Essays on Foreign Direct Investment and Entry Behaviour

by

Kazutaka Takechi

B.A., Waseda University, 1997

M.A., University of Tokyo, 1999

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

in

THE FACULTY OF GRADUATE STUDIES

(Department of Economics)

We accept this thesis as conforming

to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

September 2004

Abstract

This thesis consists of three essays that contribute to international trade and industrial organization.

The first essay investigates the extent to which R&D expenditure differences are caused by different foreign expansion decisions, namely export and Direct Investment Abroad (DIA). We adopt an international oligopoly specification that takes into account the effects of competitors' foreign expansion strategy on R&D, in which the R&D decision is endogenized. Then, this paper uses a panel data set of Japanese electronics firms to study not only the effect of own DIA but also that of other firms' DIA on own R&D. We find that the endogenous R&D model is supported by the empirical evidence. Our data support the predictions of the model associated with the level of technology transfer costs, which suggest that transfer costs are high for Asian and low for North American countries.

The second essay examines whether direct investment in distribution leads to manufacturing direct investment. The primary purpose of direct investment in distribution is to promote exports. However, by engaging in economic activities, multinational firms can learn about local markets. This might increase benefits from manufacturing direct investment. By using data on Japanese electronics firms, we find that there exists a learning effect of distribution direct investment in Asia. In other words, distribution direct investment increases the probability of manufacturing investment. This suggests that distribution affiliates are important in learning about local markets prior to setting up manufacturing affiliates due to the high uncertainty of Asian markets.

The third essay investigates the credibility of an incumbent introducing a new product for entry deterrence in a vertically differentiated good model. We show that if market size and quality dispersion are extremely large or small, such behaviour is not credible. Entry is either accommodated or blockaded depending only on entry costs. However, if market size and quality dispersion are intermediate, new good production can be a credible threat, since the effect of expanding the market share dominates the price competition effect. In this case, prohibition of new product introduction improves welfare.

Contents

List of Tables

List of Figures

Acknowledgements

I am greatly indebted to my thesis committee member, Professor Brian Copeland, Professor Keith Head, Professor John Ries, and Professor Art Shneyerov. I would like to thank Professor Mukesh Eswaran, Professor Patrick Francois, Professor Parikshit Ghosh, Professor David Green, Professor Richard Harris, Professor Keisaku Higashida, Professor Kazuharu Kiyono, Professor Ashok Kotwal, Professor Thomas Lemieux, Professor Shinichi Sakata, Professor Guofu Tan, and Professor Okan Yilankaya for helpful suggestions and discussions at various stages of this dissertation. I am also grateful to my classmates, colleagues and friends for helpful suggestions and discussions. I am solely responsible for any errors and misinterpretations.

To My Parents

Chapter 1

Overview and Summary

This thesis consists of three essays that contribute to international trade and industrial organization.

Essay 1. R&D Effects of Overseas Investment: Evidence from Japanese Electronics Firms

In the first essay, we examine the effects of direct investment abroad (DIA) on the R&D decision. R&D by multinationals is a major concern for policy makers in countries with a large outward direct investment such as Japan and Sweden. Due to the presence of technology transfer and trade costs, it is unclear whether multinationals conduct more process R&D than exporters.

This essay develops an international oligopoly model to examine the effect of DIA on the R&D decisions of Japanese electronic firms, where the R&D decision is endogenous. Unlike previous papers, which consider a single multinational enterprise or a multinational duopoly model, our framework allows us to consider the effects of competitors'

DIA decisions on the R&D of firms.

We test the propositions of our model using data on the direct investment of 141 electronic firms over the period between 1987 and 1998. Our empirical analysis is the first attempt to show how the competitors' DIA effect on R&D is related to trade and technology transfer costs. Without considering the competitors' DIA effect, we cannot discern regionally different results of the effect of DIA. By taking into account the competitors' effect, we find that the empirical results are consistent with the sign pattern of the endogenous R&D model. The effects of direct investment depend on the destinations of direct investment, since trade and technology transfer costs are considered to be different across regions.

Essay 2. Learning by Investing Abroad: Does Distribution Direct Investment Lead to Manufacturing Direct Investment?

There are advantages of having own wholesalers or retailers in foreign markets. These can provide good customer service and circumvent inefficient transactions of arm's-length contract. In fact, Japanese firms invest in the distribution sector in order to promote export sales in foreign markets. Since these firms engage in economic activities in local markets, they often know more about local markets than pure exporters. This knowledge might increase benefits from investing in manufacturing by resolving uncertainty.

This essay examines whether direct investment in distribution leads to manufacturing direct investment. In order to isolate the learning effect from a spurious correlation between distribution and manufacturing direct investments, we need to consider three factors: unobserved heterogeneity, state dependence, and serial correlation. To examine

the robustness of the identification of the learning effect, we use two empirical specifications. One is a linear probability model and the other one is a random effects probit model.

Our data support that there exists a learning effect of distribution direct investment in Asian countries, but not in North American or European countries. This might reflect the fact that uncertainty about Asian markets is higher than that about North American or European markets due to low transparency of economic policy or low political stability. Hence, our findings suggest that in the presence of a high degree of uncertainty, distribution direct investment plays an important role in the decision to build manufacturing operations. Also, our findings suggest that the effect of distribution direct investment goes beyond borders in Asia.

Essay 3. Brand Proliferation and Entry Deterrence under Vertical Differentiation

The third essay is a theoretical research to study an incumbent's behaviour that reduces competition by using one's dominant position in the market. More specifically, we will focus on the use of fighting brands, introduced selectively on a temporary basis, to discipline or eliminate a competitor. We investigate the credibility of an incumbent introducing a new product for entry deterrence in a vertically differentiated good model.

We show that if market size and quality dispersion are either extremely large or small, such behaviour is not credible. Entry is either accommodated or blockaded, depending only on entry costs. However, if market size and quality dispersion are intermediate, new good production can be a credible threat. In this case, prohibition of the introduction of the new product by the incumbent will improve welfare.

Chapter 2

R&D Effects of Overseas Investment: Evidence from Japanese Electronics Firms

2.1 Introduction

R&D by parent firms of multinationals is a major concern for policy makers in countries with a large outward direct investment such as Japan and Sweden.[1] Also, it is often documented in the literature that multinational firms are more R&D intensive than exporters (see for example Markusen (1995)). Therefore, it is important to examine what kinds of elements affect R&D activities of multinational firms and cause differences in R&D between multinationals and exporters. Due to the presence of transportation costs,

[1]For Sweden, see Fors (1997).

exporters and multinationals who serve foreign consumers by setting up local factories have different market shares (level of sales). Differences in market shares (output levels) affect the incentives to conduct process R&D – research aimed at lowering production costs. Namely, the larger a firm's market share, the higher the returns to process R&D. If it is difficult to transfer process R&D innovations to foreign affiliates, however, then the returns to such investment are lowered. In the presence of technology transfer and trade costs, it is unclear whether multinationals conduct more process R&D than exporters.

This paper examines the effect of direct investment abroad (DIA) on the R&D decisions of Japanese electronics firms by focusing on strategic interactions and trade and technology transfer costs. It extends the theoretical results of Petit and Sanna-Randaccio (1998, 2000) and Norback (2001) to an oligopolistic setting. Unlike previous papers, which consider a single multinational enterprise or a multinational duopoly model, our framework allows us to consider the effects of competitors' DIA decisions on the R&D of firms. We test the propositions of our model using data on the direct investment of 141 electronic firms over the period between 1987 and 1998 mainly in two different markets, North America and Asia. We find that the endogenous R&D model is supported by the empirical evidence.

We make two main contributions to the literature. First, our empirical analysis is the first attempt to show how the competitors' DIA effect on R&D is related to trade and technology transfer costs. This point is neglected by the previous empirical literature such as Brainard (1997) and Norback (2001). Second, we find that the effects of DIA on R&D depend on the destinations of DIA. We allow the coefficient of DIA to be region-specific in our regression analysis. We treat Asia as a region of high trade and

technology transfer costs and North America as a region of low trade and technology transfer costs. The endogenous R&D model predicts different coefficient signs depending on whether trade and technology transfer costs are high (Asia) or low (North America). The empirical results are consistent with the sign pattern of the endogenous R&D model. Our data support the predictions of the model associated with the level of technology transfer costs, which suggest that transfer costs are high for Asian and low for North American countries. Since only theoretical studies of the oligopolistic endogenous R&D model have been done, an empirical examination is new.

Our study extends an analysis that allows DIA to influence the level of process R&D aimed at lowering production costs. Petit and Sanna-Randaccio (1998) and Norback (2001) show that in an international monopoly model, if technology transfer costs are low, a multinational firm spends more R&D than an exporter; however, if these are high enough, a multinational firm spends less R&D than an exporter. Since multinationals can save trade costs, when technology transfer costs are low, multinationals have a better market access than exporters (proximity). Low technology transfer costs enable multinationals to share the outcome of R&D in source and host countries' plants. Hence, while marginal costs of R&D are the same, the marginal return of R&D for multinationals is higher than that for exporters, resulting in higher multinational firms' R&D spending. When technology transfer costs are high enough to offset this trade cost-saving advantage, multinationals spend less R&D than exporters. Petit and Sanna-Randaccio (2000) and Sanna-Randaccio (2002) develop a duopoly model without technology transfer costs and show that multinational firms tend to undertake more R&D activities than exporting firms in a duopoly model. By extending this duopoly framework to an oligopoly model

that incorporates technology transfer costs and the effect of competitors' DIA on R&D, we find not only a direct connection between R&D and own DIA, but also a relationship between R&D and competitors' DIA.[2]

With regard to the link between R&D and DIA, Norback (2001) is the closest empirical study to ours. He demonstrates that in an endogenous R&D model, there can be a negative correlation between R&D and DIA when technology transfer costs are high. He then confirms the existence of technology transfer costs by examining Swedish multinational firms' data. However, there are two main differences between Norback's and ours. First, since Norback's model is a monopoly model, it is not possible to examine the interaction effects with other firms. Second, because Norback studies Swedish firms, his model ignores the domestic market. On the other hand, our study examines Japanese firms. The Japanese market is so large that we have to construct a model that includes the domestic market.

Few empirical studies exist on the effect of DIA on parent firms' innovative activities. However, since our analysis has implications for the source country's economy, several studies are related to our research. Head and Ries (2002) analyze the effect of DIA on parent firm's skill upgrading. They find that skill intensity at home increases when Japanese firms invest in developing countries. Although their main focus is on skill-upgrading, their findings have an important implication: if parent firms specialize in research activities, they demand more skilled labour than unskilled labour. With regard

[2]To address the issue of the direction of causality between R&D and DIA, we build another model, in which R&D is treated as an exogenous firm-level fixed cost. We show that the predictions are different from those of the endogenous R&D model.

to the difference between multinationals and exporters, Head and Ries (2003) find that the most productive firms invest in high wage countries, while the least productive firms invest in low wage countries. Since the nature of R&D effect is also regional, these systematic differences in productivity are closely related to our R&D difference results.

The detailed analysis of our research is below. In the next section, we derive the predictions of the theoretical models. Section 2.3 describes our data set, Section 2.4 reports estimation results, and Section 2.5 concludes this chapter.

2.2 Predictions

In this section, we briefly describe our theoretical model to generate major predictions to be tested later. The purpose of this section is to introduce an oligopoly model and list the predictions of DIA effects.

We introduce a three-stage oligopoly model in which the R&D decision is endogenized. First, firms choose whether to be an exporter or a multinational. The second stage is the R&D decision stage. During the last stage firms compete with each other in a Cournot fashion.

2.2.1 Endogenous R&D

Our model is similar to the duopoly model of Petit and Sanna-Randaccio (2000), which is a game theoretic model endogenizing R&D expenditure. Unlike their model, however, ours has more than two firms. We assume that there are two countries, home and foreign. Firms are first located in the home country, either exporting or investing abroad. While

exporters have only one domestic plant, multinationals have two plants, one at home and one in the foreign country.[3]

There are $\bar{L}$ firms, and $\bar{L} = N + M$ where N is the number of national firms and M is the number of multinational firms. The timing of the game is as follows:

1. Decide whether to be an exporter (pay a fixed cost, G) or a multinational firm (pay $2G$);
2. Determine the R&D level simultaneously;
3. Compete in a Cournot fashion.

The demand functions of home and foreign countries are specified in a linear form:

$$p = a - b(\sum x^N + \sum x^M)$$
$$p^* = a - b(\sum x^{*N} + \sum x^{*M})$$

We use asterisks to denote foreign market variables. The superscripts, N and M, stand for a national and multinational firm, respectively.[4] We consider a process R&D that reduces marginal costs. That is,

$$mc_i^N = c - \theta I_i^N$$
$$mc_i^M = c - \theta I_i^M$$

[3]In the data set, one firm serves multiple foreign markets. If we divide each market into districts (by regions or local markets), an increase in a firm's DIA occurs when it shifts from exporting to a foreign market to serving consumers by opening a plant there. Hence, our two-country model can be interpreted as a disaggregated model focusing on a particular market in a multi-country, multi-plant world.

[4]We use "national firm" and "exporter" interchangeably in this paper.

where c is the base marginal costs term, θ is the productivity of R&D, and I_i is the amount of R&D. The profit functions for national and multinational firms are, respectively:

$$\begin{aligned}
\pi^N =& (a - b(\sum x^N + \sum x^M))x_i^N + (a - b(\sum x^{*N} + \sum x^{*M}))x_i^{*N} \\
& - mc_i^N x_i^N - (mc^N + s)x_i^{*N} - \frac{\gamma I_i^{N2}}{2} - G \\
\pi^M =& (a - b(\sum x^N + \sum x^M))x_i^M + (a - b(\sum x^{*N} + \sum x^{*M}))x_i^{*M} \\
& - mc_i^M(x_i^M + x_i^{*M}) - \frac{\gamma I_i^{M2}}{2} - \frac{\xi I_i^{M2}}{2} - 2G
\end{aligned}$$

where s is the trade costs term, $\gamma I_i^{M2}/2$ (or $\gamma I_i^{N2}/2$) is the R&D costs term, and $\xi I_i^{M2}/2$ is the technology transfer costs term, in which s, γ, and ξ are assumed to be positive. National firms have to incur trade costs, s, to supply the foreign market. Multinational firms need technology transfer costs, $\xi I_i^{M2}/2$, to produce in the foreign market. We assume a quadratic function of R&D and technology transfer costs to be a special form of the convex function. This allows us to solve for R&D explicitly.

To solve the game, we start solving the last stage – the Cournot competition stage. The optimal level of outputs is derived from the first order conditions in the domestic and foreign markets. Then, the profit functions are expressed in terms of R&D spending.

$$\begin{aligned}
\pi_i^M &= \pi^M(x^M(I^M, I^N), x^N(I^M, I^N), x^{*M}(I^M, I^N), x^{*N}(I^M, I^N), I^M) \\
\pi_i^N &= \pi^N(x^M(I^M, I^N), x^N(I^M, I^N), x^{*M}(I^M, I^N), x^{*N}(I^M, I^N), I^N)
\end{aligned}$$

where $x^M = (x_1^M, \ldots, x_M^M), x^N = (x_1^N, \ldots, x_N^N), I^M = (I_1^M, \ldots, I_M^M)$, and $I^N = (I_1^N, \ldots, I_N^N)$.

Now, we are able to solve the R&D stage game. The first order conditions of the

R&D game are obtained with the envelope theorem:

$$\frac{\partial \pi_i^k}{\partial I_i^k} = -bx_i^k[\sum_{-i} \frac{\partial x_j^k}{\partial I_i^k} + \sum_j \frac{\partial x_j^l}{\partial I_i^k}] - bx_i^{*k}[\sum_{-i} \frac{\partial x_j^{*k}}{\partial I_i^k} + \sum_j \frac{\partial x_j^{*l}}{\partial I_i^k}]$$
$$- \frac{\partial c}{\partial I_i^k} x_i^k - \frac{\partial c}{\partial I_i^k} x_i^{*k} - (\gamma + 1(k = M)\xi) I_i^k = 0, k = M, N, \ l \neq k$$

where $1(\cdot)$ is an indicator function. Best response functions of R&D are explicitly shown by

$$I^N = \frac{-2M\theta I^M + 2(a-c) - (M+1)s}{-\lambda_N}$$
$$I^M = \frac{-2N\theta I^N + 2(a-c) + Ns}{-\lambda_M}$$

where $\lambda^M = 2\theta(N+1) - \frac{b(1+N+M)^2(\gamma+\xi)}{2\theta(N+M)} < 0$ and $\lambda^N = 2\theta(M+1) - \frac{b(1+N+M)^2\gamma}{2\theta(N+M)} < 0$. Because $-2M\theta/(-\lambda_N) < 0$ and $-2N\theta/(-\lambda_M) < 0$, R&D decisions are strategic substitutes. If one type of firm (e.g., multinational) decreases R&D, the other type of firm (national firm) has an incentive to increase R&D. This is important when we consider the effect of competitors' direct investment on R&D. Equilibrium R&D is derived as a solution of the above functions.

In the first stage, firms decide whether to invest or to export. Since in the following analysis our focus is on how different market structures (M, N) affect R&D spending, we treat M and N as given.[5] In Appendix A.3, we actually derive the existence of such an equilibrium under certain parametrization. In the next section, we consider the R&D

[5]This is similar to De Bondt, Sleuwaegen, and Veugelers (1988). However, our study is different in that they set up a duopoly model and analyze R&D activities in a host country without considering technology transfer costs.

stage in order to derive the results of the R&D effects of DIA in which we are interested.

2.2.2 Direct, Competition, and Interaction Effect

Here, we consider three types of R&D effects of DIA: direct, competition, and interaction effects. The direct effect is the effect of own direct investment on R&D. The competition effect is the effect of the other firm's DIA on own R&D. The interaction effect is the effect of the other firm's DIA on the direct effect. The reason why we call this an interaction effect is that in a regression analysis, this is introduced as an interaction term, such as the number of own DIA times the number of the other firm's DIA.

In general, M and N differ. For the sake of simplicity, we will focus on a symmetric case, $M = N$. Later, in numerical simulations, we will establish our results with $M \neq N$.

Direct Effect

In order to obtain unambiguous results, we assume that there exists a lower bound of a technology transfer cost, $\underline{\xi}$, defined in Appendix A.4.[6] Also, we assume that the total number of firms is large: $K < \bar{L}$, with K defined in Appendix A.5. Then, we have the following proposition:

Proposition 1. *1. There exists a cut-off value of technology transfer cost, ξ'. If technology transfer costs are low ($\xi < \xi'$), multinationals spend more on R&D than national firms: $I^M - I^N > 0$.*

[6] $\underline{\xi} < \xi$ is needed for providing a low incentive to conduct R&D in order to exclude the possibility of zero or negative marginal costs.

2. *If technology transfer costs are high ($\xi' < \xi$), national firms spend more on R&D than multinationals: $I^M - I^N < 0$.*

The proof is in Appendix A.4. The intuition behind this proposition is as follows. Our technology transfer costs have the following property: if the technology level is high, the cost is also high. Hence, if firms spend a large amount of R&D to develop an advanced technology, those firms have to incur high technology transfer costs. However, such firms may not want to produce in a foreign plant. Instead, even though trade costs are paid, those firms prefer to export. In other words, since the extent to which foreign plants benefit from home R&D is small, foreign plant establishment is not beneficial for companies with high R&D. Firms with low R&D prefer to invest abroad because transfer costs are lower and those firms can save trade costs.

Competition and Interaction Effects

To examine the effect of the number of other multinational firms on R&D spending, we compare the R&D levels between (M, N) and $(M+1, N-1)$, which is $I^k(M+1, N-1) - I^k(M, N), k = M, N$. This is interpreted as the competition effect, because this is the effect on own R&D of a competitor switching from being an exporter to being a multinational firm. Let us introduce a simplified notation of the competition effect: $\delta^k \equiv I^k(M+1, N-1) - I^k(M, N), k = M, N$.

Two main effects determine the sign of the competition effect. The first one is a business stealing effect in the product market. If product market competition becomes intense, the return from R&D is reduced and so is the incentive to invest R&D. The second one is related to strategic substitutes in the R&D game. When some firms spend

less R&D due to intensive competition, the R&D incentive of other firms increases. The total effect depends on which effect dominates.

These effects are related to market size and trade costs. We define the critical value of market size and trade costs such as $\bar{b} = 4\bar{L}/(1+\bar{L})$ and $\bar{s} = -\psi_{M2}/\psi_{M1}$ in Appendix A.5.[7] If b is less than $\bar{b}$, the market size is considered to be large, since b is the slope of demand. If s is larger than $\bar{s}$, then trade costs are interpreted as high. The following table shows the results of the competition effect. These results are derived in Appendix A.5. The first part is the prediction of the competition effect when the market is large and the second part is the prediction when the market is small. In each case, competition effect depends on the technology transfer costs, ξ, and the level of trade costs, s. Each cell shows the competition effect of multinationals and exporters.

(Competition effect for multinationals, competition effect for national firms) $= (\delta^M, \delta^N)$:

Large Market Size: $\underline{b} < b < \bar{b}$	Low Trade Costs	High Trade Costs
Low Technology Transfer Costs	$(-,+)$	$(+,-)$
High Technology Transfer Costs	$(-,+)$	$(+,-)$
Small Market Size: $\bar{b} < b$	**Low Trade Costs**	**High Trade Costs**
Low Technology Transfer Costs	$(-,-)$	$(-,-)$
High Technology Transfer Costs	$(+,+)$	$(-,-)$

Consider, for example, the case of a large market size and low technology transfer costs: $\underline{b} < b < \bar{b}$ and low transfer costs imply $I^M - I^N > 0$. Multinationals spend more R&D than exporters. An exporter becoming a multinational firm means that there exist

[7] $\bar{s}$ is also equal to $-\psi_{N2}/\psi_{N1} = -\psi_{MN2}/\psi_{MN1}$ where ψ_{M1}, ψ_{M1}, ψ_{N1}, ψ_{N2}, ψ_{MN1}, and ψ_{MN2}, as defined in Appendix A.5.

more productive firms. Competition between multinational firms becomes intense, with business stealing effect decreasing the return from R&D and the firms reducing R&D spending. On the other hand, since R&D has a strategic substitute property and since multinationals tend to reduce R&D, exporters have the incentive to increase R&D. If s is small, the cost advantage of multinationals is not large, and the strategic substitute effect dominates the business stealing effect. Then, multinationals spend less R&D and national firms spend more R&D. This is the case of $I^M - I^N > 0, \delta^M < 0$, and $\delta^N > 0$. If we have high trade costs, the business stealing effect dominates. This decreases R&D spent by national firms, increasing R&D spent by multinationals ($I^M - I^N > 0, \delta^M > 0$, and $\delta^N < 0$).

Finally, we investigate the interaction effect. This is the effect of competitors switching to being investors on the direct effect. Hence, it is shown through the difference between the direct effect in situations with a varying number of firms:

$$I^M(M+1, N-1) - I^N(M+1, N-1) - [I^M(M,N) - I^N(M,N)] = \delta^M - \delta^N$$

Under the same assumptions for the direct and competition effect, we have the following.

Proposition 2. *1. If $s < \bar{s}$, i.e., if trade costs are low, the interaction effect is negative: $\delta^M - \delta^N < 0$.*

2. If $\bar{s} < s$, i.e., if trade costs are high, the interaction effect is positive: $\delta^M - \delta^N > 0$.

The proof is in Appendix A.5.1. The interaction effect depends on the level of trade costs. For example, suppose both direct and competition effects are negative. Then, if

trade costs are high, the decrease in I^N is greater than that in I^M, so the interaction effect is positive. These competition and interaction effects are investigated in the empirical analysis.

Direct and Interaction Effect in the Case of Asymmetric Number of Firms

In the actual data, unlike in our assumptions, the number of exporters is not equal to the number of multinational firms. Hence, it is important to analyze a case in which the number of exporters and multinationals differs. In particular, we consider the direct and interaction effects, where the number of multinationals changes with the number of national firms. Through a numerical simulation we show that under certain parametrization, the same results are obtained in the analytical section.

The results are illustrated in Figure 2.1.[8] The vertical axis is the difference of R&D, $I^M - I^N$, and the horizontal axis is the number of multinational firms. The number of national firms is set to nine. The solid line is the plot under low trade and technology transfer costs ($(s, \xi) = (0.001, 0.001)$), while the dotted line is the plot under high trade and technology transfer costs ($(s, \xi) = (10, 10)$).

In the analytical part, we consider the direct effect as the difference of I^M and I^N and the interaction effect as the effect of additional multinationals on the the difference of I^M and I^N. Therefore, here we consider the direct effect as the intercept and the interaction effect as the slope. In the case of high trade and technology transfer costs, the intercept is positive (the direct effect is positive) and the slope is negative (the interaction effect is

[8]Parameter values are $(a, b, c, \theta, \gamma) = (75, 3.89, 1, 1, 0.95)$.

negative). Similarly, in the case of low trade and technology transfer costs, the intercept is negative and the slope is positive. These are the same as in the analytical result.

Self-Selection Model: Exogenous R&D

We have demonstrated an endogenous R&D model by examining how direct investment affects R&D spending. However, previous studies such as Horstmann and Markusen (1992) and Brainard (1997) consider how R&D spending affects direct investment decisions. In order to show that such type of a model generates somewhat different predictions on the effects of the competitors' DIA, we build an exogenous R&D model in Appendix A.6. We derive the predictions and show that the competitors' DIA effect is always negative (for complete derivation, see Appendix A.6). This is the main difference from the predictions of the endogenous R&D model. It will be shown that the predictions of the exogenous R&D model are not supported by the empirical evidence.

2.3 Data

We compile data on DIA, R&D, and firm characteristics for publicly listed electronics firms. DIA is measured as the number of manufacturing foreign affiliates and comes from the *Japanese Overseas Investment* (2002) published by *Toyo Keizai* (in Japanese). Affiliates are entities owned at least 10 percent by Japanese firms which are incorporated in a foreign country. Since we use the data from 2002, our sample only captures foreign affiliates existing in 2001.[9] We derive annual counts of DIA based on the start date

[9]The data on the rate of exit are available in a different survey by the Ministry of Economy, Trade, and Industry at the industry level. In 1996, for example, the exit rate in Asia was 1.5 percent.

of investment. According to classification, we mainly have three motivations of DIA: distribution, manufacturing, and other. "Other" reflects stock holding, R&D, logistics, and corporate governance. Multiple motivations for DIA are expressed in a data source file. We take DIA to be manufacturing DIA if the manufacturing motivation is included. Many affiliates engage in both of manufacturing and distribution. The reason why we take into account manufacturing DIA only is consistency with our theory. Our model explicitly regards foreign affiliates as foreign plants to save on trade costs, so we omit DIA that is only motivated by distribution or other. Although information on whether a particular DIA is a greenfield or a merger is available in the data source, since our focus in not on the form of direct investment, we do not make a separate category for each. Also, we do not take into account the size difference between foreign affiliates according to the number of employees because of missing data.

For R&D, our data source is several issues of the *Japan Company Handbook* published by *Toyo Keizai.* Since accounting R&D input data are considered to be noisy, we collect these from the *Japan Company Handbook* (for example, Branstetter (2000) also uses this data source). Each year's R&D spending is considered. Because of data availability, our data period covers from 1987 to 1998. Since we concentrate on the electronics industry, we are using a sample of 141 publicly traded firms and providing 1692 observations. All R&D spending data are the only R&D spending by parent firms because our data set is a non-consolidated one.

For other covariates such as the number of employees, depreciable assets, sales, and raw material purchases, we use the data of Nikkei NEEDS (Nikkei Economic Electronic Database). The financial data are used to control for observable heterogeneity of firms.

Our sample has a large dispersion in terms of size, for example. The number of employees ranges from 79 to 81488. The financial data correspond to a firm's fiscal year, which is not necessarily the calendar year, as in Blonigen and Taylor (2000). Hence, we compile the DIA data that correspond to each firm's fiscal year. Also, during the sample period, several firms changed their fiscal year. At that point, R&D spending dropped irregularly, so we adjust the data proportionally.

Table 2.1 shows the summary statistics. Each year, there are on average 37 new DIA for Asia, 5 for North America, and 9 for Europe. Figure 2.2 plots the time series of the number of new establishments of DIA and R&D spending, in which mdia corresponds to the number of manufacturing DIA, sdia to the number of distribution DIA, and odia to the number of other DIA. This shows that in the early 1990s the growth of both investments slowed down. Manufacturing DIA was more frequent than distribution DIA.

To examine the basic relationship between R&D and DIA, we plot 1997 firm-level data. Figure 2.3 shows a positive relationship between own DIA and R&D. The observations on the axis are exporters (zero DIA). Figure 2.4 shows a negative relationship between competitors' DIA and own R&D. Since pure exporters face the same number of competitors' DIA, the observations at $\ln(1 + OtherDIA) = 6.72$ are exporters. Also, since our main estimator is a within estimator, we plot demeaned data of R&D and DIA (see Figure 2.5). Although R&D fluctuates more than DIA, both data series trend upward.

2.4 Empirical Analysis

Next, by using electronics industry data, we implement the panel data analysis. Our data provide information on Japanese electronics firms over the period between 1987 and 1998. Most have foreign investments in the first year of the sample and their number increases over time. However, there are also a few firms that never invested abroad. Our empirical implementation specifies the R&D of a firm as a function of its own DIA, the DIA of competing firms, and the interaction between the two variables (as well as other controls).

2.4.1 Regional Basis

Trade and technology transfer costs differ by region and country. It is difficult to transfer technology to developing countries and easy to transfer it to developed countries (see for example Mansfield and Romeo (1980)). This may be because skilled labour is a scarce resource in developing countries. Also trade costs are different across regions, which is the main idea behind the gravity model. Since trade costs include trade barriers, these can be high in developing countries due to severe trade protection. In our theory, the R&D effect of DIA depends on these characteristics. Therefore, we divide our sample of DIA into regions, mainly Asia, Western Europe, and North America.[10] This specification allows the coefficient of each effect to be region-specific. Since we argue that Asia, Western Europe, and North America have different technology transfer and trade costs,

[10]In Asia: South Korea, China, Taiwan, Hong Kong, Singapore, Thailand, the Philippines, Malaysia, Indonesia, Vietnam, India, and Sri Lanka. In Western Europe: UK, Germany, Austria, France, the Netherlands, Belgium, Luxembourg, Sweden, Spain, Italy, and Portugal. In North America: Canada, USA, and Mexico.

we expect those coefficients to be different. Particularly, we consider Asia as a region of high trade and technology transfer costs, and North America and Europe as those of low trade and technology transfer costs.

Our specification is motivated by the theory as follows. Each firm serves multiple markets either through exports or direct investment. We assume that when a Japanese firm opens a new foreign plant (DIA), it ceases to be a national firm (i.e., an exporter) vis-a-vis that market and becomes a multinational. Its R&D should be affected according to the "direct effect" derived from the theory that identifies the differences of R&D spending between multinational and national firms. Our theory indicates that each firm's R&D depends on the number of competitors producing abroad. Thus, the R&D spending of a firm will vary according to the DIA of competing firms (the competition effect). Finally, when a firm moves from being an exporter to being a multinational firm for a particular foreign market, its change in R&D will be a function of the number of foreign investments of competing firms (the interaction effect).

Direct Effect

In this section, we introduce baseline specification. First, we consider only the direct effect. Later, we take into account the competition and interaction effects.

If high technology transfer costs cause a negative correlation between R&D and DIA, we can test the existence of significant technology transfer costs by using only the direct effect. In order to illustrate this claim, we run the following regression. Here, we try to

exploit the regional differences of the direct effect:

$$\ln R\&D_{it} = \beta_0 + \beta_1 \ln AsiaDIA_{it} + \beta_2 \ln NorthAmericaDIA_{it} + \beta_3 \ln EuropeDIA_{it}$$
$$+ \beta_{10} X_{it} + D_t + \mu_i + \epsilon_{it}$$

where D_t is a time dummy and μ_i is an unobserved firm fixed effect term. The main regressor, DIA, is a form of $\ln(1 + DIA)$. Since exporters have no direct investment ($DIA = 0$), we adopt this specification. μ_i captures the unobserved heterogeneity of firms. For example, since we do not consider local firms or other foreign country firms explicitly, if Japanese firms face different competitive pressures from other local or foreign firms, these pressures are captured by this term. D_t captures the time effect. In the 1990s, Japan was in a recession. This macro-economic environment might have affected R&D and DIA decisions. We can capture the macro shock by using time dummies, so that we can isolate the firms' R&D activities from these economic environments. In addition, if all Japanese firms face the same competitive pressures from other local or foreign firms, time dummies can control for this competition effect.

Firm i's time-varying characteristics at date t, X_{it}, are used to control for observed firm's heterogeneity. We use the same set of control variables as in Head and Ries (2001). This covariate matrix X_{it} will have the following variables:

- Employment ($\ln L$)
- Capital Labour Ratio ($\ln(K/L)$)
- Productivity ($\ln(VA/L)$)

- Wage ($\ln(Pay/L)$)

L is the number of employees, K is depreciable assets, VA is sales minus purchase of raw material that is deflated by the produce price index, and Pay is the production and non-production wage. R&D is deflated by the R&D deflater published by the Statistics Bureau (1995=100). Although we only use the direct effect here, we will introduce the competition and interaction effects as well. Since our models suggest that different trade and technology transfer costs create different correlations between R&D and competitors' DIA and since we are interested in such correlations, we use the contemporaneous variables in regressors. Hence, all covariates are the variables at date t. While specifications use firm-specific fixed or random effects, these variables capture changes in firm attributes across time.

Even though there is no strategic interaction such as a monopoly model in Petit and Sanna-Randaccio (1998) and Norback (2001), a negative correlation between R&D and DIA is possible because of high technology transfer costs. By taking regional differences as a proxy for trade and technology transfer costs, we expect to have a negative direct effect for Asia DIA and a positive direct effect for North America (Europe) DIA if strategic interaction is small.

Estimation Results

In Table 2.2, columns 1 to 4 report regression results. We find that there is a positive relationship between DIA and R&D. Column 2 in Table 2.2 shows the fixed effect estimation: 0.1 for Asia, 0.105 for Europe, and 0.116 for North America. All coefficients are significant at the one percent level. However, these estimates may be biased since

we have omitted the competition effect as well as other control variables. Column 4 in Table 2.2 reports that including control variables causes all DIA coefficients to become statistically insignificant. This may reflect the omitted variable bias associated with the omitted competition effect.

Competition and Interaction Effects

Now, we include the competition and interaction effects in the regression:

$$\begin{aligned}
\ln R\&D_{it} = {} & \beta_0 + \beta_1 \ln AsiaDIA_{it} + \beta_2 \ln NorthAmericaDIA_{it} + \beta_3 \ln EuropeDIA_{it} \\
& + \beta_4 \ln OtherAsiaDIA_{it} \\
& + \beta_5 \ln OtherNorthAmericaDIA_{it} + \beta_6 \ln OtherEuropeDIA_{it} \\
& + \beta_7 \ln AsiaDIA_{it} \ln OtherAsiaDIA_{it} \\
& + \beta_8 \ln NorthAmericaDIA_{it} \ln OtherNorthAmericaDIA_{it} \\
& + \beta_9 \ln EuropeDIA_{it} \ln OtherEuropeDIA_{it} + \beta_{10} X_{it} + D_t + \mu_i + \epsilon_{it}
\end{aligned}$$

where $OtherDIA$ is the number of other firms' DIA. The first term (β_0) is a constant term, β_1, β_2, and β_3 are the coefficients of the direct effect, β_4, β_5, and β_6 are the coefficients of the competition effect, and β_7, β_8, and β_9 are the coefficients of the interaction effect. For example, the marginal effect of Asia DIA is expressed by the following:

$$\frac{\partial \ln(R\&D)}{\partial \ln(1 + AsiaDIA)} = \beta_1 + \beta_7 \ln(1 + OtherAsiaDIA)$$

Therefore, we interpret β_1 as the direct effect and β_7 as the interaction effect. The marginal effect is different across firms. Exporters have the largest number of competitors' DIA. This enables us to consider the heterogeneity of competitive positions because large multinational firms compete with fewer foreign plants of other firms than small multinational firms.

Estimation Results

Table 2.2 shows the estimation results. Columns 5 to 8 report the results including the competition and interaction effects. The main results are in columns 5 and 6. Using a Hausman test, we reject the random effects, so that we can focus on discussing the fixed effect estimation results. Without control variables, column 6 reports that the coefficient of Asia DIA is negative (-0.482) and that the coefficient of North America DIA is positive (1.636). These are statistically significant. The coefficient of Europe DIA is positive, but insignificant. With regard to the competition effect, the sign of $OtherAsiaDIA$ coefficient is negative and that of $OtherNorthAmericaDIA$ is positive, but both are statistically insignificant. However, the coefficient of $OtherEuropeDIA$ is positive (8.08) and significant. For the interaction term, we find that the coefficient of Asia is positive (0.093) and that the coefficient of North America is negative (-0.314). Both are significant, but the coefficient of Europe is insignificant.

With control variables for Asia and North America, the signs of the direct, competition, and interaction effects are qualitatively the same as in the absence of control variables (Columns 7 and 8 in Table 2.2). On the other hand, the coefficients of Europe are reversed except for the competition effect. Three out of four control variables

(productivity, number of employees, and capital labour ratio) are significant. Table 2.3 summarizes the sign pattern of predictions and regression results.

The results have three implications. First, the competition and interaction effects produce destination-specific results. When the predicted sign pattern is compared with the regression results of Asia and North America, the coefficients match the predictions of the endogenous R&D model.[11] This result of regional difference can not be obtained when we have only the direct effect.

Second, the negative direct effect for Asia supports the relationship predicted when technology transfer costs are high. Similarly, the positive direct effect for North America supports the prediction derived when technology transfer costs are low.

Third, the positive interaction effect for Asia supports the relationship predicted when trade costs are high, and the negative interaction effect for North America supports the prediction under low trade costs. At a glance, this is counter-intuitive. However, two explanations exist. First, high trade costs might be due to high trade protection. Trade costs include trade barriers such as tariffs and non-tariff barriers. There is evidence that these barriers are severe in developing countries (for the measures of trade protection, see for example Rose (2002)). Hence, these trade barriers might raise trade costs in Asia. Second, trade costs might include host countries' distribution costs. If a distribution network is not well-established in this region, shipping products is costly. On the other hand, if such a network is formulated, it is less costly. In fact, in North America, a typical dynamic pattern of DIA is first distribution DIA and then manufacturing DIA.

[11]Table 2.3 also reports that the predictions of the exogenous R&D model are not supported.

Since we look at the effect of manufacturing DIA, with a presumably existing distribution network distribution costs may be low. In total, trade costs can be high for Asia and low for North America.[12]

Examining regional differences makes it clear that there is a difference in direct effects across different regions. This result may be consistent with that of Head and Ries (2003). They find that the most productive firms invest in high wage countries, while the least productive firms invest in low wage countries. The wages in Asian countries are lower than those in North American countries. Our R&D is regarded as a process R&D which reduces marginal costs. A negative direct effect for Asia may reflect this fact.

First and Long Differences Estimation

So far, we employ the within estimation. The within estimator reflects how the trend of DIA is related to the trend of R&D. On the other hand, in order to study the effect of DIA changes on R&D changes, we can take the first difference of all variables and

[12]There might be another explanation, the export platform. It is recognized that affiliates set up in East Asian countries export their product to third markets. Countries in East Asia promote a direct investment policy, which requires foreign firms to export their goods. Therefore, our model might be subject to this phenomenon.

By slightly modifying our model, we can take into account the export platform DIA. Suppose multinational firms establish their foreign plants in a third country and ship product to a foreign market in which multinationals and exporters compete. In this case, the basic motivation to enter a third country is low production cost. We denote a new marginal cost $\tilde{c}$ when we produce in a third country. This marginal cost is smaller than that of producing in other countries, $\tilde{c} < c$.

We assume that total marginal costs, which consist of production marginal costs in the third market and trade costs between the third and foreign country, are less than the marginal costs when producing in other countries, $\tilde{c} + \tilde{s} < c$. This assumption makes the regression results consistent with the export platform case. If we define the base marginal cost as $\bar{c} \equiv \tilde{c} + \tilde{s} < c$, the marginal cost of exporting is $c + s = \bar{c} + s +$ extra term. If we regard this extra marginal cost term as a trade cost, these exporters face higher trade costs, s+extra term, rather than just s, when multinationals enter with the export platform motive. This modification allows us to provide a different interpretation of the result of high trade costs for Asia DIA. High trade cost may be due to the export platform DIA prevailing in this area.

estimate the regression equation. The first difference estimation examines short term adjustments of DIA and R&D. Although both estimations are able to control for a firm's fixed effects, the implication of the results is different.

In Table 2.4, columns 1 and 5 show the first difference estimation results. The first difference estimation does not successfully demonstrate how our model works, as more than half of the parameters are not statistically significant. The reason why direct investment is not significant to explain R&D spending is because R&D and DIA are conducted based on long-term expectations. By taking the first difference, we focus instead on the short-term adjustment of DIA and R&D. We may have to investigate the long-term connection between R&D and DIA. In this case, we have to employ a long differences estimation.

A long difference estimation is suitable not only for analyzing the long-term link between R&D and DIA, but also the measurement error. If independent variables are measured with an error, the long difference estimators are less biased than the first difference estimator (see Griliches and Hausman (1986)). We consider a difference of between two periods to ten periods to account for this problem. Hence, the regression equations are:

$$\ln R\&D_{it} - \ln R\&D_{it-k} = \beta(Z_{it} - Z_{it-k}) + \eta_{it}$$

where Z_{it} contains all regressors and $k = 2, \ldots, 10$.

The long difference estimation provides more reliable results than the first-difference estimation. In particular, we report the results of two, three, and five period difference

estimations (see Table 2.4). These are similar to the results of the within estimation. However, if the differences get too long (e.g., $k = 9$ or 10), a large number of coefficients in the regressions is not statistically significant, probably because of the small sample size.[13]

Almost all coefficients for Europe are statistically insignificant. Hence, the same argument as for the within estimation section may apply here. The only statistically significant coefficient is the competition effect, which is negative. One explanation is that the data aggregation might generate an inconclusive result. We only aggregate the number of DIA in Western European countries, where there could be a large difference between countries: one group can be, for instance, UK, Germany, and France, while the other can be Spain and Portugal. The study within the European market is interesting, but we leave it to further research.

Robustness

In order to check the sensitivity of our results, we estimate the model in the same way but with the time dummies excluded. The results are given in the last two columns of Table 2.2. The sign and magnitude of coefficients are very similar. The coefficient of other DIA in Asia and North America become statistically significant. Moreover, those signs fit the predictions of our theory better than before. Since the exclusion of time dummies does not change the signs of coefficients, we may be able to conclude that common shocks, for example the macro-economic shock, are reflected in the observable

[13]Hence, we omit these results here.

firms' specific factors.

The other robustness check is done by using lagged DIA and covariates as regressors. If we assume that lagged DIAs are predetermined, it is reasonable to run regression by using lagged DIA. Lagged variables are suitable for controlling for common shocks affecting R&D and DIA. The results for Asia and North America are the same as before (see Table 2.5). Therefore, we can purport the same claim as for the high trade and technology transfer costs for Asia DIA, and low trade and technology transfer costs for North America. However, for Europe the results support the endogenous R&D model only weakly.

2.5 Concluding Remarks

We analyze the R&D effects of DIA by focusing on the effect of competitors' DIA. We build an endogenous R&D model and show how the relationship between R&D and DIA relies on trade and technology transfer costs. Then, we use a firm level data set of Japanese electronics firms to test the predictions generated by the models. We find that the data are consistent with the endogenous R&D model. The data support the predictions associated with the level of trade and technology transfer costs. The main finding is that DIA has a negative direct effect for Asia but a positive direct effect for North America, implying that there exist high technology transfer costs for Asia but low technology transfer costs for North America.

Below are some remarks which require further research. The first is another motivation of direct investment that has an effect on R&D. Although our model does not

take into account technology acquisition motivation DIA, this motivation may exist, especially for North America (see Kogut and Chang (1991)). If home and foreign R&D activities are complement, parent firms have to spend more R&D on absorbing technology acquired through DIA. This creates a positive link between R&D and DIA. Hence, there can exist another substitute/complement problem for international trade, namely substitute or complement of R&D conduct. This requires future research.

The second remark is about data limitation. Since our data does not contain affiliation sales, we cannot distinguish between local sales and exports of affiliates. Our theory does not capture this type of proximity. However, we believe that this will not cause biases, as long as the focus is on the effect of home country's innovative activities.

The final remark is about the competition mode. It is widely recognized that quantity and price competition derive different predictions. We only analyze quantity competition at the last stage of the game. As the first attempt to examine the DIA and R&D relationship, quantity competition assumption is reasonable. However, it is interesting to examine the difference between quantity and price competition in terms of empirically testable predictions.

Although our study has the above shortcomings, our estimation produces several important findings: the R&D effects of DIA depend on the destination of DIA. This result is obtained only if we incorporate the competitors' DIA effects. We found that our data support the endogenous R&D model and that the predictions of trade and technology transfer costs are consistent with the data: for Asia, technology transfer costs are high, but for North America they are low.

Chapter 3

Learning by Investing Abroad: Does Distribution Direct Investment Lead to Manufacturing Direct Investment?

3.1 Introduction

There are several advantages of having one's own wholesalers and retailers in foreign markets. These distribution sectors can provide better customer service and circumvent inefficient transactions of arm's-length contract. Japanese firms invest in the distribution sector in order to promote export sales in foreign markets (see Yamawaki (1991), for example). Since multinational firms engage in economic activities in local markets, these

firms often know more about local markets than pure exporters. This knowledge might help resolve uncertainty about local product markets, labour markets, and business practices. Also, services offered by own wholesalers or retailers can encourage goodwill. This might increase benefits from manufacturing direct investment. Therefore, although the primary purpose of distribution direct investment is to promote exports, distribution direct investment may lead to manufacturing direct investment (see, for example, Hanson, Mataloni, and Slaughter (2001) and Moran (2001)). However, it is not clear whether the effects of such knowledge can be measured empirically.

This paper investigates whether the learning effect of distribution direct investment exists. In particular, we focus on the effect of distribution direct investment on the decision to invest in manufacturing. We consider the fact that investment in manufacturing requires a larger amount of sunk costs than investment in distribution. Under uncertainty, an investment decision with large sunk costs is inherently a dynamic problem and is dependent on the conditions of local markets (see, for example, Dixit (1989)). Since a firm's own wholesalers and retailers are able to resolve some of the uncertainty about local markets, they may encourage the firm to build manufacturing plants. If there exists such an effect, distribution direct investment increases the probability of setting up manufacturing affiliates. This study uses panel data on the Japanese electronics firms to investigate the effect of direct investment in distribution on the decision to invest in manufacturing. In order to isolate the effect from other factors that might cause a correlation between distribution direct investment and manufacturing direct investment, we control for unobserved heterogeneity, state dependence, and serial correlation in different specifications.

Our data support that there exists a learning effect of distribution direct investment in Asian countries, but not in North American or European countries. This might reflect three facts. First, as the measures of trade protection and economic freedom suggest (see, for example, Rose (2002)), it might be difficult to obtain information about local markets in Asia. As economic policies and business practices become less transparent, it becomes progressively more important to learn about local markets. This gives distribution direct investment an information acquisition role in Asia. Second, in our sample period (1988-1998) a distribution network was already established to some extent in North America and Europe, while in Asia a distribution network was only beginning to develop. In fact, in 2000 the proportion of manufacturing firms with wholesale affiliates was about 25 percent in Asia and about 50 percent in North America and Europe (see Ando and Kimura (2003) for more details). Third, in Asia the network goes beyond borders. The share of intermediate goods trade in East Asian countries is larger than that in other regions. Our estimation results are consistent with the unique characteristics of Asia. Hence, the contribution of this study to the literature is the conclusion that distribution direct investment positively affects the establishment of manufacturing direct investment in Asia.

Previous research on distribution direct investment mainly focuses on the effect on firms' exports (for example, Yamawaki (1991) and Head and Ries (2001)). These studies find that distribution direct investment increases firms' exports. This is consistent with the motivation of distribution direct investment mentioned above. With respect to the link between distribution and manufacturing direct investment, Hanson, Mataloni, and Slaughter (2001) study the strategies of US multinational firms. They examine

manufacturing firms established in 1990-1994 and evaluate whether there exist prior distribution direct investments. They find weak support for the effect of distribution direct investment on US multinationals.

In this paper, we utilize a dynamic panel model to examine whether distribution direct investment increases the probability of manufacturing direct investment. In order to isolate the learning effect from spurious correlations between distribution and manufacturing direct investments, we need to consider three factors: unobserved heterogeneity, serial correlation, and state dependence. There can be two unobserved individual differences, permanent (heterogeneity) and transitory (serial correlation). Unobserved heterogeneity might reflect managerial ability of firms, which causes unobservable productivity differences. If a firm invests in both manufacturing and distribution simply because it is productive, even in the absence of a learning effect, there may exist a correlation between distribution direct investment and manufacturing direct investment. As Head and Ries (2003) as well as Helpman, Melitz, and Yeaple (2004) show, there is a productivity difference between exporters and multinationals, so it is important to control for unobserved heterogeneity. Also, there may exist a transitory component causing dependency of investment. If error terms are serially correlated, there may exist serial persistence in manufacturing investment decisions. This might cause a biased estimation of the effects of distribution direct investment. Hence, we consider both no correlation and serial correlation cases in our empirical study.

With regard to state dependence, a search cost of investing in manufacturing generates a link between past and current investments. If a firm invested in the past, the search cost decreases in the current period. Firms that fit this profile tend to build man-

ufacturing plants during the current period due to low search costs. Thus, this study controls for state dependence to capture the dynamic decision aspect of manufacturing direct investment.

In order to examine the robustness of the identification of the learning effect, we use two empirical specifications. One is a linear probability model and the other is a random effects probit model. A linear probability specification is adopted to study the behaviour of exporting firms by Bernard and Jensen (1999, 2001) and the labour market participation by Hyslop (1999). In the linear probability model, by taking the first difference and exploiting the moment conditions, the GMM (Generalized Method of Moments) estimation developed by Blundell and Bond (1998) is able to control for fixed effects to produce consistent estimation results. We include lagged dependent variables in the regressors to control for state dependence and specify an AR(1) error form to capture serial correlation. The second specification is a random effect probit model, which is used in various studies (e.g. Roberts and Tybout (1997) for export decisions, Hyslop (1999) for labour market participation, and Lemieux and MacLeod (2000) for the learning effect of past unemployment insurance recipiency). In the random effect probit model, we treat unobserved firm specific effects as random, including the lagged dependent variable controls for state dependence, and we consider serial correlation by specifying the error term as the AR(1) process.

By controlling for possible elements causing a spurious relationship, we find evidence that the learning effect of distribution direct investment affects the decision to invest in manufacturing in Asian countries. On the other hand, in other regions there is no evidence of the existence of the learning effect. This result is robust across different

specifications. The next section of this paper sets up a dynamic decision model of firms. Section 3.3 introduces our data, and Section 3.4 specifies our empirical models. We then state our estimation results in Section 3.5, and conclude this chapter in Section 3.6.

3.2 Model

Firms face a dynamic choice problem of whether to set up a foreign manufacturing affiliate or not. Our framework is a search theoretic model (see for example Hyslop (1999)). For each period, t, firm i's gross profit is assumed to be expressed by a multiplicative separable form, $\pi(X_{it}, Y_{it})\lambda(SDIA_{it})$, where $Y_{it} = 1$ means invest, $Y_{it} = 0$ means not invest, and $\lambda(SDIA_{it})$ is a function of distribution direct investment. This λ captures the learning effect of distribution direct investment. X_{it} includes exogenous variables and state variables. If the firm invests in manufacturing, proximity ensures a large instantaneous profit: $\pi(X_{it}, 0) < \pi(X_{it}, 1)$. The problem is to maximize the discounted profit:

$$\max_{Y_i} E_t[\sum_{t=0}^{\infty} \beta^t \pi(X_{it}, Y_{it})\lambda(SDIA_{it})]$$

where $Y_i = \{Y_{i0}, Y_{i1}, \ldots\}$. We assume that firms incur a search cost if they did not invest in manufacturing in the previous period:

$$p = \begin{cases} p & \text{if } Y_{it} = 1 \text{ and } Y_{it-1} = 0 \\ 0 & \text{otherwise} \end{cases}$$

This search cost is specific to manufacturing investment such as the cost of finding a suitable location for production. Firms do not have to incur such an information acquisition cost if they have previous period experience. Similarly, we assume that there is a cost of additional investment in manufacturing due to loss of scale economy:

$$q = \begin{cases} q & \text{if } Y_{it} = 1 \text{ and } Y_{it-1} = 1 \\ 0 & \text{otherwise} \end{cases}$$

If the scale economy is large, firms do not want to set up an additional manufacturing plant, since it is beneficial to concentrate production.

Now, we derive the optimal decision rule to invest in manufacturing. The optimal decision rule consists of the cut-off values of λ. Due to state dependency, there are two optimal decision rules associated with the previous state. The value function at the beginning of period t given Y_{it-1} is

$$V(X_{it}, Y_{it-1}) = \max\{V^1(X_t, Y_{it-1}), V^0(X_t, Y_{it-1})\}$$

where superscript denotes the current period decision to invest ($V^{Y_{it}}(X_{it}, Y_{it-1}) = \pi(X_{it}, Y_{it})\lambda + \beta E_t V(X_{it+1}, Y_{it})$). Conditional on $Y_{it-1} = 0$, a comparison of V^0 and V^1 provides the cut-off value of λ, λ^*, where firms will invest in manufacturing if $\lambda^* < \lambda$:

$$V^0(X_{it}, 0|\lambda^*) = V^1(X_{it}, 0|\lambda^*)$$

$$\iff \pi(X_{it}, 0)\lambda^* + \beta EV(X_{it+1}, 0) = \pi(X_{it}, 1)\lambda^* - p - c + \beta EV(X_{it+1}, 1) \qquad (3.1)$$

where c is a cost of investment. Similarly, conditional on $Y_{it-1} = 1$, a comparison of V^0 and V^1 provides the cut-off value, λ^{**}, where firms will invest in manufacturing if $\lambda^{**} < \lambda$:

$$
\begin{aligned}
&V^0(X_{it}, 1|\lambda^{**}) = V^1(X_{it}, 1|\lambda^{**}) \\
&\iff \pi(X_{it}, 0)\lambda^{**} + \beta EV(X_{it+1}, 0) = \pi(X_{it}, 1)\lambda^{**} - q - c + \beta EV(X_{it+1}, 1) \qquad (3.2)
\end{aligned}
$$

We assume that p, q, and c are large enough to guarantee the existence of cut-off values. From Equations 3.1 and 3.2, we can derive

$$
(\pi(X_{it}, 1) - \pi(X_{it}, 0))\lambda^{**} = (\pi(X_{it}, 1) - \pi(X_{it}, 0))\lambda^{*} + (q - p)
$$

Hence, the decision to invest is based on

$$
\begin{aligned}
Y_t =& I((\pi(X_{it}, 1) - \pi(X_{it}, 0))\lambda \geq (\pi(X_{it}, 1) - \pi(X_{it}, 0))\lambda^{*} + (q - p)Y_{it-1}) \\
=& I(\tilde{\pi}\tilde{\lambda} + \tilde{p}Y_{it-1} \geq 0) \qquad (3.3)
\end{aligned}
$$

where $\tilde{\pi} = \pi(X_{it}, 1) - \pi(X_{it}, 0)$, $\tilde{\lambda} = \lambda - \lambda^{*}$, and $\tilde{p} = -(q - p)$. If the search cost is greater than the loss of scale economy ($q < p$), the coefficient of lagged dependent variable is positive. If the search cost is smaller than the loss of scale merit ($p < q$), a negative state dependency results.

The effect of distribution direct investment, λ, increases profits from exporting and direct investment. If there is no sunk cost, firms always choose to invest in manufactur-

ing, because the marginal effect of distribution direct investment on profit is higher for investing in manufacturing than for exporting. However, in the presence of sunk costs, low λ is not sufficient to pay sunk costs. Once λ is high enough to pay sunk costs, firms start to invest in manufacturing.

Equation 3.3 provides the decision to invest that will be estimated in Section 3.5. The implication of this condition is that if there is an effect from distribution direct investment, the level of distribution direct investment positively affects the likelihood of the manufacturing direct investment decision.

3.3 Data

We compile data on direct investment abroad (DIA) and firm characteristics for publicly listed electronics firms.[1] DIA is measured by the number of manufacturing foreign affiliates and originates from the *Japanese Overseas Investment* (2002) published by *Toyo Keizai* (in Japanese). Affiliates are entities owned at least 10 percent by Japanese firms which are incorporated in a foreign country. Since we collect data from 2002 only, our sample captures foreign affiliates existing in 2001. We derive annual counts of DIA based on the start date of investment. In other words, our distribution investment measure is the count of successful investments. Therefore, if firms are able to learn from unsuccessful investments, our estimate is downward-biased or our results might be interpreted as the lower bound of the effect of distribution direct investment. We construct dummy

[1]Because we assume that the motivation behind distribution direct investment is to promote exports, we exclude firms that do not export.

variable based on whether a firm invests in manufacturing. The dummy variable is 1 if a firm invests, irrespective of the number of manufacturing affiliates. This is 0 if a firm does not invest. This variable is used as our dependent variable.[2]

For other covariates such as the number of employees, depreciable assets, sales, and raw material purchases, we use the data of Nikkei NEEDS (Nikkei Economic Electronic Database). The financial data are used to control for observable heterogeneity of firms. The financial data correspond to a firm's fiscal year, which is not necessarily the calendar year as in Blonigen and Taylor (2000). Hence, we compile the DIA data that correspond to each firm's fiscal year.

Table 3.1 gives the summary statistics. Our sample has 135 firms. Each year, there are about 39 new DIA for Asia, 6 for North America, and 9 for Europe. The number of employees ranges from 96 to 81488. There is thus a large dispersion in firm size. In our sample period, 62 percent of firms (84 firms) invested in manufacturing in Asia, 32 percent (43 firms) invested in Europe, and 40 percent (54 firms) invested in North America. However, about 33 percent (44 firms) did not invest in manufacturing. On the other hand, 52 percent (70 firms) invested in distribution in Asia, 48 percent (65 firms) invested in Europe, and 51 percent (69 firms) invested in North America. Of all the firms, 27 percent (37 firms) did not invest in distribution. In addition, while 5 percent (7 firms) only invested in distribution, 7 percent (9 firms) only invested in manufacturing.

According to the classification by the publisher, there are three main motivations for

[2]Although information on whether a particular DIA is greenfield or merger is available from the data source, our focus in not on the effect of distribution direct investment, so we do not make it a different category. Also, due to missing data we do not take into account the size differences between foreign affiliates based on the number of employees.

DIA: distribution, manufacturing, and other. The category of "other" includes stock holding, R&D, logistics, and corporate governance. In a data source file, multiple motivations for DIA are shown. We take DIA to be manufacturing DIA if the manufacturing motivation is included. We take DIA to be distribution DIA if the only motivation for it is distribution. Figure 3.1 plots the time series of the number of new establishments of DIA. In it, mdia corresponds to the number of manufacturing DIA, sdia to the number of distribution DIA, and odia to the number of other DIA. Figure 3.1 shows that in the early 1990s the growth of both investments slowed down and that manufacturing DIA was more frequent than distribution DIA.

On regional basis, Figure 3.2 plots the number of new establishments of direct investment for each year. We divide our sample of DIA into regions: Asia, Western Europe, and North America.[3] In the figure, NA stands for North America, mdia for manufacturing, and sdia for distribution direct investment. In each area, distribution and manufacturing direct investment follow a similar pattern. However, there is a significant difference across regions. While in late 1980s there were no significant differences in the number of new direct investments, in the 1990s the number of direct investment increased in Asia as that in Europe and North America decreased. Hence, we expect that this difference in data variation produces different empirical results.

There are advantages and disadvantages to using regional basis data. By focusing on regions, we do not need to control for country-specific effects. If a country has a good

[3]In Asia: South Korea, China, Taiwan, Hong Kong, Singapore, Thailand, the Philippines, Malaysia, Indonesia, Vietnam, India, and Sri Lanka. In Western Europe: UK, Germany, Austria, France, the Netherlands, Belgium, Luxembourg, Sweden, Spain, Italy, and Portugal. In North America: Canada, USA, and Mexico.

policy facilitating foreign investment, a correlation can exist between manufacturing and distribution investment without learning effects. However, regional base data avoid this problem. It is not clear whether distribution investments in some countries affect the decision to invest in other countries. We implicitly assume that the benefit from distribution investment is able to go beyond borders. In fact, Ando and Kimura (2003) suggest that in East Asia a production/distribution network transcends borders because the share of intermediate goods trade in East Asian countries is larger than that in other regions. Therefore, based on the observations of direct investment in Asia, we would expect a positive impact of distribution direct investment on manufacturing investment.

3.4 Empirical Specification

Our empirical model is based on the investment decision condition given by Equation 3.3. The decision is made according to the following:

$$Y_t = \begin{cases} 1 & \text{if } \Pi\Lambda + \beta_1 Y_{it-1} \geq 0 \\ 0 & \text{otherwise} \end{cases} \tag{3.4}$$

where Π is a function of covariates and Λ is a function of distribution direct investment. To parametrize this reduced-form model we assume a particular functional form. Since we have skewed data variations in covariates, we use a log of covariates. We use one year lagged distribution direct investment in a linear form. This is a stock of distribution

direct investment to capture the learning effect. Hence, the first part of Equation 3.4 is:

$$\Pi\Lambda = \ln X_{it}\delta + \beta_2 SDIA_{it-1} + \epsilon_{it}$$

where X_{it} includes firms' observed characteristics. We use the same covariates as in Head and Ries (2001). These are productivity, capital labour ratio, the number of employees, and wage payment. Productivity is defined as a per worker value added, which is sales minus purchase of raw materials deflated by the producer price index. This controls for labour productivity. The number of employees controls for the size of the firm. The capital labour ratio is defined by the total assets divided by the number of employees, while the wage is the total wage payment. These control for capital (or labour) intensiveness of firms. Therefore, our empirical specification is:

$$Y_t = \begin{cases} 1 & \text{if } \beta_1 Y_{t-1} + \beta_2 SDIA_{t-1} + \ln X_t\delta + \epsilon_t \geq 0 \\ 0 & \text{otherwise} \end{cases}$$

The error term may include time-specific factors, individual-specific factors, and serially correlated components.

Now we specify our empirical models: a linear probability model and a panel probit model.

3.4.1 Linear Probability Model

First, we employ a linear probability model. This specification enables us to control for firms' specific effects as fixed effects. Although the predicted probability does not

constrain between zero and one, a linear probability model is more robust than a panel probit model to the form of unobserved heterogeneity. Hence, even if the error term and regressors are correlated, we can obtain a consistent estimator.

A linear probability model uses the following regression equation:[4]

$$Y_{it} = \beta_1 Y_{it-1} + \beta_2 SDIA_{it-1} + X_{it}\delta + \epsilon_{it} \tag{3.5}$$

In order to control for a firm's fixed effects, we can take the first difference or apply a within transformation. In a static model, this produces a consistent estimator. However, this estimator is not consistent in a dynamic model. Arellano and Bond (1991) develop a GMM estimator to obtain a consistent estimator. Taking the first difference yields:

$$\Delta Y_{it} = \beta_1 \Delta Y_{it-1} + \beta_2 \Delta SDIA_{it-1} + \Delta X_{it}\delta + \Delta\epsilon_{it}$$

In this case, the lagged level variables are uncorrelated with the error term. Thus, the moment condition is:

$$E[\Delta\epsilon_{it} Y_{it-s}] = 0, E[\Delta\epsilon_{it} X_{it-s+1}] = 0, t = 3, \ldots, T, \text{and} \quad s \geq 2$$

The level variables are used as instruments for the first difference estimation. Thus, the GMM estimator yields a consistent estimator.

However, Blundell and Bond (1998) show that the GMM first difference estimator

[4]Hereafter, we denote X_{it} as $\ln X_{it}$.

has poor finite sample properties when the lagged levels of the series only weakly correlate with subsequent first differences. In our model, distribution direct investment might experience this problem. Blundell and Bond (1998) go on to show that the GMM estimation in combination with level equations corrects the downward bias and improves efficiency, so we employ the Blundell and Bond GMM method. This is called a system GMM estimation, because difference equations and level equations are used at the same time. For the level equations, we use lagged variables as instruments based on the following moment condition:

$$E[\epsilon_{it}\Delta Y_{it-1}] = 0, t \geq 3.$$

We then implement both the GMM estimation of the difference equation and the GMM system equation estimation.[5] Instruments for difference equations are $Y_{it-2}, Y_{it-1}, \ldots$, $SDIA_{it-2}, SDIA_{it-1}, \ldots$, and $X_{it-1}, X_{it-2}, \ldots$. Instruments used for level equations are ΔY_{it-1}, $\Delta SDIA_{it-1}$, and ΔX_{it-1}.

Serially Correlated Error

So far, we have considered the non-serially correlated error, $\epsilon_{it} = \alpha_i + \eta_{it}$ where $\eta_{it} \sim N(0, \sigma_\eta)$. Below, we specify a serial correlation as an AR(1) process:

$$\epsilon_{it} = \alpha_i + \eta_{it}$$

$$\eta_{it} = \rho\eta_{it-1} + \nu_{it}$$

[5]DPD package for Ox is used for this estimation (see Doornik, Arellano, and Bond (2002) for usage).

We modify Equation 3.5:

$$Y_{it} = (\rho + \beta_1)Y_{it-1} - \rho\beta_1 Y_{it-2} + \beta_2 SDIA_{it-1} - \rho\beta_2 SDIA_{it-2} + X_{it}\delta - \rho X_{it-1}\delta + (1-\rho)\alpha_i + \nu_{it}$$

As in Hyslop (1999) and Blundell and Bond (2000), we estimate β_1, β_2, ρ, and δ using the Chamberlain (1982) minimum distance estimator. First, we estimate the reduced form model by GMM (the instruments are $Y_{it-3}, \ldots$, $SDIA_{it-3}, \ldots$, and $X_{it-2}, \ldots, X_{i1}$), and then we estimate structural parameters using the minimum distance estimator.

3.4.2 Random Effect Probit

This section introduces a nonlinear model, probit. One reason why we use the probit model is that while a linear probability model does not constrain the probability between zero and one, the probit model is able to take this into account. Although in this framework the unobserved firms' specific effect is treated as random, the panel probit model provides a better fit than the linear probability model. The random effect probit model is specified as follows:

$$Y_{it} = I(\beta_1 Y_{it-1} + \beta_2 SDIA_{it-1} + X_{it}\delta + \epsilon_{it} \geq 0)$$

where $\epsilon_t = \alpha_i + \mu_t + \eta_{it}$. We include a lagged dependent variable for state dependence as in the linear probability model. If we assume the correlation between error terms caused by the random effect terms to be $Cov(\epsilon_t, \epsilon_s) = Cov(\alpha_i + \eta_{it}, \alpha_i + \eta_{is}) = \sigma_\alpha$, the choice

probability for firm i conditional on the random effect factor is

$$l_i = P(Y_{i1}, \ldots, Y_{iT}) = \int_{a_1}^{b_1} \ldots \int_{a_T}^{b_T} \phi(\epsilon_t, \ldots, \epsilon_T) d\epsilon_0 \ldots \epsilon_T$$
$$= \int \Pi_{t=1}^{T} [\Phi(b_{it}|\alpha_i) - \Phi(a_{it}|\alpha_i)] \phi(\alpha_i) d\alpha_i.$$

where $a = -W\delta$ and $b = \infty$ if $d_{it} = 1$, and $a = -\infty$ and $b = -W\delta$ if $d_{it} = 0$, and $W\delta = \beta_1 Y_{t-1} + \beta_2 SDIA_{t-1} + \delta X_t$. This is because conditional on α_i, error terms are independent, making it possible to integrate out. We can estimate the above model by using the Gauss-Hermite procedure to evaluate integrals (see Butler and Moffitt (1982)).

However, in a dynamic probit model, in order to use the above specification the assumption should be made that the initial period data generating process is exogenous. If the initial conditions do not satisfy the assumption, they need to be altered. Heckman (1981) suggests a solution that approximates the marginal probability of the initial outcome by using a probit model and allows the error term in the initial period to be correlated with the errors in other periods. Hence, we specify not only the model in the subsequent years but also the initial stage model as probit:

$$Y_{it} = I(\beta_1 Y_{it-1} + \beta_2 SDIA_{it-1} + X_{it}\delta + \epsilon_{it} \geq 0)$$
$$Y_{i0} = I(X_{i0}\delta_0 + \epsilon_{i0} \geq 0)$$

In addition, we allow a correlation between the error terms at the initial point and at

subsequent periods in the following parametrized way:

$$Cov(\epsilon_{i0}, \epsilon_{it}) = \gamma_t$$

In the estimation, we impose restriction $\gamma_t = \gamma_s$, since it is difficult to estimate a model with too many parameters. The serial correlation pattern is represented by an AR(1) process:

$$\eta_{it} = \rho\eta_{it-1} + \nu_{it}$$

For identification, we assume that $Var(\epsilon_0) = 1$ and $Var(\epsilon_t) = 1$. Hence, the variance-covariance matrix for Y_i is

$$\begin{pmatrix} 1 & \gamma_1 & \gamma_2 & \gamma_3 & \cdots \\ \gamma_1 & 1 & (1-\sigma)\rho+\sigma & (1-\sigma)\rho^2+\sigma & \cdots \\ \gamma_2 & (1-\sigma)\rho+\sigma & 1 & (1-\sigma)\rho+\sigma & \cdots \\ \gamma_3 & (1-\sigma)\rho^2+\sigma & (1-\sigma)\rho+\sigma & 1 & \cdots \\ \vdots & \vdots & \vdots & \vdots & \ddots \end{pmatrix}$$

where $\sigma = \sigma_\alpha/(\sigma_\alpha + \sigma_\eta)$. The likelihood function is

$$l_i = \int_{t=0} \cdots \int_{t=T} \phi((X\delta + \epsilon_{it})(2Y_{it} - 1) \geq 0, t = 0, \ldots, T) d\epsilon_i$$

Since this specification requires high dimensional integration, we use the simulated maximum likelihood method to estimate this model (see, for example, Hajivassiliou and Ruud (1994) and Train (2002)). We use the Geweke, Hajivassiliou, and Keane (GHK) method

to evaluate this integration.

3.5 Estimation Results

In this section, we present the results for a variety of empirical specifications of the direct investment models discussed in Section 3.4. First, we show the results of the linear probability model, and then we report the results of the probit model.

3.5.1 Linear Probability Model

Asia

Since we would like to focus on state dependence, serial correlation, and the effect of distribution direct investment after controlling for heterogeneity, we discuss three main elements: lagged dependent variable, distribution direct investment, and serial correlation. Table 3.2 reports on the random effect, fixed effect, GMM estimation, and minimum distance estimation results for Asian countries.

The coefficients of the lagged dependent variable are significant except for GMM-SYS and the minimum distance estimation: 0.375 in random effect, -0.124 in fixed effect, -0.073 in GMM-DIF, -0.05 in GMM-SYS, and -0.019 in the minimum distance estimation. Therefore, there is a negative state dependency or no dependency in manufacturing direct investment after controlling for a firm's unobserved heterogeneity. This suggests that the search cost and scale economy loss cancel out or that there exists a small search cost for investing in manufacturing in Asia.

In Table 3.2, with respect to the effect of distribution direct investment, the coefficient

of the distribution direct investment is positive across different estimations: 0.016 in random effect, 0.026 in fixed effect, 0.019 in GMM-DIF, 0.027 in GMM-SYS, and 0.027 in the minimum distance estimation. These results are all statistically significant except for the GMM-DIF estimation. The marginal effect of distribution direct investment on the probability of investing in manufacturing plants is 2 to 3 percent. A comparison of coefficients between GMM-DIF and GMM-SYS shows that GMM system estimation corrects the downward biased result of GMM-DIF. In addition, since all covariates are significant in GMM-SYS, our data support this specification. The effect of distribution direct investment is robust among different estimations and specifications.

If there is no serial correlation in the error term (ϵ_{it}) in the difference equation, a negative correlation must exist, since $\hat{\epsilon_{it}} - \hat{\epsilon_{it-1}}$ follows a negative first order serial correlation. Since the test rejects no serial correlation, we might not need to be concerned about a serial correlation here. This implies that including a lagged dependent variable can take into account not only state dependence, but also correlation in errors. In Table 3.2, columns 5 and 6 present the case of using one year and two year lagged dependent variables. This does not change the results in the one year lagged model. Column 7 in Table 3.2 reports the results of the minimum distance estimator, which addresses the issue of the serially correlated error. The coefficient of the AR(1) term is -0.057. We have a weak serial correlation. Controlling for the serial correlation corrects the downwards bias of the effect of state dependency, where the coefficient is -0.05 in GMM-SYS and -0.019 in the minimum distance estimator.

Europe and North America

Table 3.3 presents the results for Europe. With respect to the state dependence term, although the random effect estimation produces a positive effect (0.4) and the fixed effect estimation produces a negative effect (−0.067), the GMM estimation does not provide significant results. One explanation is that the search cost and loss of scale economy cancel out, so the effect of the previous period investment in manufacturing is negligible. This also might suggest that the lagged dependent variable captures serial correlation instead of state dependence. The coefficient of distribution direct investment is negative for all specifications and is only significant in the fixed effect estimation, −0.023. Therefore, in the European market our data do not support the learning hypothesis.

The results for North America are reported in Table 3.4. The random effect estimation produces a positive significant effect of state dependence (0.328) and distribution direct investment (0.007). However, if we control for firms' fixed effects, the coefficients turn out to be insignificant. We do not find evidence of state dependence or the effect of distribution direct investment after controlling for heterogeneity. Therefore, our data do not support the learning effect hypothesis for Europe and North America.

3.5.2 Probit Estimation

Asia

First, we employ a static probit estimation. Then, we utilize a random effect probit model without initial conditions, and finally we estimate a probit model with the initial conditions and a serial correlation as an AR(1) form. Here, as in the previous section,

we focus on three factors: lagged dependent variable, distribution direct investment, and serial correlation.

In Table 3.5, columns 1 to 3 show probit estimation results for Asia. The coefficient of the lagged dependent variable is not significant in any estimation, so that we can not find a state dependency here. This is similar to the GMM-SYS or minimum distance estimation results in the linear probability model. In this case, the search cost might have offset the loss of scale economy. This also suggests that the lagged dependent variable might capture serial correlation instead of state dependence.

On the other hand, we find a positive significant effect of distribution direct investment on the probability of manufacturing direct investment. The coefficient is 0.053 in static probit (column 1), 0.064 in panel probit (column 2), and 0.06 in panel probit with AR(1) (column 3) with all coefficients significant. This result is similar to that of the linear probability model. The existence of the effect of distribution direct investment is robust in different models. Therefore, we can conclude that our data support the learning effect hypothesis in Asian countries.

In the random probit model, the estimated correlation parameter, $Cov(\epsilon_t, \epsilon_s)$, is 0.098. Also, in the random probit model with AR(1), the coefficient of the AR(1) error term, ρ, is -0.196. We find a weak serial correlation. This weak correlation is similar to the linear probability model results. Therefore, by allowing the lagged dependent variable to be one of the regressors, we are able not only to control for state dependence, but also for serial correlation. In the random probit model with AR(1), we have an estimate of the correlation term between the initial period error term and subsequent periods error terms ($Cov(\epsilon_0, \epsilon_t)$), which is 0.217. Hence, this weak correlation explains the similarity

of results for panel probit models with and without initial conditions.

With regard to other covariates, the results are similar across different specifications. For example, there is a significant positive effect of productivity (0.334 in static, 0.332 in panel, and 0.284 in panel with AR(1) error). High productivity firms tend to invest in manufacturing. Since large parts of other covariates are significant, the data are consistent with our specifications.

Europe and North America

For Europe and North America, the results are similar to those in the linear probability model. In Table 3.5, columns 4 to 6 report the results for Europe. The coefficients of the lagged dependent variable are 0.35 in static, 0.116 in panel, and 0.287 in panel with AR(1) error. All are insignificant and no state dependency is found. The coefficients of distribution direct investment are negative, -0.009 in static, -0.011 in panel, and -0.003 in panel with AR(1) error. All are statistically insignificant as well. These results contrast with those for Asia, in which we find a positive significant effect of distribution direct investment. Here, we can not find a significant learning effect, and point estimates are negative in all specifications. This suggests that in our sample period the learning effect is not important in Europe. In the panel estimation, the correlation between errors is $Cov(\alpha_i, \alpha_i) = 0.175$ and is statistically insignificant. In the panel AR(1) model, $Cov(\epsilon_0, \epsilon_t) = -0.234$ and $\rho = -0.112$. Hence, for Europe, there is a weak correlation between the errors. This explains the similarity of the results of panel and panel AR(1) models.

The results for North America do not differ between static and panel probit estima-

tions. The null hypothesis, which states that there is no correlation, can not be rejected. We omit panel probit results and report static probit results only. Hence, we conclude that the effect of distribution direct investment is not prevalent in Europe and North America.

This regional difference may reflect the difficulty of learning about local markets. The measures of trade policy imply that on average trade policy is not transparent and trade protection is severe in Asia (see, for example, Rose (2002)). This increases the importance of information about local markets obtained by own distribution affiliates. The other reason might be the stage of distribution network development. In order to obtain a competitive advantage and export their products to European or North American markets, Japanese firms tend to own the distribution sector (see Yamawaki (1991) for the U.S. case). Before our sample period, this type of investment strategy was already undertaken and the distribution network was developed to some extent in European and North American markets. However, in the Asian market, our sample period is the early stage of the development of this type of network. At this early stage, information about local markets is important to commit to intensive manufacturing affiliates. Therefore, in our estimation the effect of distribution direct investment is prominent in Asian markets.[6]

[6]Since our focus is on the effect of distribution direct investment, we ignore the possible regional difference between motivations to invest in manufacturing. Firms set up manufacturing plants to supply local markets (local sales), export to other countries (export platform), or export to source country (reverse imports). If the effect of distribution direct investment depends on the motivations of manufacturing direct investment, it has a positive effect if the local sales motivation is prevalent. On the other hand, it has no effect if the export platform or reverse imports motivation prevail. However, our results do not support this. Hence, we might be able to claim that distribution direct investment does not depend on the motivations of manufacturing direct investment.

3.6 Conclusion

We study whether there exists a learning effect of distribution direct investment on the decision to invest in manufacturing. We employ dynamic panel models to investigate the learning effect by controlling for unobserved heterogeneity, state dependence, and serial correlation. Our data support the hypothesis that the learning effect exists for distribution direct investment in Asian countries. However, there is no evidence of the learning effect of distribution direct investment in North America and Europe.

This regional difference might reflect the variety of difficulties in learning about local markets. Due to severe trade protection and low economic stability, it is important to obtain information on local markets. This might give distribution direct investment an information acquisition role in Asia. Also, in our sample period, especially in East Asia, there exists a trend of developing a production/distribution network. There was a lot of uncertainty about local markets in Asia as opposed to markets where such a network was already established to some extent (in our sample, Europe and North America). Hence, our findings suggest that in the presence of high uncertainty distribution direct investment plays an important role in the decision to build manufacturing operations.

Chapter 4

Brand Proliferation and Entry Deterrence under Vertical Differentiation

4.1 Introduction

In the pharmaceutical industry, an incumbent (brand-name) and entrants (generic) know the expiry date of a patent. The incumbent can expect the entry of generic firms after the expiration of a patent. Hence, before the expiration date, the incumbent may produce a new product (called a "pseudo-brand" or "pseudo-generic") to crowd the market, thereby making new entries unprofitable. Since brand-name companies tend to introduce pseudo-generic drugs just before a patent expires, a new drug may be introduced by a preemptive motive. For example, in the United States several brand-name companies such as Upjohn, Syntex, Ciba-Geigy, and Bristol-Myers Aquibb adopted this strategy

of pseudo-generic drug introduction. The resulting market shares were dominated by these pseudo-generic products.[1] Similarly, in Canada brand name firms used this strategy. As the result, in 1999 the pseudo-generic drug share of the generic drug sales was 34.6 percent.[2] So, "preexpiration generic introduction by brand-name manufactories can reasonably be seen to result in increased prices for these products post-patent expiration and thus may represent anticompetitive action" (Liang (1996)). This is an anti-trust issue raising several questions. First, does the incumbent have a first-mover advantage to deter entry (threat is credible)? Second, if it does, should the anti-trust agency be concerned about incumbent's behaviour?

In this paper, we attempt to examine the credibility of the incumbent's behaviour and its welfare consequences. One way of dealing with this problem is to adopt a vertical differentiation model. If there is a threat of entry of a low quality product at a low price, the incumbent who has produced the highest quality good may have an incentive to produce a lower quality product to crowd the market. This might deter entry. Schmalensee (1978) first analyzed brand proliferation in a horizontally differentiated model. However, Judd (1985) shows that if the incumbent can withdraw the new good, there may be incentive to do so. Using an example of a spatial model, he concludes that as substitutes become closer and as the market size decreases, crowding the market is less likely to be credible. Brand proliferation is monotonic in parameters. The basic idea is that intensive price competition achieved by crowding the market is not profitable if the incumbent can withdraw a new good. However, little is known about the credibility in a vertically

[1]Business Week, September 5, 1994, p.67. See Liang (1996) for more details.

[2]For further details, see Hollis (2003).

differentiated good model.[3]

We set up a vertically differentiated good model. At the first stage, before patent expiration, an incumbent decides whether to introduce a new drug. If the drug is introduced, the incumbent also chooses the quality level. After this decision and due to patent expiration a generic firm decides whether to enter the market or not. If the generic firm enters, it competes with the prices; if it does not enter, monopoly is sustained. Since we endogenize the quality choice of the incumbent, an uncovered or covered market outcome is endogenous. Wauthy (1996) first recognized the endogeneity of market outcome when firms can choose their quality level. This outcome depends on the fundamentals of the model, market size and quality dispersion. These factors mainly create three possible cases: large, intermediate, and small.

We show that if market size and quality dispersion are intermediate, the deterrence threat is credible. On the other hand, if these are very large or small, it is not credible. The intensity of price competition is the least severe in the intermediate case. That is why incumbent's new good expands market share but does not lead to intensive price competition in which new good introduction is profitable for the incumbent. In other words, the effect of expanding market share dominates the price competition effect. To our knowledge, there is no study that examines how credibility depends on these fundamentals in the vertical differentiation model.[4] Hence, our contribution is to show

[3]In the case of medical drugs, a brand firm's reputation differentiates its product quality from generic firms. The consumer may perceive pseudo-brand drug quality as higher because of its research activity or its manufacturing care. If a brand firm considers its reputation to be an important asset, it will devote more expenses to maintaining its reputation. Hence, the pharmaceutical industry market can be an example of a vertically differentiated good market.

[4]This has an important implication for the vertical differentiation model. If we simply confine the range of parameter values or assume a market outcome, we might lose generality of analysis.

that credible deterrence occurs in the intermediate case under the vertical differentiation framework.[5]

Our non-monotonicity result of deterrence credibility is related to that of Ellison and Ellison (2000). They show the possibility of non-monotonicity of investment by using a strategic investment model where the incumbent has an entry deterrence motive. They do not examine the strategy of pseudo-generic drug introduction. Instead, they examine proliferation of presentations: drugs are sold in tablets of different size, in bottles, and in vials. They show empirically that the incumbent's presentation proliferation is highest in the intermediate case.

With respect to welfare, the anti-trust agency can improve social welfare by prohibiting brand proliferation in the intermediate case. Since in other cases deterrence is not credible, prohibition has no effect. This result implies that if the anti-trust agency observes the incumbent's introduction of pseudo-generic drugs, it needs to investigate demand and quality level. If these are intermediate, the incumbent's behaviour can be anti-competitive. Therefore, this paper has important implications not only for theoretical studies but also for the competition policy. We show the conditions in which a competition policy is required to achieve efficiency.

This chapter will proceed as follows. In Section 4.2 we will set up the model, and in Section 4.3 we will present equilibrium outcomes. In Section 4.4 we will discuss welfare implications. Section 4.5 will offer extensions of this model, and Section 4.6 will conclude the chapter.

[5]Hollis (2003) suggests that entry is deterred in the intermediate market size case.

4.2 Model

We employ a vertically differentiated good model[6] and consider an entry deterrence game. Suppose that the incumbent already produces the highest quality (s_2) good. The entrant may enter by producing the lowest quality (s_0) good. The timing of the game is as follows. At the first stage, prior to patent expiration, the incumbent decides whether to produce a new good or not. If the decision is to produce, the incumbent also chooses the quality level of the new product ($s_1, s_0 \leq s_1 \leq s_2$). Then, after the patent expires and the entrant observes the incumbent's choice, the entrant decides whether to enter or not. If the entrant decides to do so, the incumbent will decide whether to keep the new product on the market or withdraw it. Finally, these firms compete in prices (see Figure 4.1). For the sake of simplicity, in this model production costs that depend on the quality level are set at zero, but new entry and new good introduction are costly.[7] The entry cost is a fixed amount, K, and the new good introduction cost is L.

Parameters s_2 and s_0 are assumed to be exogenous, and s_1 is no less than s_0. One justification of these assumptions is as follows. If advertisement can shift the demand curve upwards, quality can be interpreted as determined by advertisement levels. Since generic firms do not advertise as much as brand name firms, their quality level is regarded as exogenous and the lowest. Pseudo-brand drugs are usually advertised to some extent. Alternatively, because of reputation, pseudo-brand drug quality can be considered as

[6]See Constantatos and Perrakis (1997), Gabszewicz and Thisse (1979), and Shaked and Sutton (1982, 1983). Our formulation is similar to that of Choi and Shin (1992), Mussa and Rosen (1978), Tirole (1988), and Wauthy (1996).

[7]We will examine the case of positive production costs in Section 4.5.

higher than generic drug quality. It is a reasonable approximation that pseudo-brand quality is restricted to be greater than generic drug qualities.

Consumer preferences are:

$$U = s_k \cdot t - p_k$$

when consuming product k. Let t designate a type which denotes the consumer's willingness to pay and p_k designate the price of good k. We assume that consumer's type is uniformly distributed between a and b, where $0 < a < b$.

Assumption 1. $2a < b$ *(i.e. entry is feasible)*

This assumption ensures that market size is sufficient to sustain two firms. If $b < 2a$, only the incumbent can stay in the market.[8] If consumers only purchase the outside good, it is assumed that utility is 0.

Since $s_{k-1} \leq s_k$, there exists a cut off value of type, t_k,where the consumer is indifferent between $k-1$ and k:

$$s_k \cdot t_k - p_k = s_{k-1} \cdot t_k - p_{k-1} \iff t_k = \frac{p_k - p_{k-1}}{s_k - s_{k-1}}$$

The cut-off point of the consumer who is indifferent in the choice between the lowest quality good and not buying is expressed as $s_0 t_0 - p_0 = 0 \iff t_0 = p_0/s_0$.

There are two cases of price competition to consider, one in which the incumbent has a single good and another in which the incumbent has two goods. In the case of duopoly

[8]Gabszewicz, Shaked, Sutton, and Thisse (1986) demonstrate the monopoly problem if $b < 2a$.

with a single-product incumbent, the optimization problems of the incumbent and the entrant are, respectively,

$$\max_{p_2} \pi^I = (b - t_2)p_2$$

$$\max_{p_0} \pi^E = (t_2 - t_1)p_0 \text{ or } (t_2 - a)p_0$$

In the case of duopoly with a multi-product incumbent, the problems of the incumbent and the entrant are, respectively,

$$\max_{p_2, p_1} \pi^I = (b - t_2)p_2 + (t_2 - t_1)p_1$$

$$\max_{p_0} \pi^E = (t_2 - t_1)p_0 \text{ or } (t_2 - a)p_0$$

By solving this price competition stage, we can derive equilibrium prices (p_0, and p_2, or p_0, p_1, and p_2).

Our focus is on whether the incumbent has a first mover advantage or not. We investigate a case in which before entry the incumbent can announce new good production. In Section 4.5, we will discuss the case where the entrant can first commit to entering the market.

4.3 Equilibrium Outcomes

The game has three stages. In stage one, if the incumbent decides to introduce a new good, quality level, s_1, must also be chosen. After observing that, the entrant decides

whether to enter or not. If entry occurs, the incumbent decides whether to withdraw the new good from the market. We derive the subgame perfect Nash equilibrium by applying backward induction. Here, we focus on examining the conditions under which entry deterrence occurs in equilibrium.

Before stating the main result, we should introduce notations regarding the fundamental parameters and make assumptions on entry and new good introduction costs. Let $\beta = b/a$ and $\mu = s_2/s_0$. Let β designate market size and μ designate quality dispersion. We interpret a large β as large market size. If μ is small, for example, these are close substitutes. As mentioned in the introduction, there exist large, intermediate, and small cases in terms of market size and quality dispersion. Let define a large case if $(\beta - 1)/(\beta - 4)(\equiv \overline{\beta}) < \mu$, an intermediate case if $(\beta + 1)/(\beta - 2)(\equiv \underline{\beta}) \leq \mu \leq \overline{\beta}$, and a small case if $\mu < \underline{\beta}$ (see Figure 4.2).[9] The horizontal axis is $\beta(\geq 2)$ and the vertical axis is $\mu(\geq 1)$, where $\mu = \underline{\beta}$ is $c1$ and $\mu = \overline{\beta}$ is $c2$. Hence, below c1 is a small case, between c1 and c2 is an intermediate case, and above c2 is a large case.

With regard to entry costs, first we consider the condition of the level of entry costs where entry deterrence is feasible. Then we study the case in which such a condition does not hold. The profit function of the entrant (π^E) is increasing in s_1 ($d\pi^E/ds_1 > 0$). Since larger s_1 means increased quality dispersion, which leads to more profitable opportunities for the entrant, incumbent's deterring entry should decrease the quality level of the new good and make it a close substitute to the entrant's good. If the entry cost is high enough to make the entrant's profit negative, new good introduction can deter entry.

[9]This is the case where $4 < \beta$. If $\beta < 4$, we only have small and intermediate cases ($\mu < \underline{\beta}$ and $\underline{\beta} \leq \mu$).

The following is the assumption about entry costs making entry deterrence feasible:

Assumption 2. $\underline{K} < K < \overline{K}$

where $\underline{K} = (b - 2a)as_0/3$ and $\overline{K} = \min\{K_1, K_2, K_3\}$. K_1, K_2, and K_3 are entrant's profit, where the incumbent does not introduce a new good in a large, intermediate, and small case, respectively.[10]

This condition ensures that the incumbent is able to deter entry. There are two cases that violate Assumption 2. The first case is $K \notin (\underline{K}, \overline{K})$ and the second case is $\underline{K} \not< \overline{K}$. In the first case, if $K < \underline{K}$, no strategy can deter entry, and if $\overline{K} < K$, the entrant may stay out (blockaded). It is obvious that in such cases, entry is determined by entry costs. Therefore, we will study the second case as the case violating Assumption 2 in the paper.

The condition, $\underline{K} < \overline{K}$, is equivalent to the conditions in terms of fundamentals:

$$\underline{\beta} \leq \mu$$

$$0 < \beta^2(\mu^2 - \mu)/(4\mu - 1)^2 - (\beta - 2)/3.$$

The region of these is the shaded area in Figure 4.3. Notice that as long as $\underline{\beta} \leq \mu$, we can show that strategic entry deterrence is still feasible if $\underline{K} < K < K_2$ instead of using $\overline{K}$.[11] Since $\underline{K} < K_2$, if we modify Assumption 2 so that $\underline{K} < K < K_2$, the analysis is the same under Assumption 2. Therefore, we will regard the case violating Assumption 2 as $\mu < \underline{\beta}$, which is a small market size and quality dispersion case. On the other hand,

[10]Explicitly, these are $K_1 = b^2 s_0 s_2 (s_2 - s_0)/(4s_2 - s_0)^2, K_2 = (s_2 - s_0)(b - 2a)^2/9$, and $K_3 = [(abs_0 - 2s_0a^2)s_2 + (a - b)as_0^2]/2(s_2 - s_0)$.

[11]See Appendix B.2.4

under Assumption 2, we have a large or intermediate market size and quality dispersion case.

With regard to new good introduction costs, we assume that $L < \bar{L} \equiv b^2 s_2/4 - (bs_2 + (a-b)s_0)^2/4(s_2 - s_0)$.[12] This is needed because if L is too large, it is not profitable for the incumbent to produce a new good. Since in the pharmaceutical industry these costs are not so high for the incumbent, this assumption is justifiable.

The result relates to the credibility of the deterrence threat. Here, credible threat corresponds to the case in which the incumbent introduces a new good of quality s_1 and in which the entrant enters the market with the incumbent keeping the new good. If the incumbent withdraws the good, the deterrence threat is not credible. Let us introduce a function, $\phi(\beta, \mu)$, defined in Appendix B.2.3, which is used to determine the condition of credibility.[13] The following lemma shows the credibility result in the large ($\overline{\beta} < \mu$) and intermediate ($\mu \leq \overline{\beta}$) market size and quality dispersion cases.

Lemma 1. *Under Assumption 2,*

1. *If $4 < \beta$, and*

   (a) *If $\overline{\beta} < \mu$ and $\phi > 0$, the deterrence threat is not credible.*

   (b) *If $\overline{\beta} < \mu$ and $\phi < 0$, or if $\mu \leq \overline{\beta}$, the deterrence threat is credible.*

2. *If $\beta < 4$, then the threat is credible (since there can be only an intermediate case).*

---

[12] $b^2 s_2/4$ is the incumbent's profit under monopoly and $(bs_2 + (a-b)s_0)^2/4(s_2 - s_0)$ is the incumbent's profit under duopoly with a single-product incumbent when the market is covered with a corner solution.

[13] $\phi = 0$ is c3 in Figure 4.4.

The following lemma shows the result when Assumption 2 does not hold, in a small market size and quality dispersion case.

Lemma 2. *Suppose $\mu < \underline{\beta}$, then the deterrence threat is not credible.*

The proof of Lemma 1 and 2 is in Appendix B.2. It has four steps. First, we solve the price game and derive equilibrium prices corresponding to each market configuration. Second, in each market configuration, we derive the optimal quality. Third, we compare each corresponding profit and identify the highest profit. Depending on the parameter values, we have three cases: an uncovered market, a covered market with an interior solution, and a covered market with a corner solution. Finally, for each case credibility is examined. To check credibility, we apply Judd's criterion: whether the incumbent's profit from keeping the new good is greater than that from withdrawing it.

The main result is the condition of entry deterrence:

Proposition 3. *Suppose Assumption 2 holds. Then, in equilibrium, the following holds:*

1. *If $4 < \beta$, and*

   (a) *If $\overline{\beta} < \mu$ and $\phi > 0$, then entry is accommodated.*

   (b) *If $\overline{\beta} < \mu$ and $\phi < 0$, or if $\mu \leq \overline{\beta}$, then entry is deterred.*

2. *If $\beta < 4$, then entry is deterred.*

The proof is in Appendix B.3. This proposition states that entry is either blockaded or accommodated when we have a very large market size and quality dispersion (the case of a large market size and quality dispersion with $\phi > 0$). On the other hand, if market

size and quality dispersion are intermediate or if these are large with $\phi < 0$, entry is strategically deterred.

Next proposition is about entry deterrence in the case of $\mu < \underline{\beta}$, which is the case of small market size and quality dispersion:

Proposition 4. *Suppose $\mu < \underline{\beta}$. Then,*

1. *If $K < \overline{K}$, entry is accommodated.*

2. *If $\overline{K} < K$, entry is blockaded.*

That is, no deterrence threat is credible.

The proof is in Appendix B.4. This proposition implies that if $\mu < \underline{\beta}$, entry is solely determined by entry costs. Therefore, if market size and quality dispersion are intermediate ($\underline{\beta} \leq \mu \leq \overline{\beta}$) or if these are large with $\phi < 0$, the entry is strategically deterred. The entry deterrence region is the shaded area in Figure 4.4.

The intuition of these results is as follows. Small market size and quality dispersion imply that consumers are almost homogeneous and so are qualities. This is almost a homogeneous good price competition game. The price competition is very intensive. In such a market, if the incumbent supplies one more good, competition is more intensive. This is not profitable, so the incumbent accommodates entry.

If market size and quality dispersion are intermediate, even if the incumbent introduces a new good, the entrant does not respond by changing the price. The reason is as follows. If the entrant was to decrease the price, since the incumbent's good is not a close substitute, the entrant could not obtain a much larger share of the market. If the

entrant increased the price, the market configuration would shift to an uncovered market, leading to a large loss of share. Thus, from the incumbent's point of view, the market share can be expanded without dramatically lowering the price, so the introduction of a new good is profitable.

Finally, in the case of very large market size and quality dispersion, consumers have a low willingness to pay and the quality of the entrant good is very low. To supply these consumers, the entrant has to drop the price very low. Some consumer may prefer such a discounted low quality good. Since the price of such a good is very low, even if the incumbent can keep these consumers, this would not be profitable. The incumbent should keep only the high quality good and sell it only to consumers with a high willingness to pay. So, in this case the incumbent would accommodate entry. In Judd's (1985) spatial model example, if demand is high, new good introduction is credible. Here, in a vertical differentiation framework, if demand is high enough, new good introduction is not credible.

For reference, it is useful to illustrate the monopoly problem. Prior to patent expiration or in case of entry deterrence success, the single-product monopoly problem is:

$$\max_{p_2} (b - t_2)p_2 \text{ or } (b - a)p_2$$

The multi-product monopoly problem is:

$$\max_{p_2, p_1} (b - t_2)p_2 + (t_2 - t_1)p_1 \text{ or } (b - t_2)p_2 + (t_2 - a)p_1$$

The consumer who is indifferent to buying s_2 or s_1 is $t_2 = b/2$. The consumer who is indifferent to buying s_1 or not buying is $t_1 = b/2$. So, in the multi-product monopoly case, the monopolist has no incentive to provide a good of a different quality. Quality proliferation collapses, and the market is not covered. Only consumers in the range $[b/2, b]$ purchase the differentiated good.[14]

By comparing this case to the market coverage in the presence of entry, the following result are obtained.

Proposition 5. *Suppose Assumption 2 holds. In equilibrium, the following holds:*

1. *If $\overline{\beta} < \mu$ and $\phi > 0$, the market is uncovered; coverage is larger in the duopoly case than in the monopoly case.*

2. *If $\overline{\beta} < \mu$ and $\phi < 0$, or if $\mu \leq \overline{\beta}$, since entry is deterred, market coverage is the same as in the monopoly case.*

If Assumption 2 does not hold, we have:

Proposition 6. *If $\mu < \underline{\beta}$ and $K < \overline{K} < \underline{K}$, then in duopoly the market is covered.*

Even if entry is accommodated, provided $\overline{\beta} < \mu$, market size is large, so some consumers do not consume differentiated goods. If entry is deterred, the market outcome is identical to that in the monopoly case. If the market size is small, allowing the entrant in covers the market.

By taking market coverage and equilibrium prices into account, we can assess the welfare implications.

[14]For the market coverage issue in a vertical differentiated model, see for example Mussa and Rosen (1978), Gabszewicz, Shaked, Sutton, and Thisse (1986), and Constantatos and Perrakis (1997).

4.4 Welfare

The basic principle at issue in a competition policy is how and when the government can attain efficiency in the market economy. In other words, the question is how and when the authorities should intervene in private economic activities. For example, in Canada according to the Competition Act the use of fighting brands introduced selectively on a temporary basis to discipline or eliminate a competitor is considered anti-competitive. Therefore, in this section we investigate whether a competition policy can improve welfare. The policy considered here is the prohibition of pseudo-generic drug supply by brand name firms.

Expressing social welfare through the sum of consumer surplus and producer surplus produces:

Proposition 7. *If $\overline{\beta} < \mu$ and $\phi < 0$, or if $\mu \leq \overline{\beta}$, prohibition of brand proliferation improves social welfare. In other cases, it is neutral.*

The proof is in Appendix B.5. This result provides a criterion of anti-competitiveness of the incumbent's behaviour. If market size and quality dispersion are intermediate or if these are large with $\phi < 0$ in some drug markets, and if the brand-name firm introduces a pseudo-generic drug, entry would be deterred.

The intuition of this result is simple. Entry causes price competition, thus decreasing the price of the incumbent's highest quality product. The entrant starts to provide for consumers who do not purchase a differentiated product. Hence, entry enhances welfare. To encourage entry, the anti-trust agency has to prohibit incumbent's new good introduction if the deterrence threat is credible. If the deterrence threat is not credible,

the anti-trust agency does not have to take an action against the incumbent's behaviour. Irrespective of the anti-trust policy, a rational entrant will enter the market.

4.5 Extension

Two extensions are considered here. First, we have investigated a situation in which an incumbent has a first-mover advantage but also has an exit option. Here, we will discuss what happens when the incumbent produces a new good after observing the entrant's entry decision. Consider the subgame where the entrant decides to enter. The incumbent then decides whether or not to produce. The incumbent will produce only if production is profitable. Previous analysis shows that new good introduction is profitable when market size and quality dispersion are intermediate. Otherwise, the incumbent does not produce a new good. Hence, the outcome is the same as in the previous analysis, where the incumbent moves first, the entrant makes an entry decision, and then the incumbent makes an exit decision.

Second, we have assumed that there are no production costs. Suppose that we have a new good production cost, $c(s_1), c' > 0, c'' > 0$, which depends on the quality level of the good. Then, in the quality choice stage, the problem of the incumbent will be:

$$\max_{s_1} \pi^I(s_1) - c(s_1)$$

The first order condition is:

$$\frac{\partial \pi^I}{\partial s_1} - c'(\hat{s_1}) = 0$$

The value of the solution to this problem is less than that without production cost: $\hat{s_1} < s_1^*$. From the properties of π^I, we have the following relationship in a small or large market size and quality dispersion case:

$$\pi^I(\hat{s_1}) - c(\hat{s_1}) < \pi^I(\text{only supplying } s_2)$$

This implies that if entry occurs, the incumbent has an incentive to withdraw the new good, $\hat{s_1}$. Hence, if we redefine $\overline{K}$, which is the minimum of entrant's profit under $s_1 = \hat{s_1}$, and the modified Assumption 2 holds, the same logic holds as in the case without production costs.

4.6 Conclusion

We investigate the credibility of entry deterrence in a vertically differentiated good model. Credibility depends on market size and quality dispersion. If these are very large or small, deterrence threat is not credible. However, if these are intermediate, a new good production is a credible threat. Since equilibrium quality choice yields a corner solution in the price subgame in such a case, the incumbent can expand market share without intensive price competition by introducing a new good.

By examining market size and quality dispersion, we can determine the intermediate

case. The anti-trust agency needs to investigate this incumbent's behaviour in the intermediate case. The incumbent's threat is credible and entry is deterred. By prohibiting such an action, the anti-trust agency can improve welfare. The contribution of this paper is to show the conditions in which a competition policy is required to achieve efficiency.

Although we have discussed the pharmaceutical industry in the introduction, our analysis can be applied for other industries. As long as products have vertically differentiated characteristics, the result of entry deterrence is valid. For example, in the airline industry, there have been new entry firms offering low fairs and low service flights. If we observe an incumbent airline introducing a new low fair and low service flight, it is important for the anti-trust agency to decide whether this behaviour deters entry. Our results have the same policy implication in this situation.

Tables

Table 2.1: Summary Statistics

summary stat of sample	mean	standard dev	min	max
Asia DIA in each year	36.8	17.8	21	66
North America DIA in each year	5.3	4.2	0	14
Western Europe DIA in each year	8.5	5.7	1	17
R&D spending (million yen)	20308	62777.6	19	480500
Employment	5194.7	12026.8	79	81488
number of firms 141				
number of observation 1692				
year 1987-1998				

Table 2.2: R&D and DIA by Region

dependent variable: log of R&D

	1	2	3	4	5	6	7	8	9	10
									w/o t	w/o t
	Rndm	Fix	Rndm	Fix	Rndm	Fix	Rndm	Fix	Rndm	Fix
Asia	0.141^a	0.1^a	0.017	0.024	-0.595^b	-0.482^b	−0.241	−0.279	−0.148	-0.249^c
	(0.03)	(0.03)	(0.026)	(0.027)	(0.242)	(0.237)	(0.203)	(0.212)	(0.14)	(0.142)
Europe	0.167^a	0.105^b	0.098^b	0.067	0.21	0.495	−0.332	−0.104	0.059	−0.164
	(0.048)	(0.047)	(0.041)	(0.0419)	(0.6)	(0.58)	(0.511)	(0.52)	(0.266)	(0.265)
N Am	0.183^a	0.116^a	0.068^c	0.055	2.005^a	1.636^a	1.087^b	1.154^a	0.968^a	0.914^a
	(0.044)	(0.044)	(0.038)	(0.0392)	(0.494)	(0.474)	(0.425)	(0.425)	(0.273)	(0.271)
Other A					-12.276^a	−2.033	−2.982	−0.897	-0.123^b	-0.169^a
					(4.245)	(4.42)	(3.387)	(3.953)	(0.054)	(0.053)
Other E					2.582	8.08^b	−2.932	0.614	-0.198^b	−0.121
					(3.75)	(3.694)	(3.15)	(3.332)	(0.098)	(0.097)
Other NA					1.076	3.269	1.197	2.67	0.38^a	0.4^a
					(3.698)	(3.547)	(3.155)	(3.172)	(0.115)	(0.114)
Inter A					0.112^a	0.093^a	0.043	0.051^c	0.031	0.047^b
					(0.035)	(0.035)	(0.03)	(0.031)	(0.023)	(0.023)
Inter E					0.028	−0.035	0.091	0.05	0.017	0.059
					(0.118)	(0.114)	(0.1)	(0.102)	(0.06)	(0.06)
Inter NA					-0.378^a	-0.314^a	-0.209^a	-0.222^a	-0.186^a	-0.18^a
					(0.093)	(0.089)	(0.08)	(0.08)	(0.057)	(0.056)
Prod			0.355^a	0.297^a			0.339^a	0.279^a	0.348^a	0.286^a
			(0.039)	(0.0413)			(0.04)	(0.042)	(0.038)	(0.04)
Emp			1.012^a	0.788^a			0.999^a	0.775^a	1.001^a	0.773^a
			(0.032)	(0.0445)			(0.033)	(0.045)	(0.032)	(0.045)
CapLab			0.185^a	0.181^a			0.189^a	0.185^a	0.19^a	0.186^a
			(0.027)	(0.0268)			(0.027)	(0.027)	(0.026)	(0.027)
Wage			0.021	0.046			0.04	0.059	0.032	0.056
			(0.054)	(0.055)			(0.054)	(0.055)	(0.054)	(0.055)

N Am is North America, Other is competition effect, and Inter is interaction effect. The numbers in parentheses are standard errors. The superscripts ^{a}, ^{b}, and ^{c} indicate statistical significance at the 1 percent, 5 percent, and 10 percent levels. The regressions include time dummies except for the last two columns.

Table 2.3: Sign Patterns of Predictions and Regression Results

Trade and Transfer Costs		High			Low		
		Direct	Comp*	Inter*	Direct	Comp	Inter
Prediction: Endogenous R&D		−	−	+	+	+	−
Prediction: Exogenous R&D		−	−	−	+	−	−
Table 2.2 Column 6: Asia	without cv**	$-^b$	−	$+^a$			
Table 2.2 Column 8: Asia	with cv	−	−	$+^a$			
Table 2.2 Column 6: North America	without cv				$+^a$	+	$-^a$
Table 2.2 Column 8: North America	with cv				$+^a$	+	$-^a$
Table 2.2 Column 6: Europe	without cv				+	$+^b$	−
Table 2.2 Column 8: Europe	with cv				−	+	+

*, **: Comp is the competition effect and Inter is the interaction effect; cv stands for control variables; a and b denote statistical significance at the 1 and 5 percent levels, respectively.

Table 2.4: First and Long Differences Estimation

dependent variable: log of R&D

	First Dif	Two Dif	Three Dif	Five Dif	First Dif	Two Dif	Three Dif	Five Dif
Asia DIA	−0.212	−0.508^b	−0.636^a	−0.739^a	−0.047	−0.264	−0.343	−0.428^c
	(0.307)	(0.245)	(0.238)	(0.25)	(0.299)	(0.229)	(0.214)	(0.219)
Europe DIA	−0.977^c	−0.688	−0.736^c	−0.738^c	−0.841^c	−0.461	−0.399	−0.324
	(0.512)	(0.421)	(0.406)	(0.441)	(0.497)	(0.396)	(0.372)	(0.392)
North Am DIA	0.606	0.71	1.213^a	1.402^a	0.486	0.513	0.878^b	0.963^b
	(0.504)	(0.435)	(0.435)	(0.495)	(0.49)	(0.408)	(0.396)	(0.437)
Other Asia	−0.317	−0.429	−0.791^c	−0.487	−0.296	−0.437	−0.519	−0.526
	(0.228)	(0.332)	(0.446)	(0.48)	(0.222)	(0.322)	(0.43)	(0.447)
Other Europe	0.217^c	0.214	0.052	0.05	−0.002	−0.1	−0.206	−0.309^c
	(0.123)	(0.151)	(0.182)	(0.168)	(0.125)	(0.152)	(0.183)	(0.164)
Other N Am	0.46^a	0.548^a	0.798^a	0.775^a	0.414^a	0.545^a	0.638^b	0.701^a
	(0.136)	(0.207)	(0.266)	(0.255)	(0.134)	(0.203)	(0.263)	(0.242)
Inter Asia	0.048	0.1^b	0.12^a	0.126^a	0.018	0.056	0.066^c	0.071^b
	(0.053)	(0.041)	(0.04)	(0.041)	(0.052)	(0.039)	(0.036)	(0.036)
Inter Europe	0.241^b	0.178^c	0.195^b	0.203^b	0.202^c	0.115	0.109	0.092
	(0.12)	(0.097)	(0.093)	(0.1)	(0.117)	(0.092)	(0.085)	(0.089)
Inter N Am	−0.123	−0.155^c	−0.257^a	−0.296^a	−0.1	−0.111	−0.183^b	−0.2^b
	(0.107)	(0.092)	(0.091)	(0.104)	(0.104)	(0.086)	(0.083)	(0.092)
Productivity					0.198^a	0.195^a	0.208^a	0.244^a
					(0.049)	(0.046)	(0.047)	(0.055)
Employment					0.497^a	0.598^a	0.692^a	0.764^a
					(0.069)	(0.063)	(0.061)	(0.063)
Cap/Lab					0.13^a	0.17^a	0.166^a	0.226^a
					(0.039)	(0.036)	(0.035)	(0.037)
Wage					−0.001	0.013	0.072	0.084
					(0.055)	(0.055)	(0.061)	(0.074)

The numbers in parentheses are standard errors. The superscripts ^{a}, ^{b}, and ^{c} indicate statistical significance at the 1 percent, 5 percent, and 10 percent levels. The regressions do not include time dummies.

Table 2.5: R&D and DIA by Region (Lagged)

dependent variable: log of R&D

	1	2	3	4	5	6
					w/o time dm	w/o time dm
	Random	Fixed	Random	Fixed	Random	Fixed
Asia DIA	-0.745^a	-0.633^a	-0.362^c	-0.446^b	-0.329^b	-0.506^a
	(0.246)	(0.229)	(0.218)	(0.224)	(0.154)	(0.152)
Europe DIA	0.324	0.648	−0.088	0.238	0.468	0.149
	(0.603)	(0.58)	(0.542)	(0.546)	(0.278)	(0.273)
North A	1.437^a	1.168^b	0.666	0.782^c	0.759^a	0.679^b
	(0.51)	(0.485)	(0.463)	(0.456)	(0.291)	(0.284)
Other Asia	-10.514^b	0.107	−1.616	1.478	-0.102^c	-0.169^a
	(4.227)	(4.365)	(3.523)	(4.102)	(0.057)	(0.056)
Other Europe	0.384	6.155^c	−4.402	0.663	-0.489^a	-0.375^a
	(3.74)	(3.66)	(3.307)	(3.47)	(0.1)	(0.097)
Other North A	−1.318	1.966	−0.599	1.786	0.616^a	0.646^a
	(3.896)	(3.718)	(3.509)	(3.494)	(0.115)	(0.111)
Inter Asia	0.137^a	0.118^a	0.66^b	0.083^b	0.063^b	0.09^a
	(0.036)	(0.035)	(0.033)	(0.033)	(0.025)	(0.025)
Inter Europe	−0.009	−0.08	0.034	−0.024	−0.07	−0.009
	(0.12)	(0.115)	(0.107)	(0.11)	(0.063)	(0.062)
Inter North	-0.283^a	-0.236^a	−0.136	-0.16^c	-0.15^b	-0.142^a
	(0.096)	(0.091)	(0.088)	(0.086)	(0.061)	(0.059)
Productivity			0.362^a	0.58^a	0.373^a	0.276^a
			(0.042)	(0.045)	(0.041)	(0.043)
Employment			0.965^a	0.13^a	0.969^a	0.609^a
			(0.035)	(0.027)	(0.034)	(0.049)
Cap/Lab			0.135^a	0.22^a	0.13^a	0.118^a
			(0.028)	(0.035)	(0.028)	(0.028)
Wage			−0.124	−0.02	−0.14	−0.087
			(0.056)	(0.05)	(0.056)	(0.057)

The numbers in parentheses are standard errors. The superscripts ^{a}, ^{b}, and ^{c} indicate statistical significance at the 1 percent, 5 percent, and 10 percent levels. The regressions include time dummies except for the last two columns.

Table 3.1: Summary Statistics

summary stat of sample	mean	standard dev	min	max
Asia manufacturing DIA in each year	38.7	13.9	20	66
North America manufacturing DIA in each year	5.7	4.2	0	14
Europe manufacturing DIA in each year	9	5.3	1	15
Employment	5536.1	12408.8	96	81488
number of firms 135				
number of observation 1485				
year 1988-1998				

Table 3.2: Estimation Results for Asia

linear probability model

	Random	Fixed	GMM-DIF	GMM-SYS	GMM-DIF	GMM-SYS	MDS*
Y_{t-1}	0.3753^a	-0.1242^a	-0.073^c	-0.05	-0.185^a	-0.115^b	-0.019
	(0.0246)	(0.0293)	(0.04)	(0.041)	(0.063)	(0.047)	(0.419)
Y_{t-2}					-0.072^c	-0.078^b	
					(0.038)	(0.039)	
$SalesDIA_{t-1}$	0.016^a	0.026^c	0.019	0.027^a	0.024	0.032^a	0.027^a
	(0.0032)	(0.0134)	(0.021)	(0.006)	(0.023)	(0.007)	(0.012)
Productivity	0.0496^a	-0.0734	-0.01	0.073^a	0.008	0.084^a	0.074^c
	(0.0118)	(0.0697)	(0.076)	(0.026)	(0.09)	(0.03)	(0.044)
Cap/Lab	0.0266^b	0.1056^c	0.066	0.047^b	0.154^b	0.062^b	0.057^c
	(0.0108)	(0.056)	(0.074)	(0.026)	(0.078)	(0.029)	(0.032)
Employment	0.0625^a	0.0177	0.035	0.105^a	0.112	0.114^a	0.103^a
	(0.0058)	(0.0755)	(0.085)	(0.015)	(0.095)	(0.018)	(0.044)
Wage	-0.0317	-0.0026	-0.095	-0.121^c	-0.054	-0.08	-0.066
	(0.0318)	(0.0951)	(0.098)	(0.068)	(0.136)	(0.083)	(0.076)
ρ							-0.057
							(0.418)

The numbers in parentheses are standard errors. The superscripts ^{a}, ^{b}, and ^{c} indicate statistical significance at the 1 percent, 5 percent, and 10 percent levels. The regressions include time dummies. $*$: MDS is the minimum distance estimator.

Table 3.3: Estimation Results for Europe

linear probability model

	Random	Fixed	GMM-DIF	GMM-SYS	GMM-DIF	GMM-SYS	MDS*
Y_{t-1}	0.4^a	-0.067^b	0.007	0.039	-0.025	0.064	0.161
	(0.026)	(0.029)	(0.04)	(0.042)	(0.071)	(0.048)	(0.194)
Y_{t-2}					-0.007	0.006	
					(0.053)	(0.054)	
$SalesDIA_{t-1}$	-0.0005	-0.023^a	-0.01	-0.0007	-0.012	-0.0001	-0.002
	(0.001)	(0.008)	(0.011)	(0.003)	(0.016)	(0.003)	(0.003)
Productivity	0.016^b	0.03	0.027	0.031^c	0.002	0.023	0.014
	(0.006)	(0.039)	(0.037)	(0.019)	(0.039)	(0.016)	(0.012)
Cap/Lab	-0.004	-0.003	-0.008	-0.005	-0.008	-0.005	-0.001
	(0.006)	(0.031)	(0.031)	(0.012)	(0.036)	(0.011)	(0.009)
Employment	0.02^a	-0.01	-0.016	0.031^a	-0.055	0.028^a	0.025^a
	(0.003)	(0.053)	(0.051)	(0.008)	(0.042)	(0.008)	(0.008)
Wage	-0.001	0.01	0.038	0.013	-0.01	-0.016	0.009
	(0.018)	(0.023)	(0.056)	(0.034)	(0.067)	(0.035)	(0.008)
ρ							-0.104
							(0.187)

The numbers in parentheses are standard errors. The superscripts ^{a}, ^{b}, and ^{c} indicate statistical significance at the 1 percent, 5 percent, and 10 percent levels. The regressions include time dummies. $*$: MDS is the minimum distance estimator.

Table 3.4: Estimation Results for North America

linear probability model

	Random	Fixed	GMM-DIF	GMM-SYS	GMM-DIF	GMM-SYS	MDS*
Y_{t-1}	0.328^a	−0.026	0.011	0.019	−0.058	−0.048	0.194
	(0.024)	(0.028)	(0.044)	(0.041)	(0.081)	(0.06)	(0.132)
Y_{t-2}					−0.042	-0.064^a	
					(0.03)	(0.028)	
$SalesDIA_{t-1}$	0.007^a	−0.004	−0.047	0.007	0.009	0.006	0.003
	(0.003)	(0.019)	(0.05)	(0.013)	(0.055)	(0.016)	(0.194)
Productivity	−0.002	−0.034	-0.099^c	0.018	−0.066	0.024	0.025^a
	(0.006)	(0.044)	(0.055)	(0.015)	(0.061)	(0.016)	(0.008)
Cap/Lab	0.026^a	−0.015	0.066	0.006	0.037	0.007	0.003
	(0.003)	(0.047)	(0.047)	(0.016)	(0.049)	(0.017)	(0.012)
Employment	−0.02	−0.015	−0.004	0.044^a	0.0067	0.046^a	0.03^a
	(0.019)	(0.047)	(0.064)	(0.0074)	(0.066)	(0.01)	(0.01)
Wage	−0.058	−0.054	0.021	−0.069	0.008	−0.065	0.001
	(0.046)	(0.06)	(0.082)	(0.053)	(0.112)	(0.06)	(0.025)
ρ							−0.127
							(0.132)

The numbers in parentheses are standard errors. The superscripts ^{a}, ^{b}, and ^{c} indicate statistical significance at the 1 percent, 5 percent, and 10 percent levels. The regressions include time dummies. $*$: MDS is the minimum distance estimator.

Table 3.5: Probit Estimation Results

	Asia			Europe			NAm*
	Static	Panel	AR(1)	Static	Panel	AR(1)	Static
Y_{t-1}	0.07	−0.079	0.178	0.35	0.116	0.287	0.231
	(0.119)	(0.137)	(0.207)	(0.241)	(0.277)	(0.397)	(0.205)
$SalesDIA_{t-1}$	0.053^b	0.064^b	0.06^a	−0.009	−0.011	−0.003	−0.009
	(0.026)	(0.031)	(0.025)	(0.021)	(0.028)	(0.027)	(0.045)
Productivity	0.334^a	0.332^a	0.284^a	0.314^a	0.38^c	0.328^b	0.265^c
	(0.104)	(0.125)	(0.093)	(0.161)	(0.207)	(0.142)	(0.155)
Cap/Lab	0.237^b	0.287^b	0.379^a	−0.042	0.016	0.307^a	0.056
	(0.099)	(0.122)	(0.051)	(0.16)	(0.201)	(0.081)	(0.144)
Employment	0.403^a	0.437^a	0.257^a	0.318^a	0.367^a	0.0151	0.383^a
	(0.049)	(0.061)	(0.099)	(0.065)	(0.089)	(0.159)	(0.058)
Wage	−0.367	−0.421	-0.344^c	0.147	0.181	0.178	-0.533^c
	(0.227)	(0.261)	(0.216)	(0.403)	(0.473)	(0.302)	(0.305)
ρ			-0.196^b			−0.112	
			(0.11)			(0.234)	

The numbers in parentheses are standard errors. The superscripts ^{a}, ^{b}, and ^{c} indicate statistical significance at the 1 percent, 5 percent, and 10 percent levels. The regressions include time dummies. $*$: Since the results are the same in static and panel, we only report the static panel result.

Figures

Figure 2.1: Direct and Interaction Effects

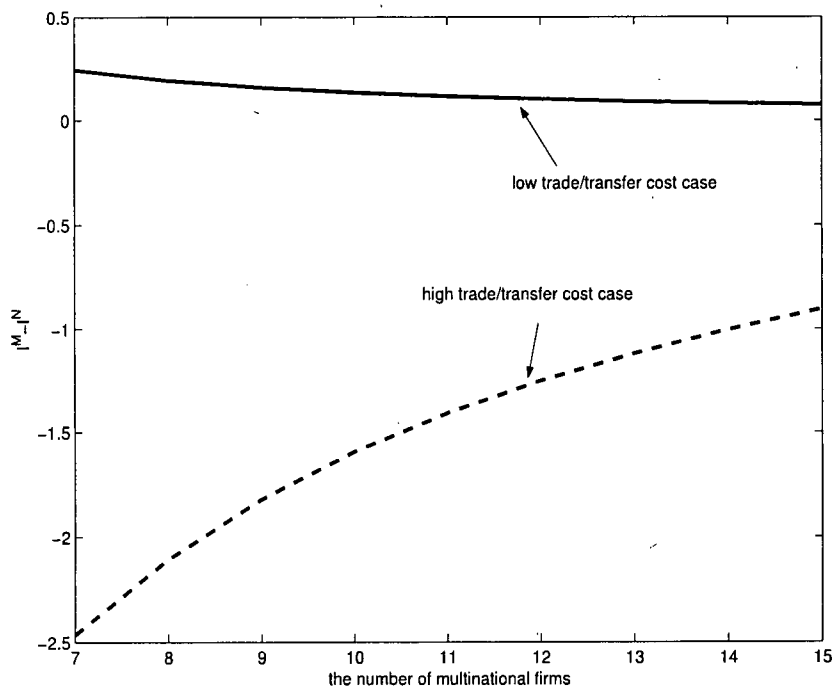


Figure 2.2: The number of new DIA and R&D

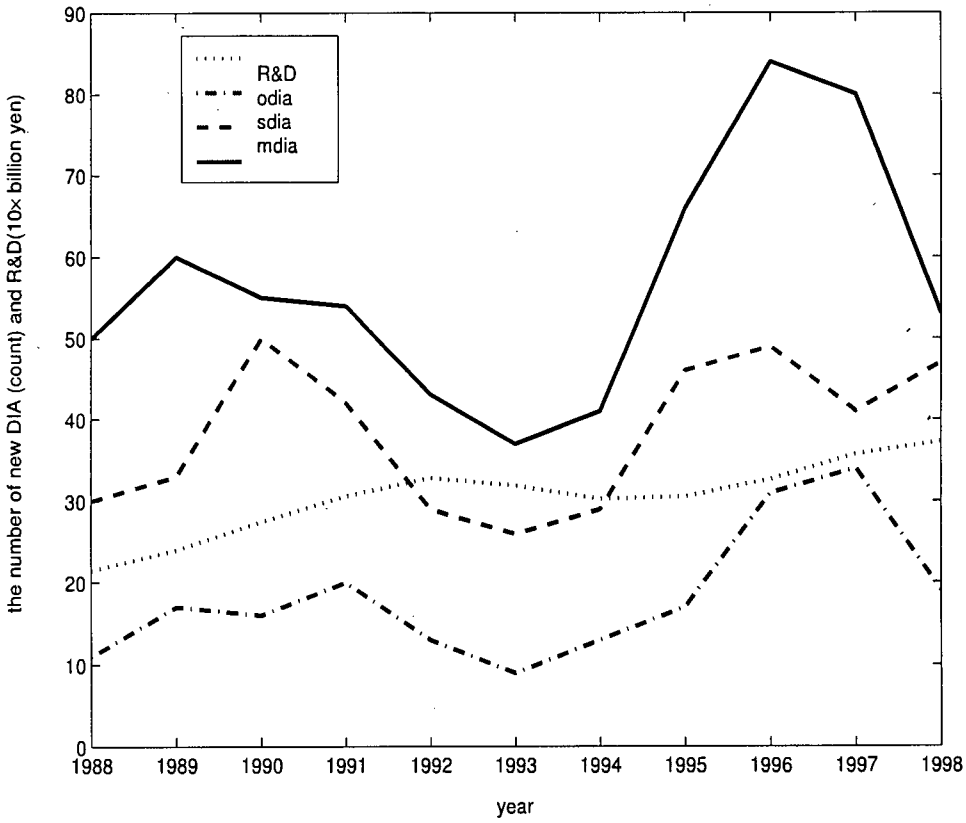


Figure 2.3: Own DIA and R&D

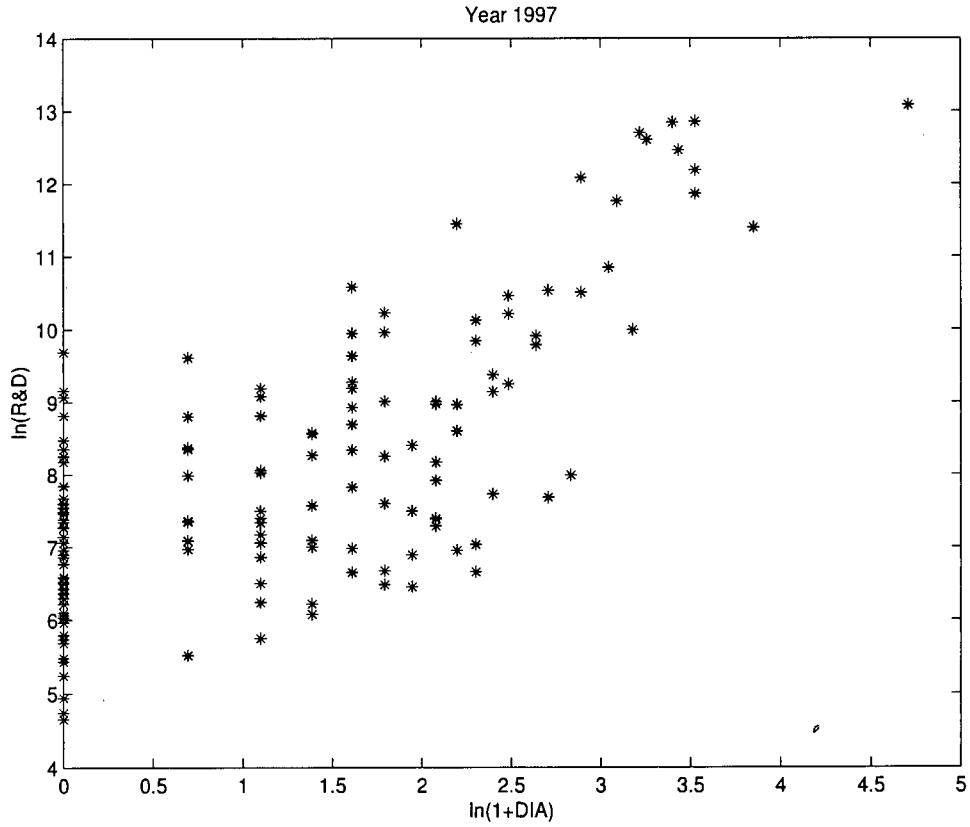


Figure 2.4: Other Firms' DIA and R&D

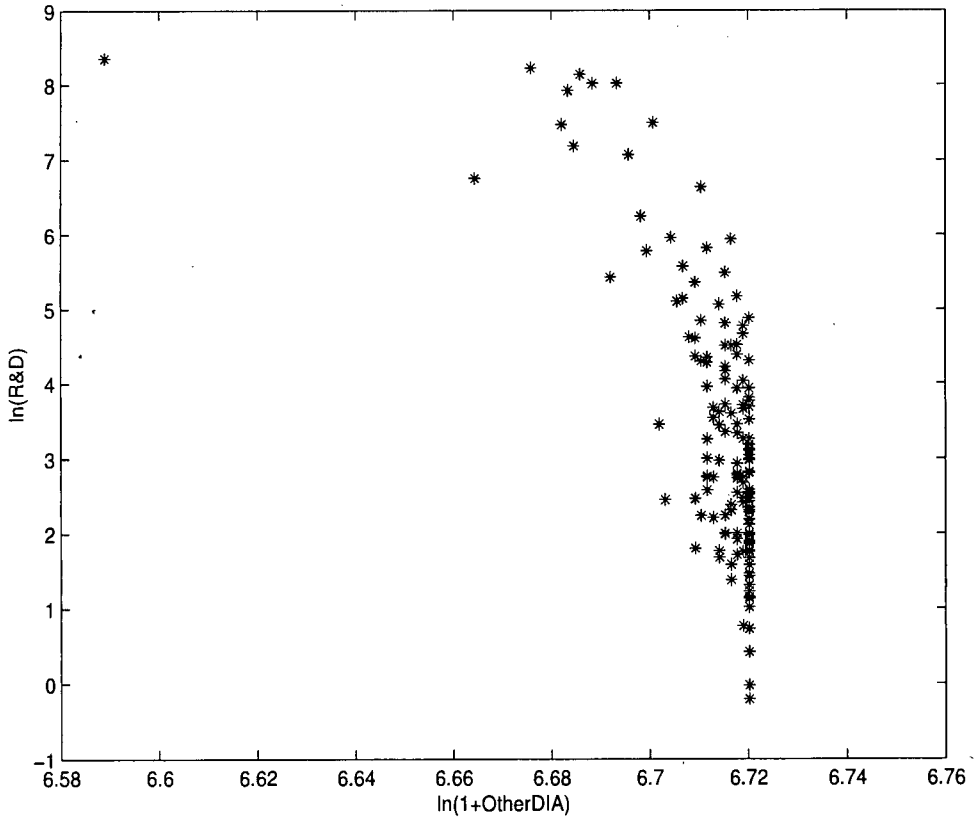


Figure 2.5: Demeaned DIA and R&D

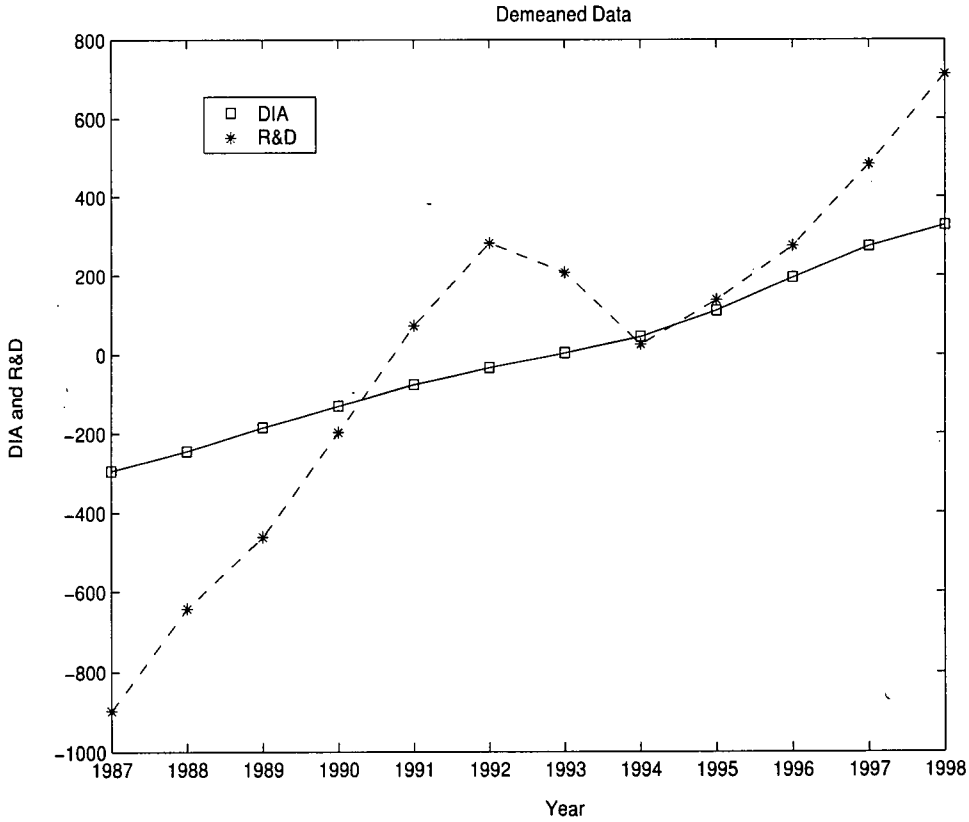


Figure 3.1: The number of new DIA

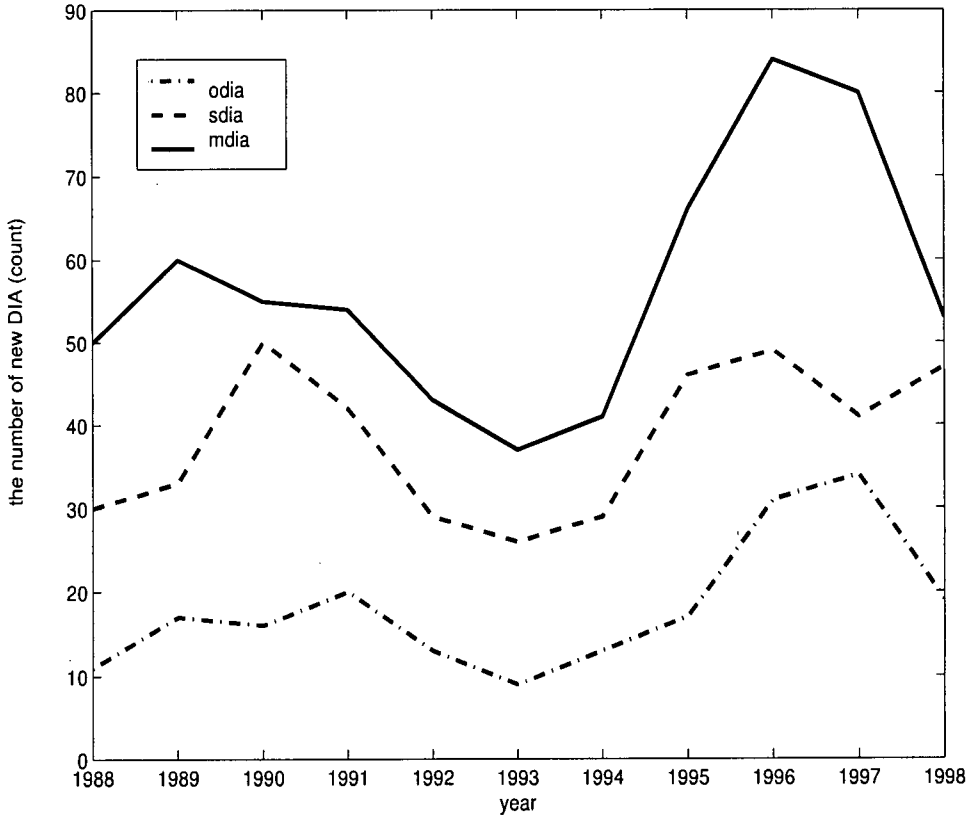


Figure 3.2: The number of new DIA: By Region

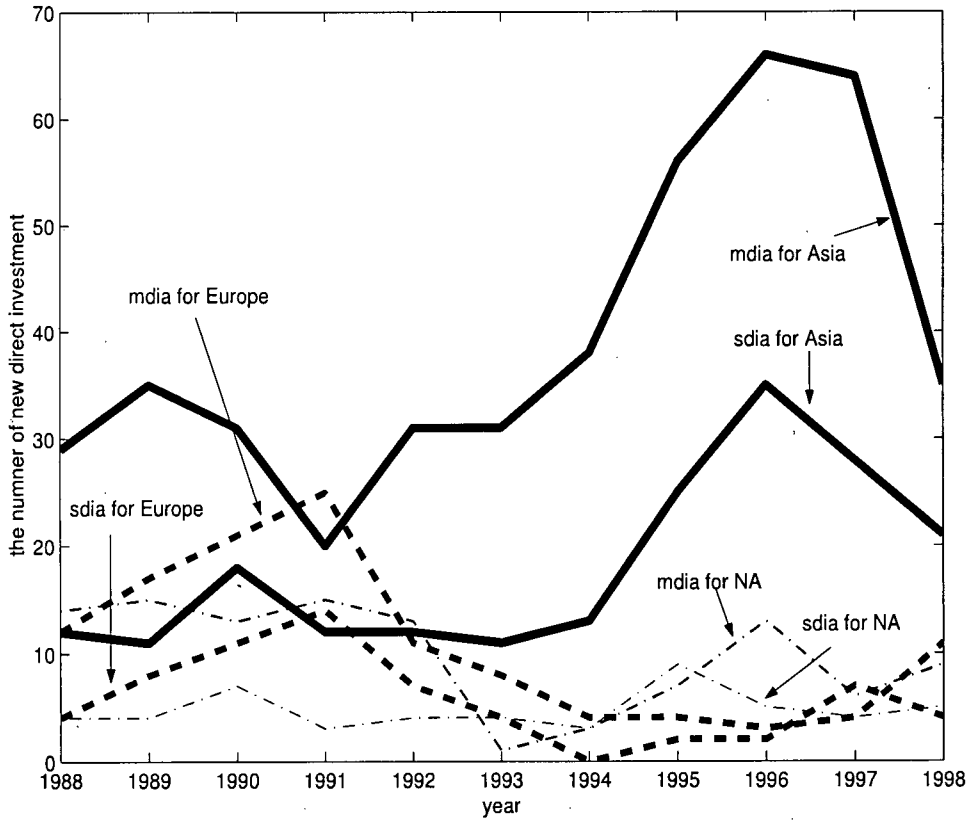


Figure 4.1: The Game Tree

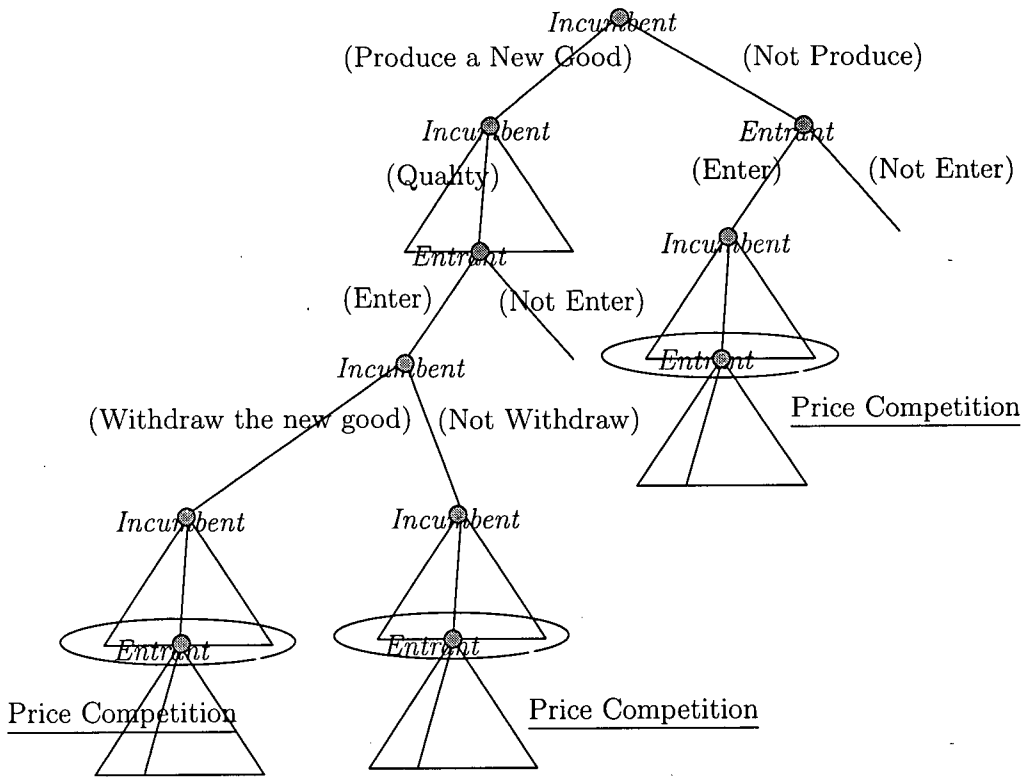


Figure 4.2: Large, Intermediate, and Small Cases

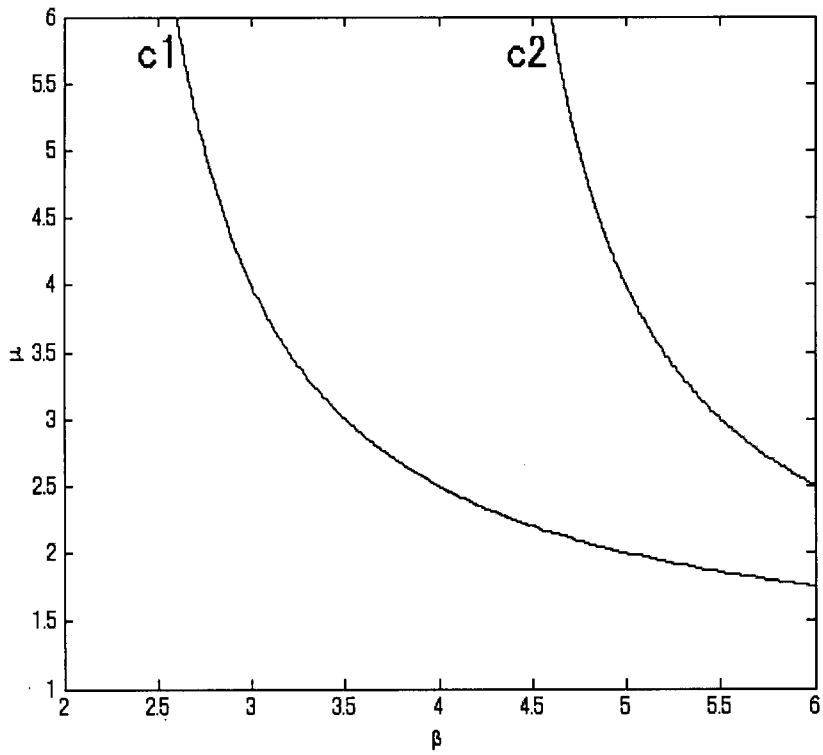


Figure 4.3: Assumption 2

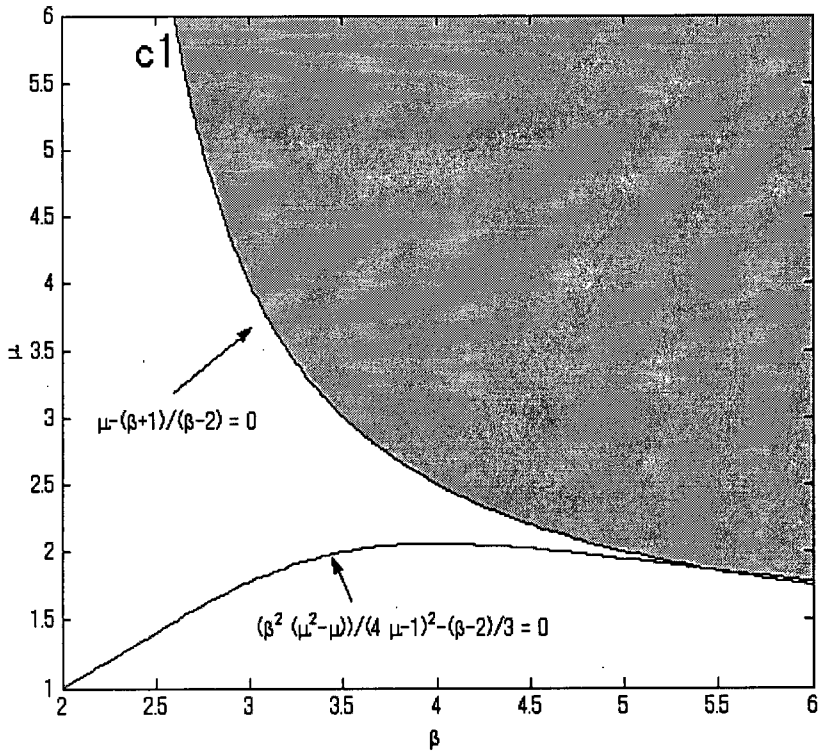
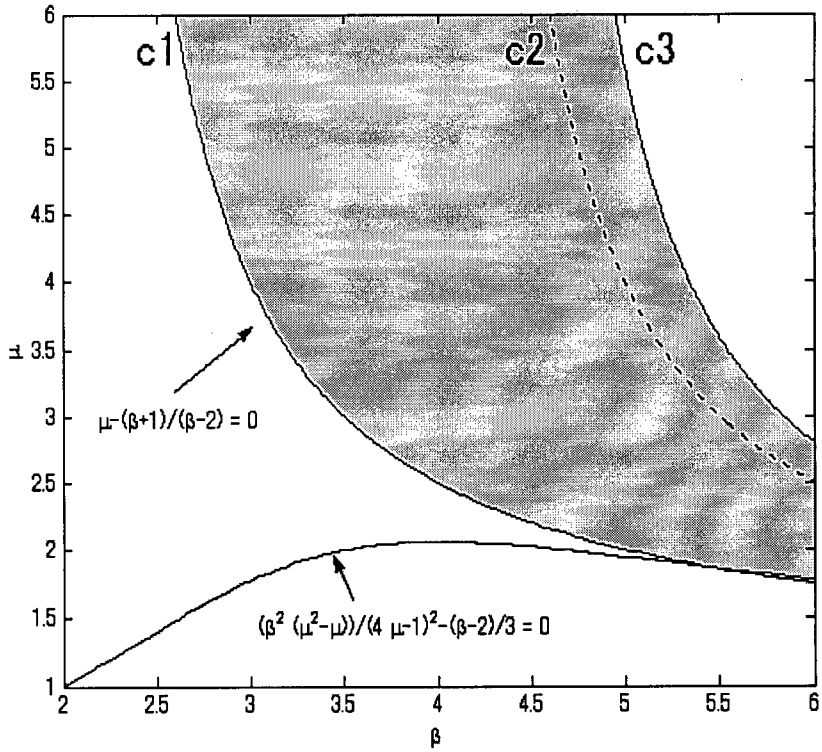


Figure 4.4: Entry Deterrence



Bibliography

ANDO, M., AND F. KIMURA (2003): "The formation of international production and distribution networks in East Asia," NBER working paper 10167.

ARELLANO, M., AND S. R. BOND (1991): "Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations," *Review of Economic Studies*, 58, 277–297.

BERNARD, A. B., AND J. B. JENSEN (1999): "Exceptional exporter performance: cause, effect, or both?," *Journal of International Economics*, 47, 1–25.

——— (2001): "Why some firms export," mimeo.

BLONIGEN, B. A., AND C. T. TAYLOR (2000): "R&D intensity and acquisitions in high-technology industries: evidence from the US electronic and electrical equipment industries," *Journal of Industrial Economics*, 48, 47–70.

BLUNDELL, R., AND S. BOND (1998): "Initial conditions and moment restrictions in dynamic panel data models," *Journal of Econometrics*, 87, 115–143.

——— (2000): "GMM estimation with persistent panel data: an application to production functions," *Econometric Reviews*, 19, 321–340.

BRAINARD, S. L. (1997): "An empirical assessment of the proximity-concentration trade-off between multinational sales and trade," *American Economic Review*, 87, 520–544.

BRANSTETTER, L. (2000): "Is foreign direct investment a channel of knowledge spillovers? Evidence from Japan's FDI in the United States," NBER working paper 8015.

BUTLER, J. S., AND R. MOFFITT (1982): "A computationally efficient quadrature procedure for the one-factor multinomial probit model," *Econometrica*, 50, 761–764.

CHAMBERLAIN, G. (1982): "Multivariate regression models for panel data," *Journal of Econometrics*, 18, 5–46.

CHOI, J. C., AND H. S. SHIN (1992): "A comment on a model of vertical product differentiation," *Journal of Industrial Economics*, 60, 229–231.

CONSTANTATOS, C., AND S. PERRAKIS (1997): "Vertical differentiation: entry and market coverage with multiproduct firms," *International Journal of Industrial Organization*, 16, 81–103.

DE BONDT, R., L. SLEUWAEGEN, AND R. VEUGELERS (1988): "Innovative strategic groups in multinational industries," *European Economic Review*, 32, 905–925.

DIXIT, A. (1989): "Entry and exit decisions under uncertainty," *Journal of Political Economy*, 97, 620–638.

DOORNIK, J. A., M. ARELLANO, AND S. BOND (2002): "Panel Data estimation using DPD for Ox," www.nuff.ox.ac.uk/Users/Doornik/papers/dpd.pdf.

ELLISON, G., AND S. ELLISON (2000): "Strategic entry deterrence and the behavior of pharmaceutical incumbents prior to patent expiration," *mimeo*.

FORS, G. (1997): "Utilization of R&D results in the home and foreign plants of multinationals," *Journal of Industrial Economics*, 45, 341–358.

GABSZEWICZ, J., A. SHAKED, J. SUTTON, AND J.-F. THISSE (1986): "Segmenting the market: the monopolist's optimal product mix," *Journal of Economic Theory*, 39, 273–289.

GABSZEWICZ, J., AND J.-F. THISSE (1979): "Price competition, quality and income disparities," *Journal of Economic Theory*, 20, 310–359.

GRILICHES, Z., AND J. A. HAUSMAN (1986): "Errors in variables in panel data," *Journal of Econometrics*, 31, 93–118.

HAJIVASSILIOU, V. A., AND P. A. RUUD (1994): "Classical estimation methods for LDV models using simulation," in *Handbook of Econometrics*, ed. by R. Engle, and D. McFadden, chap. 40. Elsevier Science.

HANSON, G. H., J. R. J. MATALONI, AND M. J. SLAUGHTER (2001): "Expansion strategies of U.S. multinational firms," NBER working paper 8433.

HEAD, K., AND J. RIES (2001): "Overseas investment and firm exports," *Review of International Economics*, 9, 108–122.

——— (2002): "Offshore production and skill upgrading by Japanese manufacturing firms," *Journal of International Economics*, 58, 81–105.

——— (2003): "Heterogeneity and the Foreign Direct Investment versus Exports Decision of Japanese Manufacturers," *Journal of the Japanese and International Economics*, 17, 448–467.

HECKMAN, J. J. (1981): "The incidental parameters problem and the problem of initial conditions in estimating a discrete time-discrete data stochastic process," in *Structural Analysis of Discrete Data*, ed. by C. Manski, and D. McFadden, chap. 3. MIT Press.

HELPMAN, E., M. J. MELITZ, AND S. R. YEAPLE (2004): "Export versus FDI with heterogenous firms," *American Economic Review*, 94, 300–316.

HOLLIS, A. (2003): "The anti-competitive effects of brand-controlled 'pseudo-generics' in the Canadian pharmaceutical market," *Canadian Public Policy*, 29, 21–32.

HORSTMANN, I. J., AND J. R. MARKUSEN (1992): "Endogenous market structures in international trade (natura facit saltum)," *Journal of International Economics*, 32, 109–129.

HYSLOP, D. R. (1999): "State dependence, serial correlation and heterogeneity in intertemporal labor force participation of married women," *Econometrica*, 67, 1255–1294.

JUDD, K. (1985): "Credible spatial preemption," *Rand Journal of Economics*, 16, 153–166.

KOGUT, B., AND S. J. CHANG (1991): "Technological capabilities and Japanese foreign direct investment in the United States," *Review of Economics and Statistics*, 73, 401–413.

LEMIEUX, T., AND W. B. MACLEOD (2000): "Supply side hysteresis: the case of the

Canadian unemployment insurance system," *Journal of Public Economics*, 78, 139–170.

LIANG, B. A. (1996): "The anticompetitive nature of brand-name firm introduction of generics before patent expiration," *Antitrust Bulletin*, pp. 599–635.

MANSFIELD, E., AND A. ROMEO (1980): "Technology transfer to overseas subsidiaries by U.S.-based firms," *Quarterly Journal of Economics*, 95, 737–750.

MARKUSEN, J. R. (1984): "Multinational, multi-plant economies, and the gains from trade," *Journal of International Economics*, 16, 205–226.

——— (1995): "The boundaries of multinational enterprises and the theory of international trade," *Journal of Economic Perspectives*, 9, 169–189.

MARKUSEN, J. R., E. R. MOREY, AND M. OLEWILER (1995): "Competition in regional environmental policies when plant locations are endogenous," *Journal of Public Economics*, 56, 55–77.

MARKUSEN, J. R., A. J. VENABLES, D. E. KONAN, AND K. H. ZHANG (1996): "A unified treatment of horizontal direct investment, vertical direct investment, and the pattern of trade in goods and services," NBER working paper 5696.

MORAN, T. H. (2001): *Parental supervision: the new paradigm for foreign direct investment and development.* Institute for International Economics, Washington, D.C.

MUSSA, M., AND S. ROSEN (1978): "Monopoly and product quality," *Journal of Economic Theory*, 18, 301–317.

NORBACK, P. (2001): "Multinationals firms, technology and location," *Journal of International Economics*, 54, 449–469.

PETIT, M. L., AND F. SANNA-RANDACCIO (1998): "Technological innovation and multinational expansion: a two-way link?," *Journal of Economics*, 68, 1–26.

——— (2000): "Endogenous R&D and foreign direct investment in international oligopolies," *International Journal of Industrial Organization*, 18, 339–367.

ROBERTS, M. J., AND J. R. TYBOUT (1997): "The decision to export in Colombia: an empirical model of entry with sunk costs," *American Economic Review*, 87, 545–564.

ROSE, A. K. (2002): "Do WTO members have a more liberal trade policy?," NBER working paper 9347.

SANNA-RANDACCIO, F. (2002): "The impact of foreign direct investment on home and host countries with endogenous R&D," *Review of International Economics*, 10, 278–298.

SCHMALENSEE, R. (1978): "Entry deterrence in the ready-to-eat breakfast cereal industry," *Bell Journal of Economics*, 8, 378–393.

SHAKED, A., AND J. SUTTON (1982): "Relaxing price competition through product differentiation," *Review of Economic Studies*, 49, 3–19.

——— (1983): "Natural oligopolies," *Econometrica*, 51, 1469–1484.

TIROLE, J. (1988): *The theory of industrial organization.* MIT Press.

TRAIN, K. (2002): *Discrete choice methods with simulation.* Cambridge University Press.

WAUTHY, X. (1996): "Quality choice in model of vertical differentiation," *Journal of Industrial Economics*, 44, 345–353.

YAMAWAKI, H. (1991): "Exports and foreign distributional activities: evidence on Japanese firms in the United States," *Review of Economics and Statistics*, 73, 284–300.

Appendix A

Appendices of Chapter 2

A.1 Quantity Competition

In this Appendix, we solve the endogenous R&D model and derive the direct, competition, and interaction effects.

We begin with the final stage game, the Cournot competition stage. Given the number of firms, N and M, and the level of R&D, national firms maximize profits by choosing x_i^N, and multinationals maximize profits by choosing x_i^M.

Since national and multinational firms are symmetric ($x_i^N = x_j^N$ and $x_i^M = x_j^M$), we have the equilibrium output levels of a national firm and a multinational firm in the domestic market:

$$x_i^N = \frac{1}{b(1+N+M)}[a - (N+M)c_i^N + \sum_{-i} c_j^N + \sum_j c_j^M]$$

$$x_i^M = \frac{1}{b(1+N+M)}[a - (N+M)c_i^M + \sum_{-i} c_j^M + \sum_j c_j^N]$$

In the foreign market, the equilibrium outputs of a national firm and a multinational firm are, respectively:

$$x_i^{*N} = \frac{1}{b(1+N+M)}[a-(N+M)(c_i^N+s)+\sum_{-i}(c_j^N+s)+\sum_j c_j^M]$$

$$x_i^{*M} = \frac{1}{b(1+N+M)}[a-(N+M)c_i^M+\sum_{-i}c_j^M+\sum_j(c_j^M+s)]$$

Hence, the prices of home and foreign markets are:

$$p = \frac{1}{b(N+M+1)}[a(N+M)-\sum_i c_i^N-\sum_i c_i^M]$$

$$p^* = \frac{1}{b(N+M+1)}[a(N+M)-\sum_i(c_i^N+s)-\sum_i c_i^M]$$

A.2 R&D decision

After solving the Cournot competition stage, firms decide how much to spend on R&D. By substituting the equilibrium quantity, the profit function is expressed by the R&D spending.

$$\begin{aligned}
\pi_i^N = & \frac{1}{b(N+M+1)}[a(N+M)-\sum_{-i}c_j^N-\sum_i c_i^M-2(c-\theta I_i^N)] \\
& \times \frac{1}{b(1+N+M)}[a-(N+M)(c-\theta I_i^N)+\sum_{-i}c_j^N+\sum_j c_j^M] \\
& + \frac{1}{b(N+M+1)}[a(N+M)-\sum_{-i}(c_j^N+s)-\sum_i c_i^M-2(c-\theta I_i^N+s)] \\
& \times \frac{1}{b(1+N+M)}[a-(N+M)(c-\theta I_i^N+s)+\sum_{-i}(c_j^N+s)+\sum_j c_j^M]-\frac{\gamma I_i^{N2}}{2}
\end{aligned}$$

For multinationals,

$$\pi_i^M = \frac{1}{b(N+M+1)}[a(N+M) - \sum_{-i} c_j^M - \sum_i c_i^N - 2(c - \theta I_i^M)]$$
$$\times \frac{1}{b(1+N+M)}[a - (N+M)(c - \theta I_i^M) + \sum_{-i} c_j^M + \sum_j c_j^N]$$
$$+ \frac{1}{b(N+M+1)}[a(N+M) - \sum_i (c_i^N + s) - \sum_{-i} c_j^M - 2(c - \theta I_i^M)]$$
$$\times \frac{1}{b(1+N+M)}[a - (N+M)(c - \theta I_i^M) + \sum_i (c_j^N + s) + \sum_{-i} c_j^M] - \frac{(\gamma+\xi)I_i^{M^2}}{2}$$

The FOCs are, in matrix form,

$$\begin{pmatrix} \lambda^N & -2\theta & \dots & & & -2\theta \\ -2\theta & \lambda^N & \dots & & & \dots \\ \vdots & & \ddots & & & \\ & & & \lambda^M & -2\theta & \ddots \\ & & & -2\theta & \ddots & \\ -2\theta & & & & & \lambda^M \end{pmatrix} \begin{pmatrix} I_1^N \\ \vdots \\ I_1^M \\ \vdots \end{pmatrix} = \begin{pmatrix} 2(a-c) - (M+1)s \\ \vdots \\ 2(a-c) + Ns \\ \vdots \end{pmatrix}$$

where $\lambda^N = 2(M+1)\theta - \frac{b\gamma(1+N+M)^2}{2\theta(N+M)}$ and $\lambda^M = 2(N+1)\theta - \frac{b(\gamma+\xi)(1+N+M)^2}{2\theta(N+M)}$. The second order condition is

$$2(N+M)\theta - \frac{b\gamma(1+N+M)^2}{2\theta(N+M)} < 0$$

Hereafter, for the sake of simplicity, we set $\theta = \gamma = 1$. Then, the above expression becomes

$$4(N+M)^2/(1+N+M)^2 \equiv b^* < b. \tag{A.1}$$

Then, by using symmetry, we can summarize the equilibrium conditions of the R&D game:

$$\lambda_N I^N - 2MI^M + 2(a-c) - (M+1)s = 0$$

$$\lambda_M I^M - 2NI^N + 2(a-c) + Ns = 0$$

where $\lambda^M = 2(N+1) - \frac{b(1+N+M)^2(1+\xi)}{2(N+M)} < 0$ and $\lambda^N = 2(1+M) - \frac{b(1+N+M)^2}{2(N+M)} < 0$.

By applying symmetry and using the best response functions, we can solve for R&D of each type of firm:

$$I^N = [2(a-c) - (M+1)s + (2M(Ns + 2(a-c)))/\lambda^M]/(\frac{4MN}{\lambda^M} - \lambda^N)$$
$$I^M = [2(a-c) + Ns + (2N((M+1)s - 2(a-c)))/\lambda^N]/(\frac{4MN}{\lambda^N} - \lambda^M)$$

A.3 Export versus DIA

Now, we consider the conditions that establish a symmetric subgame perfect equilibrium. To solve this game completely, we need to find an equilibrium satisfying such conditions that there is no incentive for either type of firm to switch to being the other type of firm. To be more precise, consider an equilibrium where there are M multinational and N national firms. Given that M firms choose to be multinational firms and $N-1$ firms choose to be national firms, consider the Nth national firm. If there is no incentive for this national firm to become a multinational firm, resulting in the $M+1$ multinational and $N-1$ national firms cases, the M multinational and N national firms situation should

be an equilibrium. Similarly, if there are $M-1$ multinational and N national firms, and if there is no incentive for a multinational firm to be a national firm, M multinational and N national firms case is an equilibrium. The following is the summary of these conditions:

- Given $M, N-1$, $\pi^N(M,N) > \pi^M(M+1, N-1)$
- Given $M-1, N$, $\pi^M(M,N) > \pi^N(M-1, N+1)$

Therefore, any M and N that satisfy the above conditions are the subgame perfect equilibrium number of firms. These conditions indicate that in a certain range of parameters, we can obtain an M multinational and N national firm equilibrium. We are not considering uniqueness here.

By substituting I^N and I^M into a profit function, we have the profit function expressed by the only fundamental parameters, $N, M, a, b, c, s, \alpha, \theta, \gamma$, and ξ. Then, we need to find the parameter values which satisfy the following Nash equilibrium conditions: $\pi^N(M,N) - \pi^M(M+1, N-1) > 0$ and $\pi^M(M,N) - \pi^N(M-1, N+1) > 0$.

As in other location choice studies (e.g., Horstmann and Markusen (1992), Markusen, Morey, and Olewiler (1995), Markusen, Venables, Konan, and Zhang (1996), and Petit and Sanna-Randaccio (2000)), since the profit function depends on many parameters, we cannot obtain analytical results on the choice of becoming an exporter or a multinational firm. Instead, a numerical simulation is created to give an example that satisfies the above condition, where $M = N = 9, a = 75, b = 4.05, c = 1, s = 0.07$, and $G = 0.07085$.

Then, the above equilibrium conditions hold:

$$\pi^N(M,N) = 0.9377 - 0.07085 = 0.86685 > \pi^M(M+1, N-1) = 1.0085 - 2(0.07085) = 0.8668$$

$$\pi^M(M,N) = 1.0089 - 2(0.07085) = 0.8672 > \pi^N(M-1, N+1) = 0.938 - 0.07085 = 0.86715.$$

An interesting case is one of high trade and technology transfer costs. Firms have an incentive to produce in foreign countries due to high trade costs. To show this, we demonstrate that increases in trade costs raise the profits of multinationals and decrease the profits of national firms. The profits associated with trade costs, $(0.071, 0.072, 0.073)$, are $\pi^M = (1.0107, 1.0125, 1.0142)$ and $\pi^N = (0.936, 0.9343, 0.9327)$. In addition, high trade and technology transfer costs induce multinational firms to spend less than exporters on R&D. Therefore, there is a large number of firms with low R&D spending. With regards to plant level fixed costs, an increase in G affects multinationals more than national firms, reducing the profits of multinationals more than those of national firms. Hence, the same type of predictions as in Horstmann and Markusen (1992) is obtained, as follows:

Proposition 8. *As transport costs increase, firms tend to become multinationals. As plant-specific costs increase, firms choose to become exporters.*

A.4 Direct Effect

Hereafter, we focus on the symmetric case: $N = M$. The main prediction is the effect of the multinational expansion decision on innovative activities.

Proposition 1 (in section 2.2.2)

1. *There exists a cut-off value of technology transfer cost, ξ'. If technology transfer costs are low ($\xi < \xi'$), multinationals spend more on R&D than national firms: $I^M - I^N > 0$.*

2. *If technology transfer costs are high ($\xi' < \xi$), national firms spend more on R&D than multinationals: $I^M - I^N < 0$.*

The proof is in the direct comparison between two R&D levels. Since there exist technology transfer costs, as in Petit and Sanna-Randaccio (1998), the direct effect depends on technology transfer costs. The expression of the direct effect is given by:

$$I^M - I^N = \frac{4x[\psi_1\xi + \psi_2 s]}{\psi_3\xi + \psi_2(2bx - 8x + b)}$$

where

$$\psi_1 = -b(1+2x)(2(a-c) - (x+1)s)$$

$$\psi_2 = (4bx^2 - 8x + 4bx + b)$$

$$\psi_3 = b(1+2x)(b + 4bx + 4bx^2 - 8x^2 - 8x)$$

To determine the sign of the direct effect ($I^M - I^N \gtrless 0$), we need to examine two cases:

- Case 1: $2bx - 8x + b > 0 \iff \bar{b} \equiv 8x/(1+2x) < b$

- Case 2: $2bx - 8x + b < 0 \iff \bar{b} \equiv 8x/(1+2x) > b$

In Case 1, since the denominator is positive, the sign depends on the numerator. Let $\xi' = \psi_2 s/\psi_1$. Then, if $\xi' < \xi$, the sign is negative, $I^M - I^N < 0$. However, if $\xi < \xi'$, the sign is positive, $I^M - I^N > 0$.

On the other hand, in Case 2 the coefficient of ξ in the numerator is negative, but that in the denominator is positive. The second term in the numerator is positive, but that in the denominator is negative. Therefore, if $-\psi_2(2bx - 8x + b)/\psi_3 \equiv \underline{\xi} < \xi < \xi'$, $I^M - I^N > 0$. If $\xi' < \xi$, $I^M - I^N < 0$. As long as $\underline{\xi} < \xi$, we obtain the same results in Cases 1 and 2.

If $\xi < \underline{\xi}$, the sign depends on s. If $\psi_2 s/\psi_1$ is greater than $-\psi_2(2bx - 8x + b)/\psi_3$, the direct effect is negative. If $\psi_2 s/\psi_1$ is smaller than $-\psi_2(2bx - 8x + b)/\psi_3$, the direct effect is either positive or negative.

A.5 Competition and Interaction Effects on R&D

To examine the effect of the changes in the number of other firms on the R&D spending, we compare the equilibrium R&D levels between (M, N) and $(M+1, N-1)$.

The following proposition is for the competition effect:

Proposition 9. *1. Suppose the direct effect is positive: $I^M - I^N > 0$.*

(a) If market size is small: $\underline{b} < b < \bar{b}$ and

i. If trade costs are low: $s < \bar{s}$, then the competition effect is positive for exporters, $I^N(M+1, N) - I^N(M, N) > 0$ and negative for multinationals, $I^M(M+1, N-1) - I^M(M, N) < 0$.

ii. If trade costs are high: $\bar{s} < s$, then the competition effect is negative for exporters, $I^N(M+1,N) - I^N(M,N) < 0$ and positive for multinationals, $I^M(M+1,N-1) - I^M(M,N) > 0$.

(b) If market size is large: $\bar{b} < b$, then the competition effect is negative, $I^N(M+1,N) - I^N(M,N) < 0$ and $I^M(M+1,N-1) - I^M(M,N) < 0$.

2. Suppose the direct effect is negative: $I^M - I^N < 0$.

(a) If market size is small: $\underline{b} < b < \bar{b}$ and

i. If trade costs are low: $s < \bar{s}$, then the competition effect is positive for exporters, $I^N(M+1,N) - I^N(M,N) > 0$ and negative for multinationals, $I^M(M+1,N-1) - I^M(M,N) < 0$.

ii. If trade costs are high: $\bar{s} < s$, then the competition effect is negative for exporters, $I^N(M+1,N) - I^N(M,N) < 0$ and positive for multinationals, $I^M(M+1,N-1) - I^M(M,N) > 0$.

(b) If market size is large: $\bar{b} < b$ and

i. If trade costs are low: $s < \bar{s}$, then the competition effect is positive, $I^N(M+1,N) - I^N(M,N) > 0$ and $I^M(M+1,N-1) - I^M(M,N) > 0$.

ii. If trade costs are high: $\bar{s} < s$, then the competition effect is negative, $I^N(M+1,N) - I^N(M,N) < 0$ and $I^M(M+1,N-1) - I^M(M,N) < 0$.

To prove this proposition, we first prove the lemma below. This lemma is on the competition effect, where we consider the changes in s given ξ.

Lemma 3. *1. If $\bar{b} < b$*

(a) *and* $\bar{s} < s$, *then* $I^M(M+1, N-1) - I^M(M, N) < 0$ *and* $I^N(M+1, N-1) - I^N(M, N) < 0$.

(b) *If* $s < \bar{s}$, *then* $I^M(M+1, N-1) - I^M(M, N) > 0$ *and* $I^N(M+1, N-1) - I^N(M, N) > 0$.

2. *If* $\underline{b} < b < \bar{b}$

(a) *and* $\bar{s} < s$, *then* $I^M(M+1, N-1) - I^M(M, N) > 0$ *and* $I^N(M+1, N-1) - I^N(M, N) < 0$.

(b) *If* $s < \bar{s}$, *then* $I^M(M+1, N-1) - I^M(M, N) < 0$ *and* $I^N(M+1, N-1) - I^N(M, N) > 0$.

Proof of Lemma 3

Let $N = M = x$ and define the difference in R&D spending:

$$\delta_M = I^M(M+1, N-1) - I^M(M, N) = \frac{\psi_{M1}s + \psi_{M2}}{\psi_{M3}}$$

where

$$\psi_{M1} = -4bx(1+2x)(2bx-8x+b)(4bx^2+4b\xi x^2+4bx+4b\xi x-8x+b+b\xi)$$

$$\psi_{M2} = -4bx(-16x\xi(1+2x)(2bx-8x+b)(a-c))$$

$$\psi_{M3} = \psi^1_{M3}\psi^2_{M3} \text{ where}$$

$$\psi^1_{M3} = (8\,x^3\xi\,b^2 - 16\,x^3\xi\,b - 32\,bx^3 + 8\,b^2x^3 - 24\,\xi\,bx^2 + 12\,x^2\xi\,b^2 + 12\,b^2x^2$$
$$+ 64\,x^2 - 48\,bx^2 + 6\,b^2x - 8\,\xi\,bx + 6\,x\xi\,b^2 - 16\,bx + \xi\,b^2 + b^2)$$

$$\psi^2_{M3} = (8x^3\xi b^2 - 16x^3\xi b - 32bx^3 + 8b^2x^3 - 40x^2\xi b + 12x^2\xi b^2$$
$$+ 12b^2x^2 + 64x^2 - 48bx^2 + 6b^2x - 16x\xi b + 6x\xi b^2 - 16xb + \xi b^2 + b^2)$$

First, we consider the numerator of δ_M, $\psi_{M1}s + \psi_{M2}$. Since in these parentheses the highest degree is the second degree, we can derive the cut-off value of x by deriving roots of those functions. For ψ_{M1}, the roots are $\frac{-4b+8-4\xi b\pm 8\sqrt{(-b+1-\xi b)}}{2(4b+4\xi b)}$. Since b is greater than 1 ($(1<)16x^2/(1+2x)^2 < b$ from the second order condition), these roots are imaginary. Hence, the sign only depends on the coefficient of the highest degree, which is positive. There are two cases:

- Case 1: the case of $\bar{b} < b$. Then, if $1/(1+\xi) < b$, $\psi_{M1} < 0$ and $\psi_{M2} > 0$.
- Case 2: the case of $b < \bar{b}$. Then, all signs are reversed ($\psi_{M1} > 0, \psi_{M2} < 0$).

With regard to the denominator, if we assume that $K_1 < \bar{L}$ such that

$$K_1 \equiv 2 \times \max\{\max(roots(\psi^1_{M3})), \max(roots(\psi^2_{M3}))\},$$

then both parentheses have the same sign and the denominator is positive. The reason for this is the coefficients of the highest degree, x^3, being the same. Notice that this is a sufficient condition, so even if it does not hold, the denominator can be positive.

Define $\bar{s} \equiv \psi_{M2}/(-\psi_{M1})$. Then, if $s < \bar{s}$, $I^M_{M+1} - I^M_M > 0$. Otherwise, $I^M_{M+1} - I^M_M < 0$. In Case 2, the sign is reversed.

For national firms,

$$\delta_N = I^N(M+1, N-1) - I^N(M, N) = \frac{\psi_{N1}s + \psi_{N2}}{\psi_{N3}}$$

where

$$\psi_{N1} = -4bx(1+2x)(4bx^2 + 4x^2\xi b + 4bx + 4x\xi b - 8x + b + \xi b)(\xi b + 2x\xi b + b - 8x + 2bx)$$

$$\psi_{N2} = -4bx[-16x\xi(1+2x)(\xi b + 2x\xi b + b - 8x + 2bx)(a-c)]$$

$$\psi_{N3} = \psi_{M3}$$

Similar to the previous case, we can solve these polynomial functions. The roots for ψ_{N1} are $-1/2$ (multiple root) and $\frac{-4b+8-4\xi b \pm 8\sqrt{(-b+1-\xi b)}}{2(4b+4\xi b)}$. For ψ_{N2}, we have 0 and $-1/2$ (multiple root). Therefore, the sign again depends on the coefficient of the highest degree, which is positive. There are three possible cases:

- Case 1: the case of $\bar{b} < b$. Then, $\psi_{N1} < 0$ and $\psi_{N2} > 0$.
- Case 2:
  - Case 2-1: the case of $8x/(1+2x)(1+\xi) = \underline{b} < b < \bar{b}$. The sign of the

numerator depends on $(\xi b + 2x\xi b + b - 8x + 2bx)$ instead of $b - 8x + 2bx$. If $\underline{b} < b < \bar{b} = 8x/(1+2x)$, the signs are the same as in Case 1.

- Case 2-2: the case of $b < \underline{b}$. The signs are reversed $(\psi_{N1} > 0, \psi_{N2} < 0)$.

From the second order condition (Inequality A.1), if x is larger than $K_2 = \{x|1/4+1/8x = 1+\xi\}$, then $\underline{b} < b^*$. We assume that $\max\{K_1, 2K_2\} \equiv K < \bar{L}$, so we do not have Case 2-2.

Since we have $\psi_{M2}/(-\psi_{M1}) = \psi_{N2}/(-\psi_{N1})$ in Cases 1 and 2-1 and if $s < \bar{s}$ holds, we have $I^N_{M+1} - I^N_M > 0$. Otherwise, $I^N_{M+1} - I^N_M < 0$. **End of the proof of Lemma 3.**

The above lemma is shown given ξ. With respect to the direct effect, the results are derived given s. Therefore, in the following proof, in order to make sure the consistency of results, we check the conditions that derive the results of both the direct and competition effects.

Proof of Proposition

By using Lemma 3, first we consider the case of $I^M - I^N > 0$. If $\bar{b} < b$, the competition effect is negative. However, if $\underline{b} < b < \bar{b}$, the competition effect depends on s. Next, we consider the case of $I^M - I^N < 0$. In this case, we show that depending on s, the competition effect can be either negative or positive.

Suppose $\bar{b} < b$. Consider the numerator of $I^M - I^N$ and δ^M (or δ^N). The conditions

in which both are positive are

$$0 < -b(1+2x)(2(a-c)-(1+x)s)\xi + (4bx^2 - 8x + 4bx + b)s$$

$$0 < -[(1+2x)^2\xi bs + (4bx^2 - 8x + 4bx + b)s] + 16x\xi(a-c)$$

Summarizing these conditions yields

$$((1+2x)^2\xi bs + (4bx^2 - 8x + 4bx + b)s)/16x\xi \tag{A.2}$$

$$< a - c < [b(1+2x)(1+x)s\xi + (4bx^2 - 8x + 4bx + b)s]/2b(1+2x)\xi$$

$$\Longleftrightarrow 0 < bs\xi^2(1+2x)[16x(1+x) - 2b(1+2x)^2] + \xi(4bx^2 - 8x + 4bx + b)s[16x - 2b(1+2x)]$$

To be positive, we need $b < 8x/(1+2x)$ or $b < 8x(1+x)/(1+2x)^2 (< 8x/(1+2x))$. This contradicts the assumption $\bar{b} < b$. Therefore, the case that $I^M - I^N > 0, \delta^M > 0$, and $\delta^N > 0$ is not possible.

Now, consider $\underline{b} < b < \bar{b}$. We show that a positive competition effect is possible. Suppose that $\xi < \xi'$ and $\bar{s} < s$. Under these conditions, we have $I^M - I^N > 0$, $I^M(M+1, N-1) - I^M(M,N) > 0$ and $I^N(M+1, N-1) - I^N(M,N) < 0$. In order to check the consistency of the conditions in which the above results are derived, we examine whether these conditions contradict each other. These are equivalent to $0 < (-((1+2x)^2\xi bs + (4bx^2 - 8x + 4bx + b)s) + 16x\xi(a-c))(2bx - 8x + b)$ and $0 > \{-[(1+2x)^2\xi bs + (4bx^2 -$

$8x + 4bx + b)s] + 16x\xi(a - c)\}(2bx(1 + \xi) - 8x + b(1 + \xi))$. Thus,

$$0 < -b(1 + 2x)(2(a - c) - (1 + x)s)\xi + (4bx^2 - 8x + 4bx + b)s$$

$$0 > -[(1 + 2x)^2\xi bs + (4bx^2 - 8x + 4bx + b)s] + 16x\xi(a - c)$$

In this case, we need

$$a - c < ((1 + 2x)^2\xi bs + (4bx^2 - 8x + 4bx + b)s)/16x\xi$$

$$a - c < [b(1 + 2x)(1 + x)s\xi + (4bx^2 - 8x + 4bx + b)s]/2b(1 + 2x)\xi$$

Because $\bar{s} < s$, these conditions are consistent. Therefore, we are able to obtain $I^M_{M+1} - I^M_M > 0$ and $I^N_{M+1} - I^N_M < 0$.

On the other hand, suppose $s < \bar{s}$.

$$0 < -b(1 + 2x)(2(a - c) - (1 + x)s)\xi + (4bx^2 - 8x + 4bx + b)s$$

$$0 < -[(1 + 2x)^2\xi bs + (4bx^2 - 8x + 4bx + b)s] + 16x\xi(a - c)$$

This is the same as Inequality A.2. We need to have $b < 8x/(1 + 2x)$ or $b < 8x(1 + x)/(1+2x)^2(< 8x/(1+2x))$. Since $\underline{b} < b < \bar{b}$, we have $I^M_{M+1} - I^M_M < 0$ and $I^N_{M+1} - I^N_M > 0$.

So far, we have considered the positive direct effect case ($I^M - I^N > 0$). Now we turn to the case of $I^M - I^N < 0$. Suppose $\bar{b} < b$ and $\bar{s} < s$. .Then, for the competition

effect to be negative,

$$0 > -b(1+2x)(2(a-c)-(1+x)s)\xi + (4bx^2 - 8x + 4bx + b)s$$

$$0 > -[(1+2x)^2\xi bs + (4bx^2 - 8x + 4bx + b)s] + 16x\xi(a-c)$$

This is equivalent to the following:

$$((1+2x)^2\xi bs + (4bx^2 - 8x + 4bx + b)s)/16x\xi$$

$$> a - c > [b(1+2x)(1+x)s\xi + (4bx^2 - 8x + 4bx + b)s]/2b(1+2x)\xi$$

$$\iff 0 < bs\xi^2(1+2x)[16x(1+x) - 2b(1+2x)^2] + \xi(4bx^2 - 8x + 4bx + b)s[16x - 2b(1+2x)]$$

This condition holds under $\bar{b} < b$. It is possible to have $I^M_{M+1} - I^M_M < 0$ and $I^N_{M+1} - I^N_M < 0$.

If $s < \bar{s}$, we have

$$0 > -b(1+2x)(2(a-c)-(1+x)s)\xi + (4bx^2 - 8x + 4bx + b)s$$

$$0 < -[(1+2x)^2\xi bs + (4bx^2 - 8x + 4bx + b)s] + 16x\xi(a-c)$$

Then,

$$a - c > ((1+2x)^2\xi bs + (4bx^2 - 8x + 4bx + b)s)/16x\xi$$

$$a - c > [b(1+2x)(1+x)s\xi + (4bx^2 - 8x + 4bx + b)s]/2b(1+2x)\xi \qquad \text{(A.3)}$$

Because $s < \bar{s}$, there is no contradicting conditions for $I^M_{M+1} - I^M_M > 0$ and $I^N_{M+1} - I^N_M > 0$.

The last part of this proof follows. Suppose $\underline{b} < b < \bar{b}$. Also, suppose that $s < \bar{s}$. This implies that

$$0 > -b(1+2x)(2(a-c)-(1+x)s)\xi + (4bx^2 - 8x + 4bx + b)s$$

$$0 < -[(1+2x)^2\xi bs + (4bx^2 - 8x + 4bx + b)s] + 16x\xi(a-c)$$

Therefore, we have the same condition as in Inequality A.3:

$$a - c > ((1+2x)^2\xi bs + (4bx^2 - 8x + 4bx + b)s)/16x\xi$$

$$a - c > [b(1+2x)(1+x)s\xi + (4bx^2 - 8x + 4bx + b)s]/2b(1+2x)\xi$$

If $s < \bar{s}$, we are able to obtain $I^M_{M+1} - I^M_M < 0$ and $I^N_{M+1} - I^N_M > 0$.

On the other hand, suppose $\bar{s} < s$. This implies that

$$0 > -b(1+2x)(2(a-c)-(1+x)s)\xi + (4bx^2 - 8x + 4bx + b)s$$

$$0 > -[(1+2x)^2\xi bs + (4bx^2 - 8x + 4bx + b)s] + 16x\xi(a-c)$$

Then,

$$((1+2x)^2\xi bs + (4bx^2 - 8x + 4bx + b)s)/16x\xi$$

$$< a - c < [b(1+2x)(1+x)s\xi + (4bx^2 - 8x + 4bx + b)s]/2b(1+2x)\xi$$

$$\iff 0 < bs\xi^2(1+2x)[16x(1+x) - 2b(1+2x)^2] + \xi(4bx^2 - 8x + 4bx + b)s[16x - 2b(1+2x)]$$

If $\bar{s} < s$, we are able to obtain $I^M_{M+1} - I^M_M > 0$ and $I^N_{M+1} - I^N_M < 0$. □

A.5.1 Interaction Effect

With respect to the effect on the R&D difference,

$$[I^M(M+1, N-1) - I^N(M+1, N-1)] - [I^M(M, N) - I^N(M, N)]$$
$$= \frac{\psi_{MN1}s + \psi_{MN2}}{\psi_{MN3}}$$

where

$$\psi_{MN1} = 4x\xi b^2(1+2x)^2(4bx^2 + 4bx - 8x + b + (1+2x)^2\xi b)$$

$$\psi_{MN2} = 4x\xi b^2(-16x\xi(2x+1)^2(a-c))$$

$$\psi_{MN3} = \psi_{M3}$$

We have $\psi_{MN1} > 0$ and $\psi_{MN2} < 0$. Hence, from the above we can derive:

Proposition 2. (in section 2.2.2)

1. *If $s < \bar{s}$, i.e., if trade costs are low, the interaction effect is negative: $\delta^M - \delta^N < 0$.*

2. *If $\bar{s} < s$, i.e., if trade costs are high, the interaction effect is positive: $\delta^M - \delta^N > 0$.*

A.6 Exogenous R&D – Firm Level Fixed Costs

We have considered an international oligopoly model, which takes into account the fact that foreign expansion strategies affect the parent firms' R&D decisions. Here, we con-

sider an alternative illustration of R&D spending. We will introduce a theoretical model that views R&D as a firm level fixed cost. We consider a trade-off between saving trade costs and saving technology transfer costs, as in Norback (2001). We consider a free entry model, in which it is required to incur fixed costs to operate. The fixed costs are interpreted as R&D. We regard technology transfer costs as additional costs required to build a foreign plant. If technology transfer costs are small, the effect of saving trade costs dominates the foreign plants' set up costs, so multinational firms are able to incur high R&D costs. However, if technology transfer costs are high, multinationals are burdened with high costs of setting up foreign plants. Hence, multinationals cannot incur high R&D costs. The trade-off between trade and technology transfer costs determines the mode of foreign entry. This type of model is called a "self-selection" model.

We develop a self-selection model with oligopolistic interaction. Our framework is similar to that of Horstmann and Markusen (1992). R&D spending is recognized as follows: "The firm-specific fixed cost is intended to represent knowledge-based assets, such as those obtained from R&D, that are joint inputs across plants" (Markusen (1984)). Therefore, we interpret a firm-level fixed cost as R&D. The basic motivation to set up foreign plants is to save on trade costs. While our model is similar to that of Horstmann and Markusen (1992), there are three important differences. First, there are more than two firms in our model. Second, we consider a free entry equilibrium. Third, we introduce a firm level fixed cost heterogeneity of firms. Different types of firms (M or N) have different types of R&D levels (F^M or F^N). We consider an equilibrium in which firms drawing F^M (F^N) actually become multinational firms (exporters).

The timing of the game is as follows:

1. Draw fixed entry costs (F^M or F^N) to enter or not enter (simultaneous move)

2. Decide whether to be an exporter (pay G) or a multinational firm (pay $G + G^*$)

3. Compete in a Cournot fashion (supply x and x^*)

Contrary to the endogenous R&D model, in this model the R&D level differs depending on the type of firm (exporter or multinational), but the R&D level is given for each firm.

If we change only F^M and F^N and preserve other parameters, the ratio of firm level and plant level fixed costs, F^M/G (or F^N/G), will change and so will the number of multinationals. In an equilibrium, from zero profit conditions these F^M and F^N are expressed through the associated equilibrium number of firms and fundamental parameters. Therefore, we are able to compare these fixed costs under the equilibrium number of firms, M and N. Hence, if $F^N < F^M$, multinational firms incur higher R&D than national firms. On the other hand, if $F^N > F^M$, we consider the R&D level of national firms as greater than that of multinational firms.

Model

Under a linear demand and constant marginal costs specification, the profits for national and multinational firms are, respectively:

$$\begin{aligned}\pi^N = r^N - F^N - G =& (a - b(\sum x^N + \sum x^M))x_i^N + (a - b(\sum x^{*N} + \sum x^{*M}))x_i^{*N} \\ & - cx_i^N - (c+s)x_i^{*N} - F^N - G \\ \pi^M = r^M - F^M - (G + G^*) =& (a - b(\sum x^N + \sum x^M))x_i^M + (a - b(\sum x^{*N} + \sum x^{*M}))x_i^{*M} \\ & - c(x_i^M + x_i^{*M}) - F^M - (G + G^*)\end{aligned}$$

where G^* is the set up cost of a foreign plant and r^M and r^N are variable profits for multinational firms and exporters, respectively. Since firms only need to transfer technology when they have a foreign plant, G^* includes technology transfer costs: $G^* = G$+technology transfer costs.

We begin by solving the Cournot competition stage. Since F^M and F^N are given, we can solve this stage in a similar way to the previous section. Substituting the profit maximizing output into a variable profit function yields:

$$r^M = \frac{(a-c)^2}{b(N+M+1)^2} + \frac{(a-c+Ns)^2}{b(N+M+1)^2}$$
$$r^N = \frac{(a-c)^2}{b(N+M+1)^2} + \frac{(a-c-(M+1)s)^2}{b(N+M+1)^2}$$

Now, let us consider the foreign expansion mode choice. To obtain an equilibrium where M multinationals and N national firms co-exist, we need a "no-switching" condition. This is the condition according to which there is no incentive to switch the type of firm (e.g., no incentive for exporters to become multinationals). In an equilibrium, firms drawing F^M become multinationals by paying plant level fixed costs, $G + G^*$. If a firm drawing F^M switches to being an exporter, it can save G^*; in this case, the number of firms in the market is $M - 1$ multinational and $N + 1$ national firms. Therefore, the

no-switching conditions for multinational and national firms are:

$$r^M(M,N) - G - G^* - F^M_{M,N} > r^N(M-1,N+1) - G - F^M_{M,N}$$

$$r^N(M,N) - G - F^N_{M,N} > r^M(M+1,N-1) - G - G^* - F^N_{M,N}$$

where the subscript of $F^M_{M,N}(F^N_{M,N})$ denotes the number of multinational and national firms.

At the first stage, firms enter the market until no profitable opportunities exist. This constructs the free entry condition, ensuring that returns from both entry modes are the same, zero:

$$r^M(M,N) - (G+G^*) - F^M_{M,N} = 0$$

$$r^N(M,N) - G - F^N_{M,N} = 0$$

Mixed Equilibrium

We consider a mixed equilibrium, in which both multinationals and exporters exist. In order to obtain this equilibrium, G^* should satisfy the following from the no-switching condition:

$$r^M(M+1,N-1) - r^N(M,N) < G^* < r^M(M,N) - r^M(M-1,N+1) \qquad \text{(A.4)}$$

The zero profit conditions determine M and N. Therefore, given different values of F^M and F^N, we have a corresponding different market structure (M, N).

Direct Effect

We will derive a relationship between the parameter values (F^M and F^N) and the endogenous variables, the number of firms (M and N). For the direct effect, we investigate the difference between F^M and F^N.

The direct effect is the fixed cost difference of multinational and national firms:

$$F^M_{M,N} - F^N_{M,N} = r^M(M,N) - r^N(M,N) - G^* = 2(M+N+1)s(a - c - \frac{1}{2}(M+1-N)s) - G^*$$

The first term is positive. The sign of the direct effect depends on G^*. Suppose the changes in G^* are due to the changes in technology transfer costs. If G^* is small enough, the above expression is positive. Since G^* satisfies (A.4) and since

$$r^M(M+1, N-1) - r^N(M,N) < r^M(M,N) - r^N(M,N) < r^M(M,N) - r^M(M-1, N+1),$$

the sign of $r^M - r^N - G^*$ can be negative. Therefore, we have the following:

Proposition 10. *1. If technology transfer costs are low so that G^* is small, the direct effect is positive: $F^M_{M,N} - F^N_{M,N} > 0$.*

2. If technology transfer costs are high so that G^* is large, the direct effect is negative: $F^M_{M,N} - F^N_{M,N} < 0$.

We can obtain a prediction similar to that of the endogenous R&D model. In an

equilibrium, firms earning high variable profits should be able to afford high entry costs. In this context, since trade costs are reduced, multinational firms can earn higher profits than exporters, so multinational firms will pay higher fixed costs. However, if set up costs of foreign plants are high, multinationals can not spend much on R&D. National firms conduct more R&D than multinationals. This is interpreted as the high technology transfer cost case. If firms do not set up foreign plants, technology transfer costs are unnecessary.

Competition and Interaction Effects

In the exogenous R&D model, the competition effect is the fixed cost difference corresponding to two equilibria, where each equilibrium has a different number of firms. In particular, here we compare the case of M multinational and N national firms with that of $M+1$ multinational and $N-1$ national firms. If we change the fixed costs, the resulting equilibrium number of firms changes. Hence, we change the fixed costs so as to obtain (M, N) and $(M+1, N-1)$ equilibrium. These particular fixed costs should satisfy zero profit conditions. By using zero profit conditions, we can express fixed costs in terms of fundamental parameters and the number of firms. Therefore, we are able to compare the level of fixed costs associated with different equilibrium number of firms.

The competition effects for multinational and national firms are, respectively:

$$F^M_{M+1,N-1} - F^M_{M,N} = r^M_{M+1,N-1} - r^M_{M,N}$$
$$= -2(a-c)s - 2Ns^2 + s^2 = -2(a - c + Ns + s/2) < 0$$
$$F^N_{M+1,N-1} - F^N_{M,N} = r^N_{M+1,N-1} - r^N_{M,N}$$
$$= -2(a-c)s + 2(M+1)s^2 + s^2 = -2(a - c - (M+1)s + s/2)s < 0$$

We always obtain a negative competition effect. In zero profit conditions, R&D spending is proportional to variable profit. If there are many multinationals, all firms earn less profit because there are more firms enjoying a cost advantage. This produces low variable profits, and a low level of R&D results.

The interaction effect is the difference of the direct effect:

$$F^M_{M+1,N-1} - F^N_{M+1,N-1} - [F^M_{M,N} - F^N_{M,N}] = r^M_{M+1,N-1} - r^N_{M+1,N-1} - [r^M_{M,N} - r^N_{M,N}]$$
$$= -2Ns^2 - 2(M+1)s^2 < 0$$

The reduction of variable profit is proportional to the level of the initial profit. Therefore, the scale of the drop in profits is larger for multinational than for national firms. Hence, the interaction effect is negative. The proposition below summarizes the results:

Proposition 11. *In the exogenous R&D model, the competition and interaction effects are negative.*

The most important point here is that both positive competition and interaction effects are impossible. They are possible in the endogenous R&D model, however. In

the endogenous R&D model, the effect of competitors' DIA can be separated into two effects: the business stealing effect and the strategic substitute effect. Here, since R&D is exogenous, only the business stealing effect is present. Since the effect of strategic substitute causes a positive relationship between R&D and competitors' DIA, we cannot obtain a positive competition effect. Therefore, a comparison of two models can be used not only to analyze the timing of the R&D decision, but also to determine the extent to which the strategic substitute effect is prevalent.

The table below summarizes the predictions of both the endogenous and exogenous R&D models. For the endogenous R&D model, we use the prediction in the case of a large market. Each cell reports the direct, competition, and interaction effects:

$$\text{(Direct, Competition, Interaction)}$$
$$= (I^M - I^N, (\delta^M, \delta^N), \delta^M - \delta^N)$$

		High Tech Costs	Low Tech Costs
High Trade Costs	Endogenous R&D Model	$(-,(+,-),+)$	$(+,(+,-),+)$
	Exogenous R&D Model	$(-,(-,-),-)$	$(+,(-,-),-)$
Low Trade Costs	Endogenous R&D Model	$(-,(-,+),-)$	$(+,(-,+),-)$
	Exogenous R&D Model	$(-,(-,-),-)$	$(+,(-,-),-)$

The sign pattern differs across the two models as long as either the competition or the interaction effect is positive.

Appendix B

Appendices of Chapter 4

B.1 Monopoly

B.1.1 A Single-Product Monopolist

In order to evaluate profits of the incumbent withdrawing the new good, we first examine the problem of a single-product monopoly. In this case, the quality of the incumbent's product is s_2 and the price is p_2.

$$\pi_I = \begin{cases} (b - t_2)p_2 & \text{if the market is uncovered} \\ (b - a)p_2 & \text{if the market is covered} \end{cases}$$

The prices are:

$$p_2 = \begin{cases} \frac{bs_2}{2} & \text{if the market is uncovered} \\ as_2 & \text{if the market is covered} \end{cases}$$

The profits are:

$$\pi^I = \begin{cases} \frac{b^2 s_2}{4} & \text{if uncovered} \\ (b-a)as_2 & \text{if covered with a corner solution} \end{cases}$$

B.1.2 Market Configuration

If $a < t_2$, the market is uncovered. The cut-off value is $t_2 = p_2/s_2$. Hence, if $bs_2/2 > s_2 a \iff b/2 > a$, the market is uncovered. In Assumption 1, we only consider the case of the uncovered market.

B.1.3 A Multi-Product Monopolist

The monopolist's profits are:

$$\pi^I = \begin{cases} (b-t_2)p_2 + (t_2 - t_1)p_1 & \text{if the market is uncovered} \\ (b-t_2)p_2 + (t_2 - a)p_1 & \text{if the market is covered} \end{cases}$$

By maximizing the profit function, we have:

$$p_2 = bs_2/2$$

$$p_1 = \begin{cases} \frac{bs_1}{2} & \text{if uncovered} \\ as_1 & \text{if covered with a corner solution} \end{cases}$$

The interior solution in the covered market case does not exist. The cut-off values are: $t_2 = b/2$and $t_1 = b/2$. The profit in the uncovered market case is

$$\pi^I = \frac{b^2 s_2}{4} \tag{B.1}$$

B.1.4 Market Configurations

Similar to the previous case, since $p_1 = as_1$ in the covered market and $p_1 = bs_1/2$ in the uncovered market, if $bs_1/2 > as_1$, we have the uncovered market case. If $a < b/2$, the market is uncovered. Similar to Section B.1.2, in Assumption 1 we have only the uncovered market case.

B.2 Proof of Lemmas 1 and 2

Here, we will solve the duopoly game. We accomplish this in four steps. First, we will consider each market configuration and solve the resulting price competition subgame. Second, after solving the price game, we derive the best quality level of the incumbent. Third, by comparing profits associated with each market configuration, we derive the highest profit. Finally, we check for credibility by comparing profits.

B.2.1 Price Competition

We first look at the price competition stage. There are two cases: a duopoly consisting of a multi-product incumbent and a duopoly with a single-product incumbent. The multi-product incumbent arises if the incumbent introduces a new good and keeps it after entry. If, after entry the incumbent withdraws the good, a single-product incumbent case results.

Notice that we have a case in which the market is covered (all consumers consume differentiated goods) and one in which it is uncovered (some consumers refrain from consumption). If the market is covered, we have an interior solution or a corner solution,

depending on the parameter values. We denote the uncovered market case with UC, the covered with an interior solution case with CI, and the covered with a corner solution case with CC.

Duopoly with a Single-Product Incumbent

The problem of the incumbent and entrant are, respectively,

$$\max\ (b - t_2)p_2$$

$$\max \begin{cases} (t_2 - t_0)p_0 & \text{if uncovered} \\ (t_2 - a)p_0 & \text{if covered} \end{cases}$$

By solving the price game, we have the entrant and incumbent price, respectively,

$$p_0 = \begin{cases} \frac{s_0(s_2-s_0)b}{4s_2-s_0} & \text{if UC} \\ \frac{(s_2-s_0)(b-2a)}{3} & \text{if CI} \\ as_0 & \text{if CC} \end{cases}$$

$$p_2 = \begin{cases} \frac{2s_2(s_2-s_0)b}{4s_2-s_0} & \text{if UC} \\ \frac{(s_2-s_0)(2b-a)}{3} & \text{if CI} \\ \frac{bs_2+(a-b)s_0}{2} & \text{if CC} \end{cases}$$

The cut-off values are:

$$t_2 = \begin{cases} \frac{b(2s_2-s_0)}{4s_2-s_0} & \text{if UC} \\ \frac{b+a}{3} & \text{if CI} \\ \frac{bs_2-(a+b)s_0}{2(s_2-s_0)} & \text{if CC} \end{cases}$$

The profits are:

$$\pi^I = \begin{cases} \frac{4b^2 s_2^2 (s_2 - s_0)}{(4s_2 - s_0)^2} & \text{if UC} \\ \frac{(s_2 - s_0)(2b - a)^2}{9} & \text{if CI} \\ \frac{(bs_2 + (a-b)s_0)^2}{4(s_2 - s_0)} & \text{if CC} \end{cases} \tag{B.2}$$

$$\pi^E = \begin{cases} \frac{b^2 s_0 s_2 (s_2 - s_0)}{(4s_2 - s_0)^2} & \text{if UC} \\ \frac{(s_2 - s_0)(b - 2a)^2}{9} & \text{if CI} \\ \frac{(abs_0 - 2a^2 s_0)s_2 + (a-b)as_0^2}{2(s_2 - s_0)} & \text{if CC} \end{cases}$$

Market Configurations

Whether the market is covered depends on t_0 and a. If $t_0 (\equiv p_0/s_0) > a$, the market is uncovered. Hence, if $p_0 = s_0(s_2 - s_0)b/(4s_2 - s_0) > as_0$, the market is uncovered. If $(s_2 - s_0)(b - 2a)/3 < as_0$, we have a covered market with an interior solution. If neither of the above conditions hold, we have a corner solution. For such a region to exist, we need $s_0(s_2 - s_0)b/(4s_2 - s_0) < (s_2 - s_0)(b - 2a)/3$. This does not hold if μ and β are too small. In such a case, a CI case results.

By rearranging the terms of these conditions, if $b - 4a > 0$,

$$\text{if } \frac{(b-a)s_0}{b - 4a} < s_2, \text{UC}$$

$$\text{if } s_0 < s_2 < \frac{(a+b)s_0}{b - 2a}, \text{CI}$$

$$\text{if } \frac{(a+b)s_0}{b - 2a} \leq s_2 \leq \frac{(b-a)s_0}{b - 4a}, \text{ CC}$$

If $b - 4a < 0$,

$$\text{if } s_0 < s_2 < \frac{(a+b)s_0}{b-2a}, \text{CI}$$
$$\text{if } \frac{(a+b)s_0}{b-2a} \leq s_2, \text{CC}$$

Duopoly with a Multi-Product Incumbent

The incumbent's problem is:

$$\max(b - t_2)p_2 + (t_1 - t_2)p_1$$

The entrant's problem is:

$$\max \begin{cases} (t_1 - t_0)p_1 & \text{if uncovered market} \\ (t_1 - a)p_1 & \text{if covered market} \end{cases}$$

By solving this price game, we have:

$$p_0 = \begin{cases} \frac{s_0 p_1}{2s_1} & \text{if UC} \\ \frac{(s_1 - s_0)(b-2a)}{3} & \text{if CI} \\ s_0 a & \text{if CC} \end{cases}$$

$$p_1 = \begin{cases} \frac{2bs_1(s_1 - s_0)}{4s_1 - s_0} & \text{if UC} \\ \frac{(s_1 - s_0)(2b-a)}{3} & \text{if CI} \\ \frac{bs_1 + (a-b)s_0}{2} & \text{if CC} \end{cases}$$

$$p_2 = \begin{cases} \frac{bs_0(s_1 - s_0)}{2(4s_1 - s_0)} + \frac{b(s_2 - s_0)}{2} & \text{if UC} \\ \frac{3bs_2 + (b-2a)s_1 + 2(a-2b)s_0}{6} & \text{if CI} \\ \frac{bs_2 + (a-b)s_0}{2} & \text{if CC} \end{cases}$$

The cut-off values are:

$$t_2 = \begin{cases} \frac{b}{2} & \text{if UC} \\ \frac{b}{2} & \text{if CI} \\ \frac{b}{2} & \text{if CC} \end{cases}$$

$$t_1 = \begin{cases} \frac{b(2s_1-s_0)}{4s_1-s_0} & \text{if UC} \\ \frac{b+a}{3} & \text{if CI} \\ \frac{bs_1-(a+b)s_0}{2(s_1-s_0)} & \text{if CC} \end{cases}$$

$$t_0 = \begin{cases} \frac{b(s_1-s_0)}{4s_1-s_0} & \text{if UC} \end{cases}$$

The profits are:

$$\pi^I = \begin{cases} \frac{b^2 s_0(s_1-s_0)}{4(4s_1-s_0)} + \frac{b^2(s_2-s_0)}{4} + \frac{b^2 s_0 s_1(s_1-s_0)}{(4s_1-s_0)^2} & \text{if UC} \\ \frac{(b-2a)(7b-2a)(s_1-s_0)}{36} + \frac{b^2(s_2-s_0)}{4} & \text{if CI} \\ \frac{b^2 s_2+b(a-b)s_0}{4} + \frac{a(a-b)s_0^2+abs_0s_1}{4(s_1-s_0)} & \text{if CC} \end{cases}$$

$$\pi^E = \begin{cases} \frac{b^2 s_0 s_1(s_1-s_0)}{(4s_1-s_0)^2} & \text{if UC} \\ \frac{(s_1-s_0)(b-2a)^2}{3} & \text{if CI} \\ \frac{(abs_0-2s_0a^2)s_1+(a-b)as_0^2}{2(s_1-s_0)} & \text{if CC} \end{cases}$$

Market Configurations

By applying the same logic as in the previous section, if $b - 4a > 0$,

$$\text{if } \frac{(b-a)s_0}{b-4a} < s_1, \text{UC}$$

$$\text{if } s_0 \leq s_1 < \frac{(a+b)s_0}{b-2a}, \text{CI}$$

$$\text{if } \frac{(a+b)s_0}{b-2a} \leq s_1 \leq \frac{(b-a)s_0}{b-4a}, \text{CC}$$

If $b - 4a < 0$,

$$\text{if } s_0 < s_1 < \frac{(a+b)s_0}{b-2a}, \text{ covered with interior solution}$$
$$\text{if } \frac{(a+b)s_0}{b-2a} \leq s_1, \text{ covered with corner solution}$$

B.2.2 Quality Choice

Here, we derive the optimal quality associated with each market configuration given that the incumbent chooses to produce a new good. As before, we have three market configurations if $b - 4a > 0$ and two configurations if $b - 4a < 0$. First, we investigate the quality choice in the $b - 4a > 0$ case.

UC

If $s_2 > (b-a)s_0/(b-4a) \iff \overline{\beta} < \mu$, the incumbent can choose a market configuration freely by taking s_1: it can take $((b-a)s_0/(b-4a), s_2]$ to be an uncovered market, $[(a+b)s_0/(b-2a), (b-a)s_0/(b-4a)]$ to be a covered market with a corner solution, or $[s_0, (a+b)s_0/(b-2a))$ to be a covered market with an interior solution. Suppose the incumbent chooses the uncovered market configuration. The other two cases will be considered below.

Since $d\pi^I/ds_1 = b^2 s_0^2(20s_1 + s_0)/4(4s_1 - s_0)^3 > 0$, the optimal s_1, s_1^*, is s_2. If $s_1^* = s_2$, $p_1 = p_2 = 2bs_2(s_2 - s_0)/(4s_2 - s_0)$. If $s_1^* = s_2$ and $p_1 = p_2$, we have:

$$\pi^I_{\text{multi}} = \frac{4b^2 s_2^2(s_2 - s_0)}{(4s_2 - s_0)^2} = \pi^I_{\text{single}} \tag{B.3}$$

where $\pi^I_{\text{multi}}$and π^I_{single} denote the profits of a multi-product incumbent and a single-product incumbent, respectively.

CC

If $(a+b)s_0/(b-2a) \leq s_2 \leq (b-a)s_0/(b-4a) \iff \underline{\beta} \leq \mu \leq \overline{\beta}$, the incumbent can choose two market configurations: a covered market with a corner solution or one with an interior solution. Suppose the incumbent chooses the covered with a corner solution. Because $d\pi^I/ds_1 \leq 0$, the incumbent sets the quality of the new good to $s_1^* = (a+b)s_0/(b-2a)$. This holds when $\overline{\beta} < \mu$ and the incumbent chooses the covered with a corner solution as well. If $s_1^* = (a+b)s_0/(b-2a)$, the profit is

$$\pi^I_{\text{multi}} = \frac{b^2 s_2}{4} + \frac{(7b-2a)as_0}{12} - \frac{b^2 s_0}{4} \tag{B.4}$$

CI

If $s_2 < (a+b)s_0/(b-2a) \iff \mu < \underline{\beta}$, the incumbent can choose the covered with an interior solution case. Since $d\pi^I/ds_1 \geq 0$, the incumbent sets $s_1^* = s_2$. The price is $p_1 = p_2$. The profit is

$$\pi^I_{\text{multi}} = \frac{(s_2 - s_0)(2b-a)^2}{9} = \pi^I_{\text{single}} \tag{B.5}$$

When $\underline{\beta} \leq \mu \leq \overline{\beta}$ or $\overline{\beta} < \mu$ and the incumbent chooses the covered with an interior solution case, the incumbent chooses $s_1 = (a+b)s_0/(b-2a) - \epsilon$, where ϵ is a small positive number. The profit under CI at $s_1 = (a+b)s_0/(b-2a)$ is equal to the profit

presented by Equation B.4. Since $d\pi^I/ds_1 \geq 0$ and $s_1 \in [s_0, (a+b)s_0/(b-2a))$, the profit under CI is less than that under CC:

$$\pi^I(CI) < \pi^I(CC) = \frac{b^2 s_2}{4} + \frac{(7b-2a)as_0}{12} - \frac{b^2 s_0}{4} \tag{B.6}$$

where $\pi^I(CI)$ and $\pi^I(CC)$ are the incumbent's profits under CI and CC, respectively.

B.2.3 Optimal Quality

After choosing s_1, the profits depend on parameter values. The incumbent will choose the highest profit.

Case1: $\overline{\beta} < \mu$

In this case, by comparing profits B.3 and B.4, and considering B.6, we can show that profits under UC and CC are greater than those under CI. We need to derive the condition when UC is chosen.

1. Case 1-1: If $\frac{b^2 s_2}{4} + \frac{(a(7b-2a)-3b^2)s_0}{12} < \frac{4b^2 s_2^2 (s_2 - s_0)}{(4s_2 - s_0)^2}$, the incumbent prefers the uncovered case, so the choice of the quality of the new good is s_2.

2. Case 1-2: if $\frac{b^2 s_2}{4} + \frac{(a(7b-2a)-3b^2)s_0}{12} > \frac{4b^2 s_2^2 (s_2 - s_0)}{(4s_2 - s_0)^2}$, the incumbent prefers the covered case, so the choice of the quality of the new good is $\frac{(a+b)s_0}{b-2a}$.

The condition that $b^2 s_2/4 + (a(7b-2a)-3b^2)s_0/12 < 4b^2 s_2^2(s_2-s_0)/(4s_2-s_0)^2$ is checked as follows. Define the function:

$$\begin{aligned}\Phi &= \frac{4b^2 s_2^2(s_2-s_0)}{(4s_2-s_0)^2} - (\frac{b^2 s_2}{4} + \frac{(a(7b-2a)-3b^2)s_0}{12}) \\ &= \frac{(24b^2-112ab+32a^2)s_0 s_2^2 + (-27b^2+56ab-16a^2)s_0^2 s_2 + (3b^2-7ab+2a^2)s_0^3}{12(4s_2-s_0)^2}\end{aligned}$$

The numerator of Φ is written by:

$$\phi = (24\beta^2 - 112\beta + 32)\mu^2 + (-27\beta^2 + 56\beta - 16)\mu + (3\beta^2 - 7\beta + 2) \tag{B.7}$$

For β, μ which are greater than β^*, μ^* such that $\phi(\beta^*, \mu^*) = 0$, we have

$$0 < \phi(\beta, \mu)$$

in which the incumbent prefers the uncovered case. If $\phi < 0$, the incumbent prefers the covered case.

For all β and μ such that $\mu = \overline{\beta}$, $\phi < 0$. This is verified by substituting $\mu = \overline{\beta}$ into ϕ. Let $(\tilde{\beta}, \tilde{\mu})$ be the combination of β and μ satisfying $\mu = \overline{\beta}$. Then, for all β and μ such that $\beta < \tilde{\beta}$ and $\mu < \tilde{\mu}$, we have $\phi < 0$. In Figure 4.4, this is the region below c2.

Additionally, we can find (β, μ) satisfying $\tilde{\beta} < \beta$, $\tilde{\mu} < \mu$, and $0 < \phi$. Also, there are (β, μ) satisfying $\tilde{\beta} < \beta$, $\tilde{\mu} < \mu$, and $\phi < 0$. Therefore, there can be both cases ($\phi > 0$ and $\phi < 0$) above c2, which is the region that $\overline{\beta} < \mu$ holds. In Figure 4.4, $c3$ is locus of points, where $\phi = 0$.

Case 2: $\underline{\beta} \leq \mu \leq \overline{\beta}$

In this region, by comparing profits B.3 and B.4, and considering B.6, the profit under CC is the highest. Thus, the choice of the quality of the new good will be $\frac{(a+b)s_0}{b-2a}$, and we have the covered market with a corner solution case.

Case 3: $\mu < \underline{\beta}$

In this case since the market configuration is CI, the incumbent firm's choice of quality for the new good will be s_2.[1,2]

B.2.4 Credibility

To examine credibility, we need to compare the incumbent's profit in the case of keeping the new good after entry with the case of withdrawing it after entry, which is the criterion of Judd (1985).

Before investigating the incumbent behaviour here, we explain Assumption 2. In UC, if the incumbent chooses $s_1 = s_0$, the entrant's profit will be 0 and if $s_1 = s_2$, then $\pi^E = b^2 s_0 s_2 (s_2 - s_0)/(4s_2 - s_0)^2$. Let $K_1 = b^2 s_0 s_2 (s_2 - s_0)/(4s_2 - s_0)^2$. If $0 < K < K_1$,

[1]Notice that if the vertical model does not have the "finiteness property" (see Shaked and Sutton (1983)), this proposition no longer holds. The finiteness property is a property that horizontally differentiated good models do not have. This property is guaranteed by the assumption that $a > 0$. Suppose $a = 0$. Then, we only have the uncovered market configuration, so there is no non-monotonic relationships between credibility and parameters.

[2]With regards to the case of $b - 4a < 0 \iff \beta < 4$, the results correspond to the covered market with a corner solution case and the covered market with an interior solution case in the above analysis. If $(a+b)s_0/(b-2a) < s_2$, the market configuration can be a covered market with a corner solution. Since $d\pi^I/ds_1 < 0$, the incumbent decreases the quality level until the boundary, $s_1 = (a+b)s_0/(b-2a)$. If $s_0 < s_2 < (a+b)s_0/(b-2a)$, the only possible market configuration is a covered market with an interior solution. Since $d\pi^I/ds_1 > 0$, the incumbent chooses the highest possible quality level, $s_1 = s_2$. Hence, we only have two cases when $\beta < 4$.

the incumbent can deter entry. Similarly, in CI, if $s_1 = s_0$, $\pi^E = 0$ and if $s_1 = s_2$, then $\pi^E = (s_2 - s_0)(b - 2a)^2/9$. Let $K_2 = (s_2 - s_0)(b - 2a)^2/9$. In CC, since the incumbent chooses $s_1 = (a + b)s_0/(b - 2a)$, then $\pi^E = (b - 2a)as_0/3$. Let $\underline{K} = (b - 2a)as_0/3$. If $s_1 = s_2$, then $\pi^E = [(abs_0 - 2a^2s_0)s_2 + (a - b)as_0^2]/2(s_2 - s_0)$. Let $K_3 = [(abs_0 - 2a^2s_0)s_2 + (a - b)as_0^2]/2(s_2 - s_0)$. Hence, the upper-bound is $\min\{K_1, K_2, K_3\}$.

Hence, if $\underline{K} < K < \overline{K}$ holds, the incumbent is able to deter entry. If $K < \underline{K}$, no strategy can deter entry. If $\overline{K} < K$, entry can be blockaded. To examine credibility, we concentrate on the case of $\underline{K} < K < \overline{K}$. This is Assumption 2. For the existence of such a K, we need $\underline{K} < \overline{K}$.

For $\underline{K} < \overline{K}$, we need to check $\underline{K} < K_1, K_2,$ and K_3. The conditions that $\underline{K} < K_2$ and $\underline{K} < K_3$ are equivalent to $\underline{\beta} \leq \mu$, and the condition $\underline{K} < K_1$ is equivalent to $0 < \beta^2(\mu^2 - \mu)/(4\mu - 1)^2 - (\beta - 2)/3$. This region of $\underline{\beta} \leq \mu$ and $0 < \beta^2(\mu^2 - \mu)/(4\mu - 1)^2 - (\beta - 2)/3$ is the shaded area in Figure 4.3. Under Assumption 2, we will have only the intermediate market size and quality dispersion case (CC), and the large market size and quality dispersion case (UC).

There are three possible cases violating the conditions $\underline{\beta} \leq \mu$ and $0 < \beta^2(\mu^2 - \mu)/(4\mu - 1)^2 - (\beta - 2)/3$. The first case is $\mu < \underline{\beta}$ and $0 < \beta^2(\mu^2 - \mu)/(4\mu - 1)^2 - (\beta - 2)/3$, the second case is $\underline{\beta} \leq \mu$ and $\beta^2(\mu^2 - \mu)/(4\mu - 1)^2 - (\beta - 2)/3 \leq 0$, and the last case is $\mu < \underline{\beta}$ and $\beta^2(\mu^2 - \mu)/(4\mu - 1)^2 - (\beta - 2)/3 \leq 0$. However, as we mentioned, as long as $\underline{\beta} \leq \mu$, we can show the possibility of credible threat by modifying Assumption 2: $\underline{K} < K < K_2$. Therefore, we only consider the case that $\mu < \underline{\beta}$. Then, we have the case of $\underline{K} \not< \overline{K}$, in which there is the small market size and quality dispersion case. This means that we consider the CI case.

UC

The incumbent can choose $s_1 = s_0$ to deter entry. Then, profit is $\pi^I|_{s_1=s_0}$. Since $d\pi^I/ds_1 > 0$, the relationship between profits is:

$$\pi^I|_{s_1=s_0} < \pi^I|_{s_1=s_2} = \pi^I_{\text{single}}.$$

The incumbent will withdraw the new good if entry actually occurs. A new good production is not a credible threat. In Figure 4.4, this is the region above the line c3.

CC

In this case, $s_1 = (b+a)s_0/(b-a)(< s_2)$. If the profit in the case when the incumbent keeps the new good is greater than that in the case when the incumbent withdraws it, a new good introduction is credible. In fact, from B.2 and B.4,

$$\pi^I_{\text{multi}} > \pi^I_{\text{single}} \iff \frac{b^2 s_2}{4} + \frac{(7b-2a)as_0}{12} - \frac{b^2 s_0}{4} > \frac{(bs_2 + (a-b)s_0)^2}{4(s_2 - s_0)}.$$

Therefore, if CC is chosen, the entry deterrence threat is credible. In Figure 4.4, this is the region between curves c1 and c3. This region is larger than the area of $\underline{\beta} \leq \mu \leq \overline{\beta}$, which is the region between c1 and c2.[3] We have thus completed the proof of lemma 1.

The following is the proof of lemma 2. If $\mu < \underline{\beta}$, we have the CI case.

[3]If $\underline{K} \not< \overline{K}$ and $\underline{\beta} < \mu$, credibility depends on whether $\underline{K} < K$ or $K < \underline{K}$. Because in equilibrium the market outcome will be CC irrespective of K_1, it is possible that new good introduction is a credible threat if $\underline{K} < K < K_2$.

CI

Since $d\pi^I/ds_1 > 0$, we have

$$\pi^I|_{s_1=s_0} < \pi^I|_{s_1=s_2} = \pi^I_{\text{single}}.$$

Therefore, this deterrence behaviour is not credible. This is the region below c1 in Figure 4.4. The same argument holds for the $b - 4a < 0$ case in which we only have the covered with an interior and a corner solution cases. The deterrence strategy is credible in the shaded area in Figure 4.4. □

B.3 Proof of Proposition 3

We have shown that only when the market size and quality dispersion are intermediate is the incumbent threat credible. The equilibrium is classified by these parameters. First, we will investigate the case of $b - 4a > 0 \iff \beta > 4$.

B.3.1 $\overline{\beta} < \mu$

From equation (B.7), when β and μ are large, we have $\phi > 0$. The incumbent prefers the uncovered market configuration and allows the new entrant to enter. However, if $\phi < 0$, the incumbent deters entry by lemma 1.

B.3.2 $\underline{\beta} \leq \mu \leq \overline{\beta}$

In this case, through lemma 1 the deterrence threat is credible. Since $\underline{K} < K < \overline{K}$ and $L < \bar{L}$, entry is deterred. In the $b - 4a < 0$ case, the same argument holds.

B.4 Proof of Proposition 4

B.4.1 $\mu < \underline{\beta}$

If $\mu < \underline{\beta}$, the entry deterrence threat is not credible by lemma 2. Therefore, entry is accommodated if entry costs are small enough and the entrant stays out if they are large enough.

B.5 Proof of Proposition 7

All we need to show is that entry enhances welfare. Since we know that in the intermediate case, if the anti-trust agency prohibits the incumbent's new good, the entrant enters. In the other cases, irrespective of the anti-trust agency's policy, deterrence is not credible, so entry occurs.

Proof: In the large market size and quality dispersion case, if entry is accommodated, we have:

$$W^e = \frac{1}{b-a}\int_{t_2}^{b}(s_2 t - p_2^e)ds + \frac{1}{b-a}\int_{t_2}^{b} p_2^e ds$$
$$+ \frac{1}{b-a}\int_{t_0}^{t_2}(s_0 t - p_0)ds + \frac{1}{b-a}\int_{t_0}^{t_2} p_0 ds - K$$

where p^e denotes the price under new entry. In the monopoly case, social welfare is:

$$W^m = \frac{1}{b-a}\int_{t_2}^{b}(s_2 t - p_2^m)ds + \frac{1}{b-a}\int_{t_2}^{b} p_2^m ds$$

where p^m denotes the price under monopoly. In the monopoly case, $t_2 = b/2$. In the duopoly case, $t_2 = b(2s_2 - s_0)/(4s_2 - s_0)(< b/2)$. The market share of the incumbent expands and the price decreases ($p_2^e < p_2^m$). This means that more people can consume the highest quality good at a lower price. The sum of the first two terms in W^e is greater than that in W^m. Since the last three terms of W^e are non-negative, we have $W^m < W^e$. Entry improves social welfare. This argument also holds in the small market size and quality dispersion case.

In the entry deterrence case, even though the incumbent produces a new good, once the deterrence succeeds, the price of the lower quality good is increased until no one purchases it. We have the same social welfare as the monopoly case:

$$W^d = \frac{1}{b-a}\int_{t_2}^{b}(s_2 t - p_2^d)ds + \frac{1}{b-a}\int_{t_2}^{b} p_2^d ds$$

where p^d denotes the price under deterrence. If the anti-trust agency prohibits such incumbent behaviour, the incumbent can not produce a new good and entry occurs. Social welfare is:

$$\begin{aligned} W^e = &\frac{1}{b-a}\int_{t_2}^{b}(s_2 t - p_2^e)ds + \frac{1}{b-a}\int_{t_2}^{b} p_2^e ds \\ &+ \frac{1}{b-a}\int_{a}^{t_2}(s_0 t - p_0)ds + \frac{1}{b-a}\int_{a}^{t_2} p_0 ds - K \end{aligned}$$

where p^e denotes the price under entry. In the deterrence case, $t_2 = b/2$. If new good introduction is prohibited, $t_2 = [bs_2 - (a+b)s_0]/2(s_2 - s_0) < b/2$. More consumers purchase the highest quality good. The price under prohibition, p^e, is less than that under deterrence, p^d. The sum of the first two terms in W^e is greater than that in W^d. The last three terms of W^e are non-negative, so prohibition improves social welfare. $\square$