gamma}^C_{2B}\} = \overline{\gamma}^C_{2B}$ to identify the condition for interior solution. Define $N_{iB} \equiv v - 2z_{iB} + z_{jB}$. Note that $N_{1B} > N_{2B}$, and then $\overline{\gamma}^C_{2A} > \overline{\gamma}^C_{1A}$ and $> \overline{\gamma}^C_{1B} > \overline{\gamma}^C_{2B}$. Comparing $\overline{\gamma}^C_{1A}$ and $\overline{\gamma}^C_{2B}$, we have $\overline{\gamma}^C_{1A} > \overline{\gamma}^C_{2B}$. Therefore the interior solution conditions are satisfied if and only if $\gamma < \overline{\gamma}^C_{2B}$ holds.

The difference between the profits of the downstream firms is as follows.

$$\pi^C_{D1} - \pi^C_{D2} = \frac{(z_{2B} - z_{1B})(N_{1B} + N_{2B} - 2v\gamma)}{3(1 - \gamma^2)}.$$

We can thus prove the proposition if $N_{1B} + N_{2B} - 2v\gamma > 0$. Since the expression is decreasing in γ, it suffices to show the above inequality at $\gamma = \overline{\gamma}^C_{2B}$. Substituting $\gamma = \overline{\gamma}^C_{2B}$, we have $3(z_{2B} - z_{1B}) > 0$. This shows that for any $\gamma < \overline{\gamma}^C_{2B}$, $\pi^C_{D1} > \pi^C_{D2}$. ■

Proof of Proposition 3:

We first show $\min\{\overline{\gamma}^E_{1A}, \overline{\gamma}^E_{1B}, \overline{\gamma}^E_{2A}, \overline{\gamma}^E_{2B}\} = \overline{\gamma}^E_{2B}$. Define $M_{iA} \equiv 20v + 16z_{iB} - 11z_{jB}$, $M_{iB} \equiv 20v - 44z_{iB} + 19z_{jB}$. Note that $M_{2A} > M_{1A}$ and $M_{1B} > M_{2B}$, and then $\overline{\gamma}^E_{2A} > \overline{\gamma}^E_{1A}$ and $\overline{\gamma}^E_{1B} > \overline{\gamma}^E_{2B}$. Comparing $\overline{\gamma}^E_{1A}$ and $\overline{\gamma}^E_{2B}$, we also have $\overline{\gamma}^E_{1A} > \overline{\gamma}^E_{2B}$. Therefore the interior solution conditions are satisfied if and only if $\gamma < \overline{\gamma}^E_{2B}$ holds. A few lines of computations establish that $\overline{\gamma}^E_{2B} > \overline{\gamma}^E_{d}$. Thus it is sufficient to show the proposition for $\gamma < \overline{\gamma}^E_{d}$.

Differentiating π^E_{D1} with respect to z_{2B}, we have

$$\frac{d\pi^E_{D1}}{dz_{2B}} < 0 \Leftrightarrow \gamma > \frac{80v - 506z_{1B} + 241z_{2B}}{80v + 394z_{1B} - 209z_{2B}} \equiv \underline{\gamma}^E_{\pi 1}.$$

Differentiating π^E_{D2} with respect to z_{2B}, we have

$$\frac{d\pi^E_{D2}}{dz_{2B}} < 0 \Leftrightarrow \gamma < \frac{140v + 253z_{1B} - 548z_{2B}}{140v - 197z_{1B} + 352z_{2B}} \equiv \overline{\gamma}^E_{\pi 2}.$$

We compare $\underline{\gamma}^E_{\pi 1}$ and $\overline{\gamma}^E_{\pi 2}$. A few lines of computations establish that

$$\overline{\gamma}^E_{\pi 2} > \underline{\gamma}^E_{\pi 1} \Leftrightarrow v > \frac{z_{2B}(16z_{1B} - 11z_{2B})}{10(6z_{1B} - 5z_{2B})} \equiv \hat{v}^E.$$

After some calculations, we can show that $\overline{\gamma}^E_{d}$ is greater than $\overline{\gamma}^E_{\pi 2}$, and thus $v > \hat{v}^E$ is the condition for the proposition. ■

Proof of Proposition 4:

We first show that if the technology transfer occurs, then the consumer surplus increases. The condition that the technology transfer enhances the consumer surplus is

$$\frac{dCS^E}{dz_{2B}} < 0 \Leftrightarrow \gamma < \frac{16v - 13(z_{1B} + z_{2B})}{16v + 5(z_{1B} + z_{2B})} \equiv \overline{\gamma}_{CS}.$$

Proposition 3 shows that the technology transfer can occur if and only if $\gamma \in (\underline{\gamma}^E_{\pi 1}, \overline{\gamma}^E_{\pi 2})$. Hence, we will show $\overline{\gamma}_{CS} > \overline{\gamma}^E_{\pi 2}$. Define $T_1 \equiv 140v + 253z_{1B} - 548z_{2B}$ and $T_2 \equiv 140v - 197z_{1B} + 352z_{2B}$. We have

$$
\begin{aligned}
\overline{\gamma}_{CS} - \overline{\gamma}^{E}_{\pi 2} &= \frac{108(110vz_{2B} - 90vz_{1B} - 17z_{2B}^2 - 5z_{1B}z_{2B} + 12z_{1B}^2)}{[16v + 5(z_{1B} + z_{2B})]T_2} \\
&= \frac{108[90v(z_{2B} - z_{1B}) + 17z_{2B}(v - z_{2B}) + 3vz_{2B} - 5z_{1B}z_{2B} + 12z_{1B}^2]}{[16v + 5(z_{1B} + z_{2B})]T_2} \\
&> \frac{108[90v(z_{2B} - z_{1B}) + 17z_{2B}(v - z_{2B}) + 3z_{2B}^2 - 5z_{1B}z_{2B} + 12z_{1B}^2]}{[16v + 5(z_{1B} + z_{2B})]T_2} \\
&= \frac{108[90v(z_{2B} - z_{1B}) + 17z_{2B}(v - z_{2B}) + 3(z_{2B} - \frac{5}{6}z_{1B})^2 + \frac{119}{12}z_{1B}^2]}{[16v + 5(z_{1B} + z_{2B})]T_2} > 0.
\end{aligned}
$$

We next show that if the technology transfer occurs, then social welfare increases. The condition that the technology transfer enhances social welfare is

$$\frac{dW^E}{dz_{2B}} < 0 \Leftrightarrow \gamma < \frac{280v + 407z_{1B} - 727z_{2B}}{280v - 223z_{1B} + 263z_{2B}} \equiv \overline{\gamma}_W.$$

Hence we will show $\overline{\gamma}_W > \overline{\gamma}^E_{\pi 2}$.

$$
\begin{aligned}
\overline{\gamma}_W - \overline{\gamma}^E_{\pi 2} &= \frac{(280v + 407z_{1B} - 727z_{2B})T_2 - (280v - 223z_{1B} + 263z_{2B})T_1}{(280v - 223z_{1B} + 263z_{2B})T_2} \\
&= \frac{540[(z_{2B} - z_{1B})(70v - 67z_{2B}) + 140z_{2B}(v - z_{2B}) + z_{1B}(114z_{2B} - 44z_{1B})]}{(280v - 223z_{1B} + 263z_{2B})T_2} > 0,
\end{aligned}
$$

which proves the proposition. ■

Proof of Proposition 5:

Comparing the profits of the downstream firms, we have

$$\pi^E_{D2} > \pi^E_{D1} \Leftrightarrow \gamma > \frac{16v - 19(z_{1B} + z_{2B})}{16v + 11(z_{1B} + z_{2B})} \equiv \underline{\gamma}^E.$$

Now we show that there exists γ satisfying both the above condition and the interior solution condition.

$$\overline{\gamma}^E_d > \underline{\gamma}^E \Leftrightarrow v > \frac{(z_{1B} + z_{2B})[(43 - 24\sqrt{2})z_{2B} - (11 - 9\sqrt{2})z_{1B}]}{82z_{1B} - (60\sqrt{2} - 46)z_{2B}} \equiv \underline{v}^E.$$

This yields the condition for the proposition. ■

Proof of Proposition 6:

The proof follows the lines of the proof of Proposition 1. Define $E_A \equiv 4v + z_{1B} + z_{2B}$, $E_{iB} \equiv 4v - 15z_{iB} + 9z_{jB}$. We first show $\min\{\overline{\gamma}_{1A}^{MU}, \overline{\gamma}_{1B}^{MU}, \overline{\gamma}_{2A}^{MU}, \overline{\gamma}_{2B}^{MU}\} = \overline{\gamma}_{2B}^{MU}$. Note that $E_{1B} > E_{2B}$, and therefore $\overline{\gamma}_{2A}^{MU} > \overline{\gamma}_{1A}^{MU}$ and $\overline{\gamma}_{1B}^{MU} > \overline{\gamma}_{2B}^{MU}$. We then compare $\overline{\gamma}_{1A}^{MU}$ and $\overline{\gamma}_{2B}^{MU}$,

$$\overline{\gamma}_{1A}^{MU} - \overline{\gamma}_{2B}^{MU} = \frac{(E_A - E_{2B})E_A - (E_{1B} - E_A)E_{2B}}{E_A E_{1B}}.$$

Since $E_A > E_{2B}$ and $E_A - E_{2B} > E_{1B} - E_A$, thus $\overline{\gamma}_{1A}^{MU} > \overline{\gamma}_{2B}^{MU}$. Therefore the interior solution conditions are satisfied if and only if $\gamma < \overline{\gamma}_{2B}^{MU}$ holds. (since we can confirm $\overline{\gamma}_{2B}^{MU} > \overline{\gamma}_{d}^{MU}$, it is sufficient to show the proposition for $\gamma < \overline{\gamma}_{2B}^{MU}$.)

Differentiating π_{D1}^{MU} with respect to z_{2B}, we have

$$\frac{d\pi_{D1}^{MU}}{dz_{2B}} < 0 \Leftrightarrow \gamma > \frac{E_A + 9E_{1B}}{E_{1B} + 9E_A} \equiv \underline{\gamma}_{\pi 1}^{MU}.$$

We now show that the above condition violates the interior solution condition.

$$\underline{\gamma}_{\pi 1}^{MU} - \overline{\gamma}_{2B}^{MU} = \frac{9E_A(E_{1B} - E_{2B}) + E_A^2 - E_{1B}E_{2B}}{E_A(E_{1B} + 9E_A)} > 0,$$

which proves the proposition. ($\overline{\gamma}_{1A}^{MU} > \overline{\gamma}_{2B}^{MU}$ implies $E_A^2 - E_{1B}E_{2B} > 0$) ■

Proof of Proposition 7:

The proof follows the lines of the proof of Proposition 2. Comparing the profits of the downstream firms, we have

$$\pi_{D1}^{MU} - \pi_{D2}^{MU} = \frac{(E_{1B} - E_{2B})(E_{1B} + E_{2B} - 2\gamma E_A)}{9 \cdot 8^2(1 - \gamma^2)}.$$

We can prove the proposition if $E_{1B} + E_{2B} - 2\gamma E_A > 0$. Since the expression is decreasing in γ, it suffices to show this at $\gamma = \overline{\gamma}_{2B}^{MU}$. Substituting $\gamma = \overline{\gamma}_{2B}^{MU}$, we have $E_{1B} - E_{2B} > 0$. This shows that for any $\gamma < \overline{\gamma}_{2B}^{MU}$, $\pi_{D1}^{MU} > \pi_{D2}^{MU}$. ■

Proof of Proposition 8:

The proof follows the lines of the proof of Proposition 1. Differentiating π_{D1}^{MD} with respect to z_{2B}, we have

$$\frac{d\pi_{D1}^{MD}}{dz_{2B}} < 0 \Leftrightarrow \gamma > \frac{2v - 10z_{1B} + 5z_{2B}}{2v + 6z_{1B} - 3z_{2B}} \equiv \underline{\gamma}_{\pi 1}^{MD}.$$

Differentiating π_{D2}^{MD} with respect to z_{2B}, we have

$$\frac{d\pi_{D2}^{MD}}{dz_{2B}} < 0 \Leftrightarrow \gamma < \frac{2v + 5z_{1B} - 10z_{2B}}{2v - 3z_{1B} + 6z_{2B}} \equiv \overline{\gamma}_{\pi 2}^{MD}.$$

Now we show there does not exist γ satisfying the above conditions. Since $2v - 10z_{1B} + 5z_{2B} > 2v + 5z_{1B} - 10z_{2B}$ and $2v - 3z_{1B} + 6z_{2B} > 2v + 6z_{1B} - 3z_{2B}$, thus $\underline{\gamma}_{\pi 1}^{MD} > \overline{\gamma}_{\pi 2}^{MD}$, which proves the proposition. ■

Proof of Proposition 9:

The proof follows the lines of the proof of Proposition 5. Define $H_{iA} \equiv 2v + 2z_{iB} - z_{jB}$, $H_{iB} \equiv 2v - 6z_{iB} + 3z_{jB}$. We first show $\min\{\overline{\gamma}_{1A}^{MD}, \overline{\gamma}_{1B}^{MD}, \overline{\gamma}_{2A}^{MD}, \overline{\gamma}_{2B}^{MD}\} = \overline{\gamma}_{2B}^{MD}$. Note that $H_{2A} > H_{1A}$ and $H_{1B} > H_{2B}$, and thus $\overline{\gamma}_{2A}^{MD} > \overline{\gamma}_{1A}^{MD}$ and $\overline{\gamma}_{1B}^{MD} > \overline{\gamma}_{2B}^{MD}$. We then compare $\overline{\gamma}_{1A}^{MD}$ and $\overline{\gamma}_{2B}^{MD}$,

$$\overline{\gamma}_{1A}^{MD} - \overline{\gamma}_{2B}^{MD} = \frac{(H_{1A} - H_{2B})H_{2A} - (H_{1B} - H_{2A})H_{2B}}{H_{2A}H_{1B}}.$$

Since $H_{2A} > H_{2B}$ and $H_{1A} - H_{2B} > H_{1B} - H_{2A}$, $\overline{\gamma}_{1A}^{MD} > \overline{\gamma}_{2B}^{MD}$. Therefore the interior solution conditions are satisfied if and only if $\gamma < \overline{\gamma}_{2B}^{MD}$ holds.

We next show $\overline{\gamma}_{2B}^{MD} \geq \overline{\gamma}_{d}^{MD}$, which implies the no deviation condition assures the interior solution.

$$\overline{\gamma}_{2B}^{MD} - \overline{\gamma}_{d}^{MD} = \frac{2(z_{2B} - z_{1B})(2v - z_{2B})[2(\sqrt{69} - 3)v + (9 - \sqrt{69})z_{1B} - 2(12 - \sqrt{69})z_{2B}]}{H_{2A}[v(20v + 22z_{2B} - 14z_{1B}) - (25z_{2B}^2 - 13z_{1B}z_{2B} + z_{1B}^2)]} > 0.$$

Comparing the profits of the downstream firms, we have

$$\pi_{D2}^{MD} > \pi_{D1}^{MD} \Leftrightarrow \gamma > \frac{4v - 5z_{1B} - 5z_{2B}}{4v + 3z_{1B} + 3z_{2B}} \equiv \underline{\gamma}^{MD}$$

Finally, we show there exists γ satisfying the above condition and the no deviation condition. With some algebra, we obtain the condition for the proposition,

$$\overline{\gamma}_{d}^{MD} > \underline{\gamma}^{MD} \Leftrightarrow v > \frac{[2(17 - \sqrt{69})z_{2B} - (5 + \sqrt{69})z_{1B}](z_{1B} + z_{2B})}{4[22z_{1B} - (3\sqrt{69} - 7)z_{2B}]} \equiv \underline{v}^{MD}.$$

■

References

[1] Ahmadjian, C. L., Oxley, J. E., 2013. Vertical Relationships, Hostages, and Supplier Performance: Evidence from the Japanese Automotive Industry. Journal of Law, Economics and Organization 29, 485-512.

[2] Arya, A., Mittendorf, B., 2010. Input Price Discrimination When Buyers Operate in Multiple Markets. Journal of Industrial Economics 58, 846-867.

[3] Arya, A., Mittendorf, B., 2011. Supply Chains and Segment Profitability: How Input Pricing Creates a Latent Cross-Segment Subsidy. Accounting Review 86(3), 805-824.

[4] Bailey, E. E., Friedlaender, A. F., 1982. Market Structure and Multiproduct Industries. Journal of Economic Literature 20, 1024-1048.

[5] Bernard, A., Redding, S., Schott, P., 2010. Multiple-Product Firms and Product Switching. American Economic Review 100(1), 70-97.

[6] Bernard, A., Redding, S., Schott, P., 2011. Multiproduct Firms and Trade Liberalization. Quarterly Journal of Economics 126, 1271-1318.

[7] Brander, J. A., Eaton, J., 1984. Product Line Rivalry. American Economic Review 74(3), 323-334.

[8] Creane, A., Konishi, H., 2009. The Unilateral Incentives for Technology Transfers: Predation (and Deterrence) by Proxy. International Journal of Industrial Organization 27(3), 379-389.

[9] Cusumano, M. A., Takeishi, A., 1991. Supplier Relations and Management: A Survey of Japanese, Japanese-transplant, and U.S. Auto Plants. Strategic Management Journal 12(8), 563-588.

[10] DeGraba, P., 1990. Input Market Price Discrimination and the Choice of Technology. American Economic Review 80(5), 1246-1253.

[11] Dyer, J., 1996. Specialized Supplier Networks as a Source of Competitive Advantage: Evidence from the Auto Industry. Strategic Management Journal 17, 271-292.

[12] Eckel, C., Neary, P. J., 2010. Multi-product Firms and Flexible Manufacturing in the Global Economy. Review of Economic Studies 77, 188-217.

[13] Ghosh, A., Morita, H., 2012. Knowledge Transfer and Partial Equity Ownership. UNSW Australian School of Business Research Paper, No. 2012 ECON 18, University of New South Wales.

[14] Helper, S., Sako, M., 1995. Supplier Relations in Japan and the United States: Are They Converging? Sloan Management Review 36 (3), 77-84.

[15] Ishikawa, J., Horiuchi, E., 2012. Strategic Foreign Direct Investment in Vertically Related Markets. Economic Record 88, 229-242.

[16] Johnson, J. P., Myatt, D. P., 2003. Multiproduct Quality Competition: Fighting Brands and Product Line Pruning. American Economic Review 93(3), 748-774.

[17] Johnson, J. P., Myatt, D. P., 2006. Multiproduct Cournot Oligopoly. RAND Journal of Economics 37(3), 583-601.

[18] Kogut, B., 1988. Joint Ventures: Theoretical and Empirical Perspectives. Strategic Management Journal 9, 319-332.

[19] Lahiri, S., Ono, Y., 1988. Helping Minor Firms Reduces Welfare. Economic Journal 98(393), 1199-1202.

[20] Lin, P., Saggi, K., 1999. Incentives for Foreign Direct Investment under Imitation. Canadian Journal of Economics 32, 1275-1298.

[21] Lin, P., Zhou, W., 2013. The Effects of Competition on the R&D Portfolios of Multiproduct Firms. International Journal of Industrial Organization 31, 83-91.

[22] Marjit, S., 1990. On a Non-cooperative Theory of Technology Transfer. Economics Letters 33, 293-298.

[23] Matsushima, N., Ogawa, S., 2012. Profit-enhancing Know-how Disclosure: A Strategic View. The Manchester School 80(5), 560-579.

[24] Matsushima, N., Zhao, L., 2015. Strategic Dual Sourcing as a Driver for Free Revealing of Innovation. ISER Discussion Paper No. 936, Institute of Social and Economic Research, Osaka University.

[25] Milliou C., Petrakis, E., 2012. Vertical Integration, Knowledge Disclosure and Decreasing Rival's Cost. Economics Working Papers 12-13, Universidad Carlos III de Madrid, Departamento de Economía.

[26] Morita, H., 2001. Partial Ownership induces Customised Investments under Repeated Interaction: An Explanation of Japanese Manufacturer-suppliers Relationships. Scottish Journal of Political Economy 48, 345-359.

[27] Morita, H., Hayashi, S., Arai, K., Nishimura, M., 2010. Kigyou no Teikei Bubuntekiketsugou ni Kansuru Kenkyu. (in Japanese) CR02-10, Competition Policy Research Center, Japan Fair Trade Commission.

[28] Mowery, D. C., 1983. The Relationship between Intrafirm and Contractual Forms of Industrial Research in American Manufacturing, 1900-1940. Explorations Economic History 20, 351-374.

[29] Mukherjee, A., Pennings, E., 2011. Unionization Structure, Licensing and Innovation. International Journal of Industrial Organization 29, 232-241.

[30] Nishiguchi, T., 1994. Strategic Industrial Sourcing: The Japanese Advantage. Oxford University Press, New York.

[31] Nobeoka, K., 1996. Alternative Component Sourcing Strategies within the Manufacturer-supplier Network: Benefits of Quasi-market Strategy in the Japanese Automobile Industry. Kobe Economic and Business Review 41, 69-99.

[32] Schrader, S., 1991. Informal Technology Transfer between Firms: Cooperation through Information Trading. Research Policy 20(2), 153-170.

[33] Sen, D., Stamatopoulos, G., 2015. When an Inefficient Competitor Makes Higher Profit than its Efficient Rival. Operations Research Letters 43, 148-150.

[34] Suzuki, K., 1993. R&D Spillovers and Technology Transfer among and within Vertical Keiretsu Groups: Evidence from the Japanese Electrical Machinery Industry. International Journal of Industrial Organization 11, 573-591.

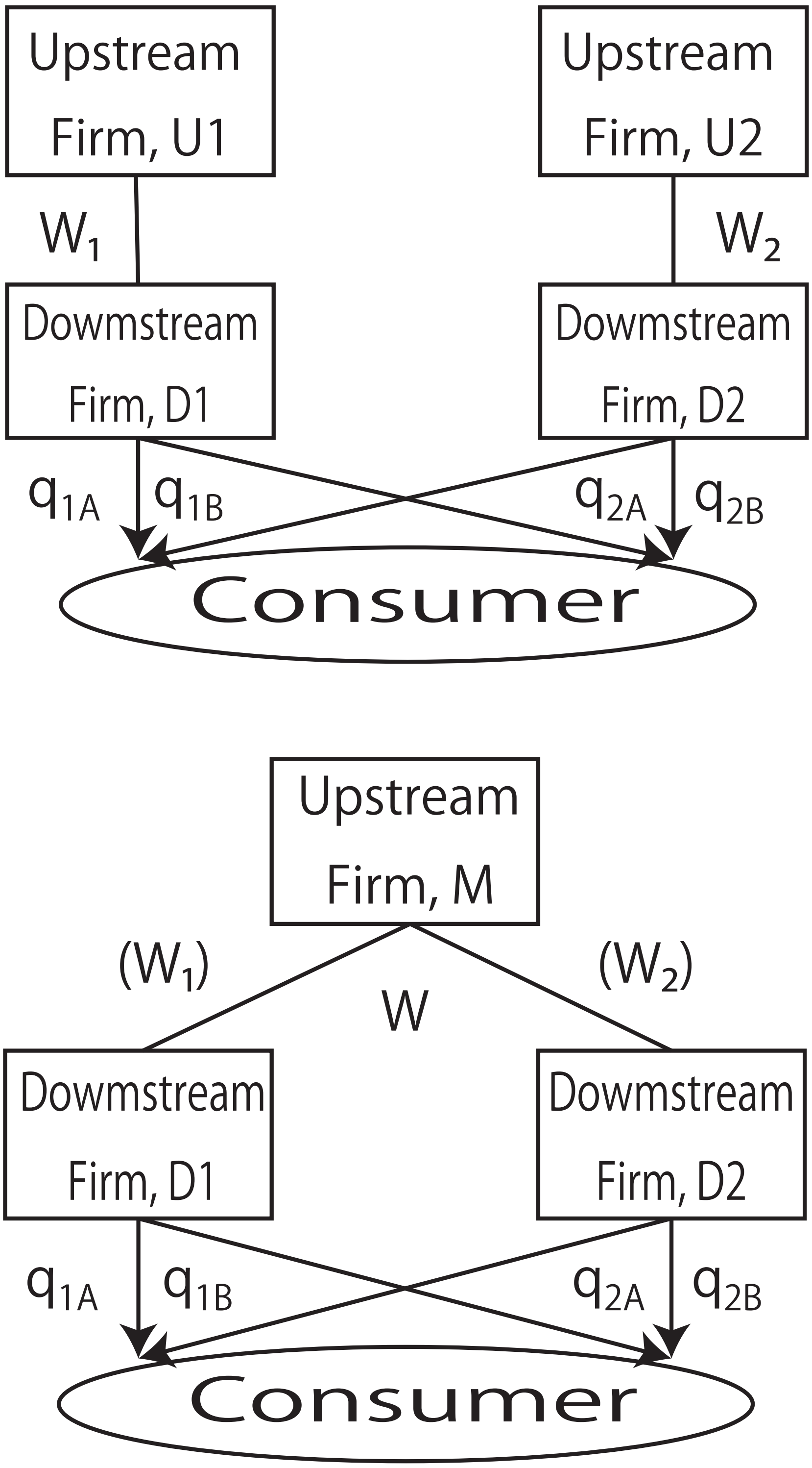

Figure 1: The structure of the model.
Top: exclusive suppliers
Bottom: monopolist employing uniform (discriminatory) pricing

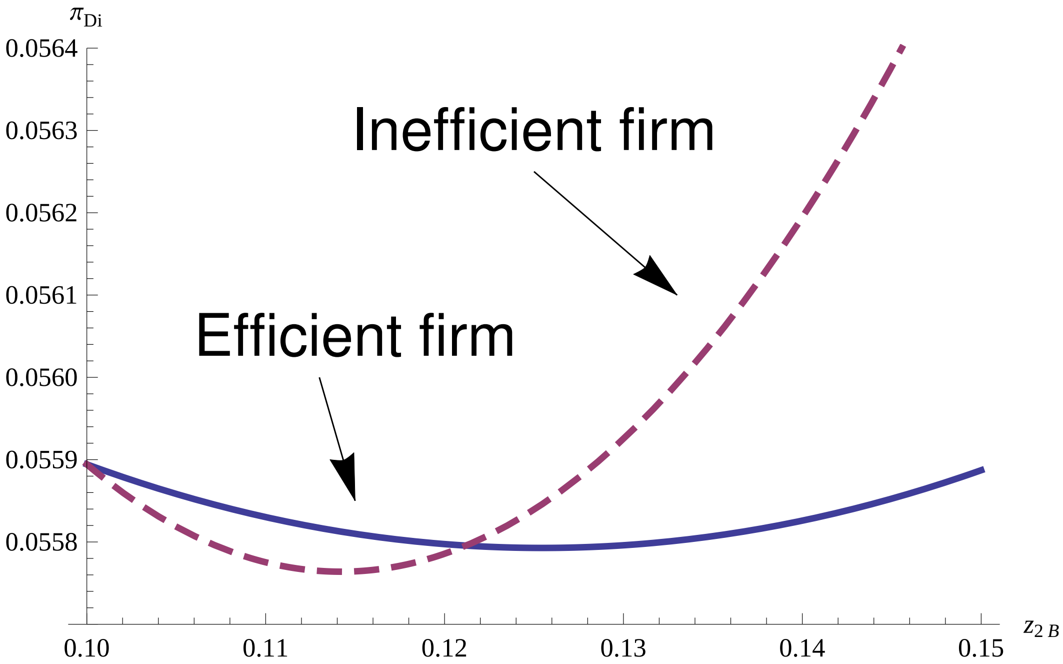

Figure 2: The relations between profits and z_{2B} (Exclusive suppliers case).
Solid (dotted) line shows the profit of the (in)efficient firm
[$v = 1, z_{1B} = 0.1, \gamma = 0.64$]

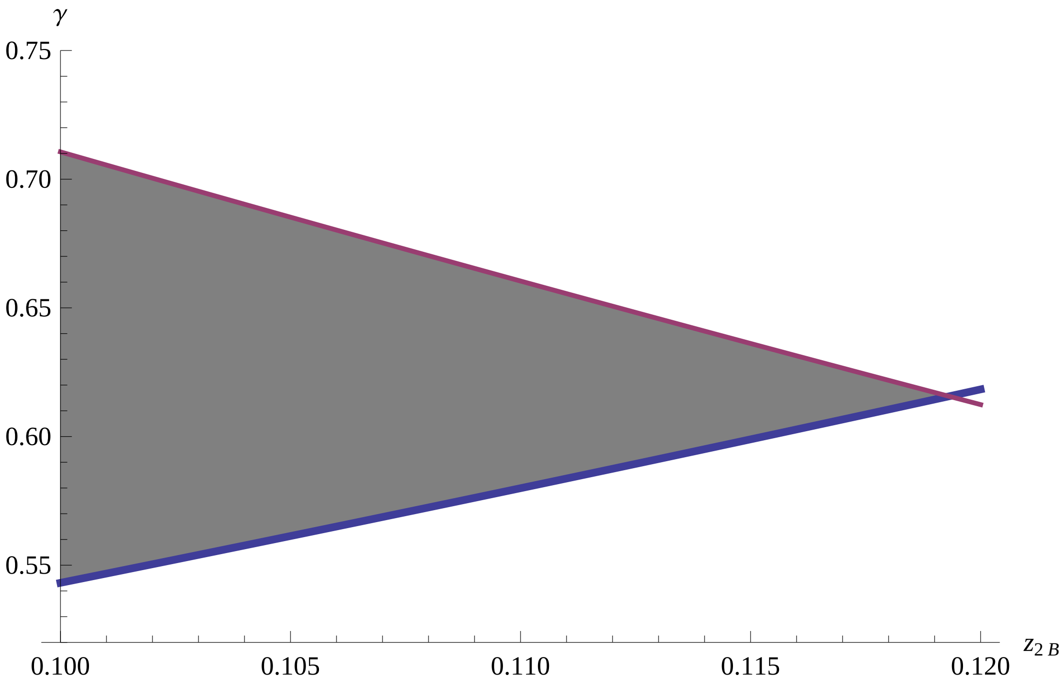

Figure 3: The condition under which the technology transfer raises the downstream firms' profits (Exclusive suppliers case).
[$v = 1, z_{1B} = 0.1$]

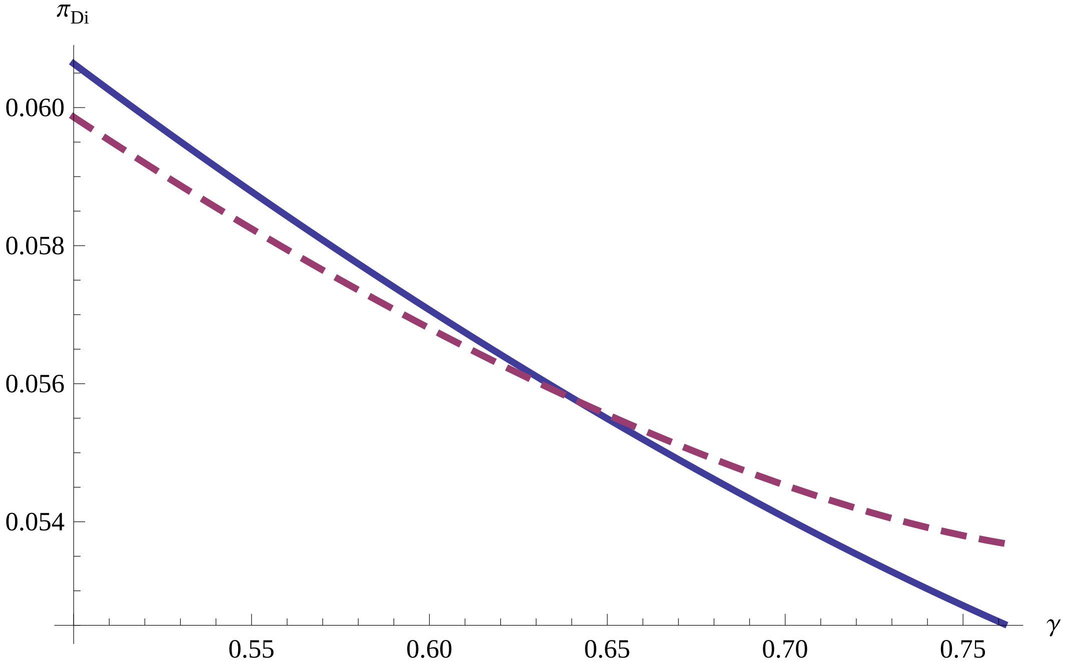

Figure 4: The relations between profits and γ (Exclusive suppliers case).
[$v = 1, z_{1B} = 0.1, z_{2B} = 0.12$]

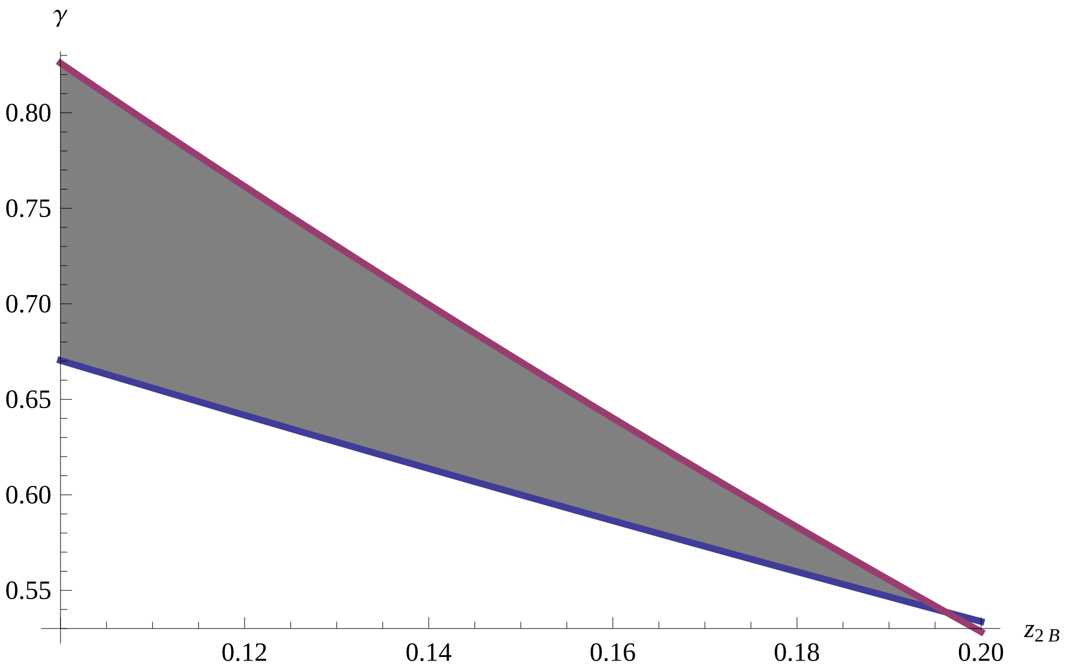

Figure 5: The condition under which the inefficient firm earns more profit (Exclusive suppliers case).
[$v = 1, z_{1B} = 0.1$]

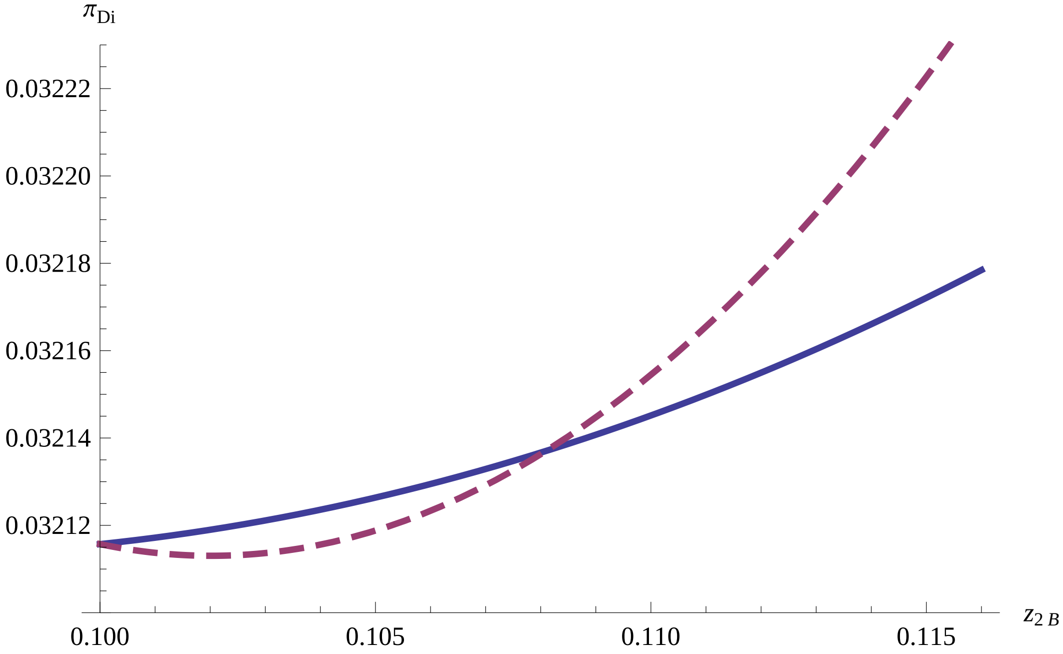

Figure 6: The relations between profits and z_{2B} (Discriminatory monopolist case).
[$v = 1, z_{1B} = 0.1, \gamma = 0.64$]

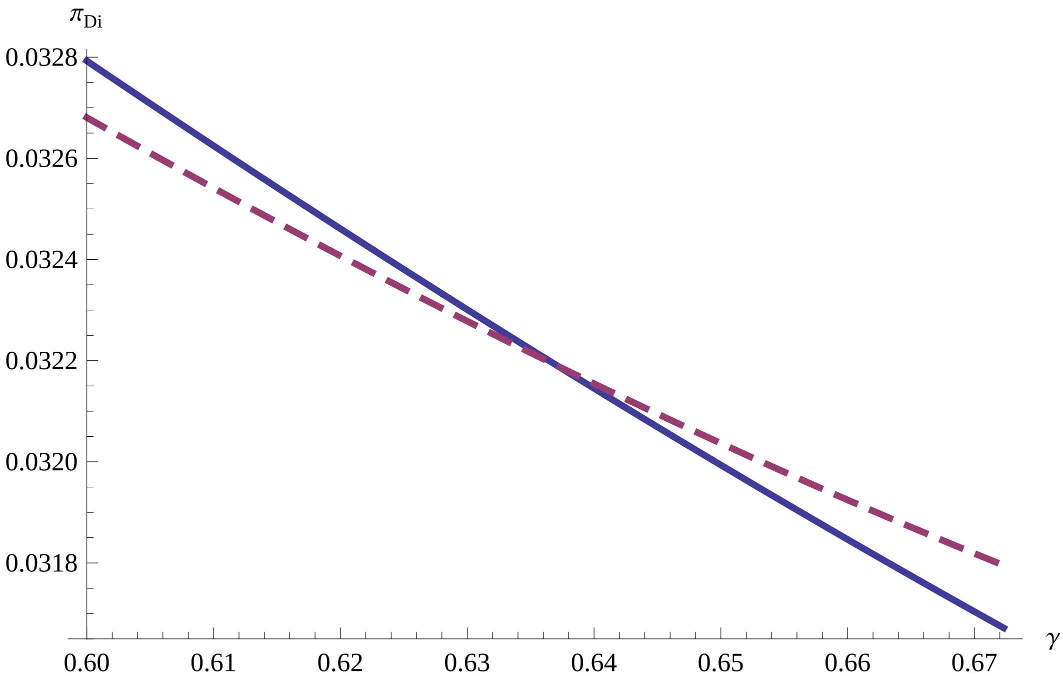

Figure 7: The relations between profits and γ (Discriminatory monopolist case).
[$v = 1, z_{1B} = 0.1, z_{2B} = 0.11$]

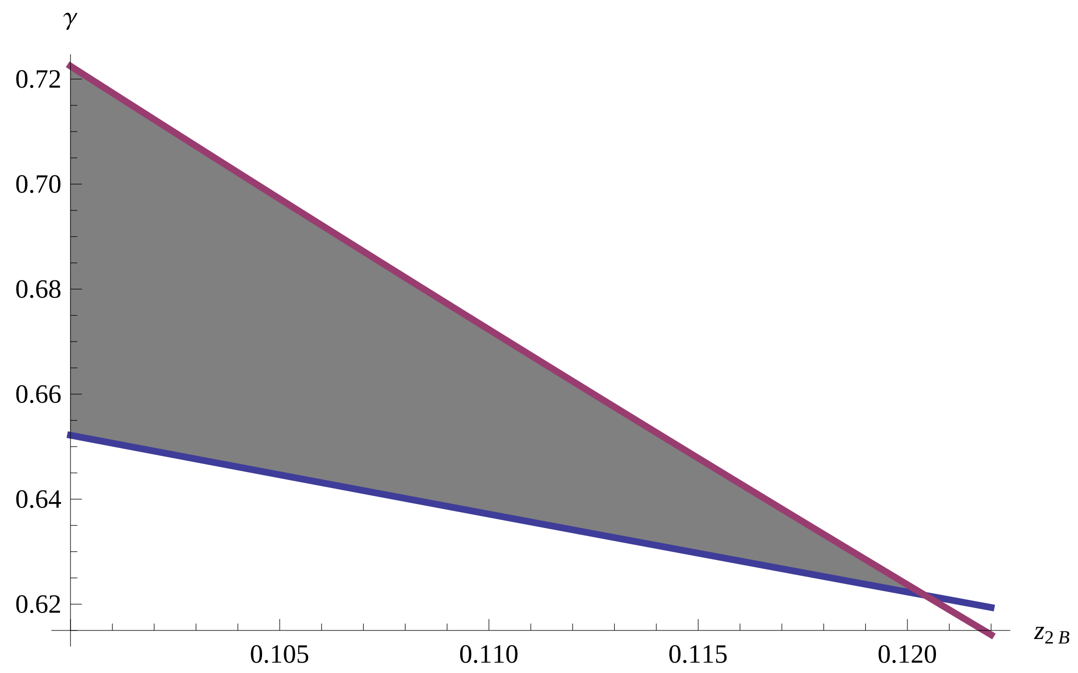

Figure 8: The condition under which the inefficient firm earns more profit (Discriminatory monopolist case).

$[\ v = 1, z_{1B} = 0.1]$

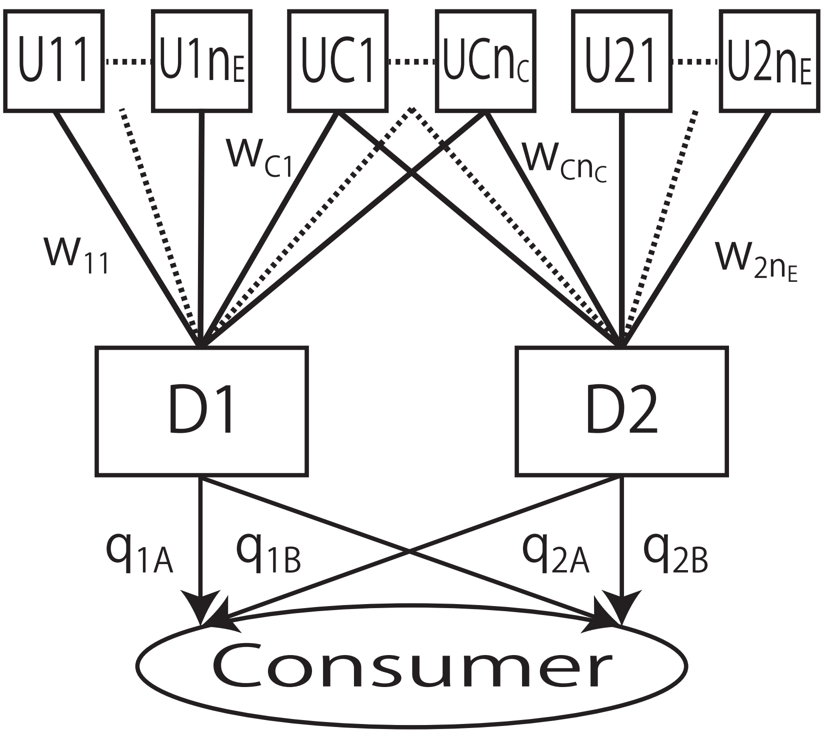

Figure 9: The structure of the extended model (Many suppliers case).

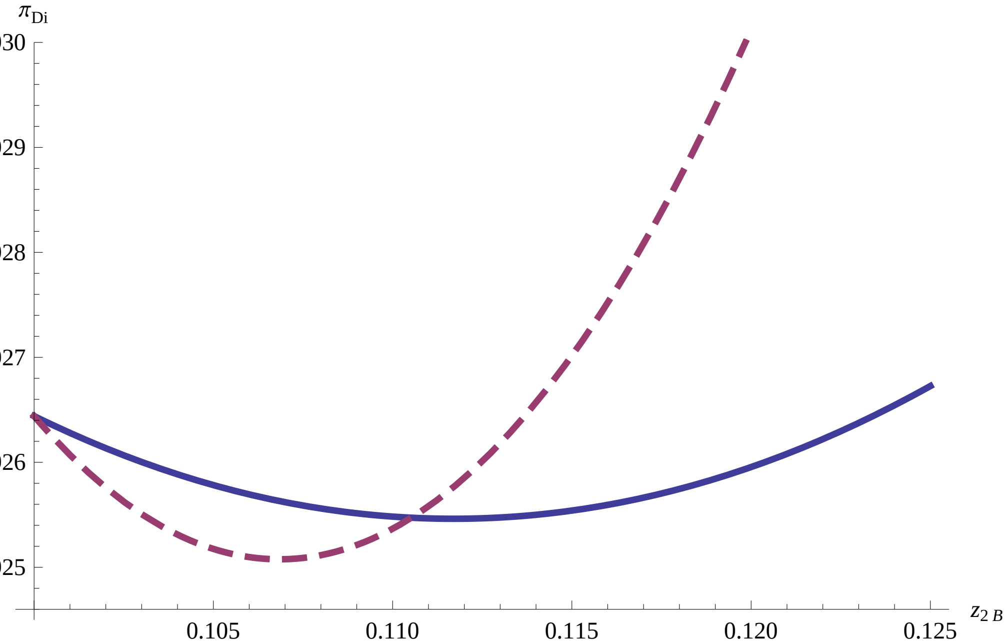

Figure 10: The relations between profits and z_{2B} (Many suppliers case).
$[\, v = 1, z_{1B} = 0.1, \gamma = 0.2, n_C = 1, n_E = 2]$

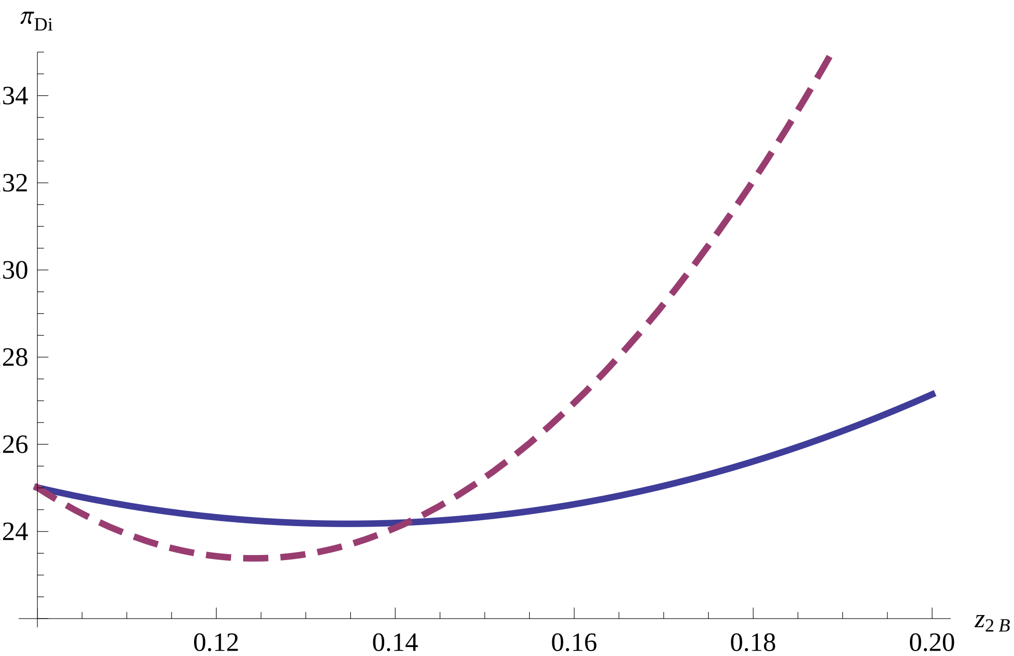

Figure 11: The relations between profits and z_{2B} (Many suppliers case).
$[\, v = 100, z_{1B} = 0.1, \gamma = 0.2, n_C = 8, n_E = 30]$