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Endogenous Productivity, Export Decision & Mode Choice

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Endogenous Productivity, Export Decision & Mode Choice

by

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A thesis submitted to the
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Doctor of Philosophy
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This thesis entitled:
Endogenous Productivity, Export Decision & Mode Choice
written by Yiqing Xie
has been approved for the Department of Economics

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Date ______________

The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.
Multinational firms play an important role in the world economy with both international trade and foreign direct investment being fast growing economic activities. Multinational firms need to make a series of decisions before and after they enter the world market. There are three major steps in the decision process relating to the productivity of multinational firms that have triggered a lot of research interest. The first step in the decision process is the relationship between a firm’s export decision and its R&D investment (productivity) choice – what type of firm will self-select into the export market. The second step of the decision process is associated with the mode choice – exporting, licensing, or foreign direct investment. The third step of the decision process is how to choose a target firm to implement FDI or licensing in the host country if a parent firm has already made its mode choice. In order to set up a foreign direct investment, the parent firm can choose among greenfield investment, acquiring a more productive host-country firm and acquiring a less productive firm. As to the licensing target choice, the parent firm also can choose to license its technology to a more productive firm or a less productive firm in the host country.

My thesis aims to search for a general method to analyze these three major steps in the decision process and to relate these to the productivity decision at firm level in a single theoretical framework. I also find empirical support for some of the theoretical predictions from the Chilean plant-level data.

Following the first introduction chapter, in the second and third chapters, I set up an oligopolistic Cournot competition model in which heterogeneous firms can choose their productivity levels by adjusting their R&D investments before and after trade. I analyze the relationship between the productivity choice and the exporting decision in chapter 2, and discuss the interaction between the productivity choice and the mode choice in chapter 3. Similar to some recent
literature, firms are heterogeneous in their ex-ante productivity. But I generalize this by allowing firms to make investment in R&D, with the marginal product of these investments increasing in their ex-ante cost functions. Productivity is no longer only a determinant of the export decision and mode choice by including this investment choice stage before and after trade. Instead the productivity choice interacts with the export decision and mode choice. After exposure to trade, letting firms adjust their productivity induces a further divergence in their ex-post productivity difference and leads to a stronger intra-industry reallocation effect on quantities, price and profits.

In the fourth chapter, I simplify the model in the previous chapters by fixing firms’ productivity levels to analyze the third step in the decision process. How a parent firm chooses among different alternative host-country targets to implement either FDI or licensing mode choice is a largely unexplored question in the trade literature. The optimal FDI or licensing implementation target in the host country depends on the level of heterogeneity among all firms (including the parent firm and host-country firms) and the profitability in the market. There is a trade-off between the FDI set-up costs and the parent firm’s ex-post market share under different FDI implementation choices. Greenfield FDI is preferred when the market profitability is high, while cross-border acquisition of a more productive host-country firm is optimal when the market profitability is low. The parent firm will choose to acquire a less productive host-country firm with a medium-level market profitability. The choice of licensing implementation target is similar, with licensing to a less productive host-country firm if the market profitability is high and licensing to a more productive host-country firm if the market profitability is low.

In the fifth chapter, I use the Chilean plant-level data from 2001 to 2007 to check some of the theoretical predictions in chapter 3. The data shows that firms with access to foreign linkages (either FDI or licensing) are related to higher productivity and larger market share, with foreign subsidiaries even more productive and larger in size than domestic licensees. Empirical support is also found for the theoretical statement that FDI is associated with a larger productivity difference between less productive domestic firms and more productive foreign firms, while licensing is related to a smaller productivity difference.
Dedication

To my parents.
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Chapter 1

Introduction

Multinational firms are of considerable importance in the world economy. According to the world investment report 2011, foreign direct investments, sales of foreign affiliates and licensing have been growing at a faster pace than world GDP and most other economic activities. Yet most research on international trade tends to focus on trade in goods by national firms, in spite of the fact that sales by foreign affiliates of multinational firms are now about three times the value of world trade. At a general level, my work is directed toward this disconnect.

Firms need to make a series of decisions before and after they enter the world market. There are three major steps in the decision process relating to the productivity of firms that have motivated my research interest. The first step in the decision process is the relationship between a firm’s export decision and its productivity choice, it is the question about what type of firm will self-select into the export market. By using longitudinal plant or firm-level data from several countries, recent empirical research has shown a strong positive correlation between a firm’s productivity level and its exports behavior. Some papers, such as BEJK 2003, Melitz 2003, Melitz and Ottaviano 2008, Helpman, Melitz and Yeaple 2004, Costantini and Melitz 2007, Ekholm and Midelfart 2005, and Yeaple 2005, have attained some good theoretical explanations for this relationship.

The second step of the decision process is associated with the mode choice. The mode choice means that usually a firm may choose one of the following ways to serve the foreign market after they decide to enter the world market: exporting, licensing, or foreign direct investment. The belief that some technological improvement of the production process is brought by the multinational firms
has induced a lot of research to reveal the relationship between trade behaviors (mode choice) and productivity. Quite a few papers, such as Helpman, Melitz, and Yeaple AER 2004, Horstmann and Markusen CJE 1987, Ethier and Markusen JIE 1996, Saggi RIE 1999, and Ghosh and Saha RIE 2008, have discussed the mode choice and productivity choice both theoretically and empirically.

The third step is when a firm has already made its mode choice, how it is going to choose its acquisition target\(^1\) to implement FDI or how it is going to select its licensing target\(^2\) to implement licensing in the host country. Nocke and Yeaple (2007, 2008) have distinguished the difference between the greenfield investment and the cross-border acquisition according to the characteristics of the parent firm, which do not consider alternative host-country acquisition targets. Guadalupe, Kuzmina and Thomas, 2010 and some corporate finance merger literature (Lichtenberg and Siegel,1992; Jovanovic and Rousseau, 2002) have studied what type host-country firm is more preferred in a cross-border merger and acquisition.

This chapter is organized with four sections. The first three sections (section 1.1, 1.2 and 1.3) give brief summaries of the theoretical explanations of these three steps of the decision process relating to the productivity choice at firm level. The last section (section 1.4) summaries the empirical findings from the Chilean plant level data.

1.1 The Causality between Productivity and Trade

I present a trade model that captures the ”self-selection” effect of trade on both individual firm’s productivity choice and industry’s aggregate productivity in chapter 2. Firms are heterogeneous in their ex-ante cost functions with different efficiency parameters (R&D investment to productivity transformability \(\theta\) and base productivity level \(\eta\)) which influence the returns from R&D investment on the reduction of marginal cost. These heterogeneous firms first determine

\(^1\) The acquisition targets for a parent firm can be setting up a new subsidiary (greenfield investment), acquiring a more productive host-country firm or acquiring a less productive host-country firm.

\(^2\) The licensing targets for a parent firm can be licensing to a more productive host-country firm or licensing to a less productive host-country firm.
their productivity levels by choosing R&D investment in an oligopolistic Cournot competition market in the closed economy. Then they revise their endogenous productivity choice by changing their R&D investment after exposure to trade. The change in market size and toughness of competition after trade affect the R&D investment choice of an individual firm, and thus affect the productivity choice of that firm.

After exposure to trade, besides the intra-industry reallocation of market shares and profits among all firms, firms with less efficient cost functions are more likely to exit the market, which induces industry’s aggregate productivity improvements. Meanwhile larger market size in the open economy will encourage firms to invest in R&D and improve their individual productivity.

Letting firms choose their own productivity levels by introducing cost functions enhances the trade effect on profit decrease of all firms in the open economy due to not only the pro-competitive effect (more competing firms reduce the market price), but also the productivity-improvement effect (firms' lower marginal cost choices are associated with much higher outputs).

1.2 Exporting, Licensing, FDI and Productivity Choice

I extend the trade model developed in the previous chapter into a three stage model by adding the mode choice stage. Two heterogeneous firms, located in two different countries, compete under Cournot competition in both countries. They make their productivity choices by choosing their optimal R&D investment levels. By assuming one firm is more efficient in its ex-ante cost function without loss of generality, this ex-ante more efficient firm makes the mode choice between exporting, licensing and FDI in the open economy, leaving the other firm with an ex-ante less efficient cost function always accepting the mode choice.\footnote{3 The ex-ante less efficient firm is never productive enough to conduct FDI in the more efficient firm’s country and it always weakly prefers the licensing mode choice in this model. This assumption simplifies the model that only the ex-ante more efficient firm makes the mode choice and the less efficient firm will have to accept it.}

The ex-ante difference in the cost efficiency of two firms will lead to difference combinations of ex-post productivity difference and mode choice. A small ex-ante difference ends up with the
choice of licensing and zero ex-post productivity difference; an intermediate ex-ante difference leads
to the combination of exporting and an enlarged ex-post productivity difference; a large ex-ante
difference brings the choice of FDI and an even larger ex-post productivity difference.

The chapter also shows how the difference in market demand sizes of two countries causes
different preference among mode choices. Given the ex-ante cost efficiency difference is not too
large or too small to dominate the mode choice, firm with better ex-ante cost efficiency parameters
in a big country is more likely to directly export to a small country. However, if this firm locates
in a small country, it will probably choose to license its technology to another firm located in a big
country. FDI has a larger chance to occur if the host country is large enough to make the variable
exporting cost outweigh the fixed FDI cost but not large enough to have the endogenous licensing
fee to cover the profit loss due to the market share loss and market price decrease.

1.3 Choosing a Target Firm to Implement FDI or Licensing

I simplify the model in the previous chapters by fixing firms’ productivity levels (marginal
costs) to analyze the third step in the decision process, how to choose a target firm to implement
FDI or licensing. The basic model set up is using a Cournot oligopolistic competition with three
heterogeneous firms. The most productive parent firm is located in another country and two less
productive firms are located in the host-country market. The two host-country firms are also
heterogeneous with one more productive than the other. The parent firm has to decide its optimal
FDI or licensing implementation target (acquisition target or licensing target). This choice depends
on the level of heterogeneity among all firms and different market profitability in this model.

There are three FDI targets for the parent firm in the host country – a new subsidiary
(greenfield investment), the productive host-country firm and the less productive host-country
firm. There is a trade-off between the FDI set-up costs\(^4\) and the parent firm’s ex-post market

\(^4\) In chapter 4, I assume that setting up a new subsidiary (greenfield investment) has the lowest the FDI set-up
cost, while acquiring a more productive host-country firm is the most expensive target for the parent firm.
share under different FDI target choices. If the market profitability is relatively low, it will be optimal for the parent firm to choose to acquire a more productive host-country firm, which might be the case for the traditional industries with more mature markets. When the profitability in the market is very high (some high-tech emerging industries), greenfield investment becomes most profitable for the parent firm to implement FDI. Acquisition of a less productive firm is the best choice when the profitability in the market is in the middle range.

As to licensing, there are two ways for the most productive parent firm (licensor) to implement its licensing mode choice – licensing to a more productive firm or licensing to a less productive firm. Similar results are derived as the FDI mode choice. The optimal licensing choice is to license its technology to a more productive host-country firm when the market profitability is relatively low, while licensing to a less productive host-country firm is the best response for the licensor firm when the market has a high profitability.

1.4 Foreign Linkages & Productivity Advantage: Evidence from Chilean Data

I test three sets of empirical hypotheses to support some of the theoretical predictions in Chapter 3 by using the Chilean plant level panel data from 2001 to 2007. First, aligned with the theoretical predictions, foreign linkages including FDI and licensing are related to higher total factor productivity of a plant. Foreign subsidiaries and domestic plants with some licenses on average show a higher productivity level than plants with no access to foreign linkages. Moreover, foreign subsidiaries (FDI plants) have an even higher productivity level compared to domestic licensees.

Second, together with the basic productivity advantage associated with foreign linkages, plants with access to foreign linkages (foreign subsidiaries and domestic licensees) on average are also larger in size and have a larger market share with respect to three plant-level dependent variables - total sales, value added and total employment. Similarly, this intra-industry allocation effect from FDI is also larger than that from licensing.
Third, I also find consistent empirical results from the Chilean data set that the productivity difference between more productive foreign plants and less productive domestic plants affects the mode choice. A larger average productivity difference between domestic Chilean plants and foreign subsidiaries indicates a larger productivity advantage of relatively more productive foreign firms. If this is the case in an industry, more foreign direct investment is observed in the data. If the productivity advantage of more productive foreign firms is smaller in one industry, more licensing transactions are observed.
Chapter 2

The Causality between Productivity and Trade

The relationship between exports and productivity has been an important research topic for a long time. By using longitudinal plant or firm-level data from several countries, recent empirical research has shown a strong positive correlation between a firm’s productivity level and its exports behavior. After exposure to trade, more productive firms self select into the exporting market while less productive firms choose to exit the market due to the initial heterogeneity of the firms before trade; this "self selection" effect will show up directly. The "self selection" effect on the aggregate productivity level can be decomposed into two parts. One is the effect on the aggregate productivity level through entry and exit, which means that more productive firms enter, less productive firms exit, and the remaining firms have no productivity change. Several papers, such as BEJK 2003, Melitz 2003, Melitz and Ottaviano 2008, Helpman, Melitz and Yeaple (2004), Bustos (2011), have discussed this effect and have attained some good theoretical explanations. The other is the effect on individual firm’s productivity level. Instead of keeping their productivity level constant, the surviving firms after exposure to trade may choose to invest and increase their productivity levels. Costantini and Melitz 2007 and Yeaple 2005 attempted to explain this effect theoretically.

In this chapter, I introduce a trade model in which heterogeneous firms choose their productivity levels by incurring different R&D investment before and after exposure to trade in a Cournot competition market. In the closed economy, two oligopoly firms (in the extended model) compete against each other to win their part of market share and also determine their optimal productivity levels by choosing their R&D investment levels. In the open economy, the Cournot competition
model has four firms. The model attempts to capture the two parts of the productivity enhancing "self selection" effect of trade. More productive firms will self select to enter the export market while the least productive domestic firms might choose to exit; and firms will self select to improve their productivity after exposure to trade, i.e., more productive firms are more likely to increase their R&D investments and thus increase their productivity.

This chapter presents a model under an oligopoly Cournot competition market. There are only a few firms in the market and they strategically interact with each other. Most of the previous literature such as Costantini and Melitz 2007 and Yeaple 2005 analyzed the "self selection" effect of trade on individual firms' productivity improvement under monopolistic competition market. The model in this chapter captures the firms' heterogeneity in a more tractable way and focuses more on how the strategic interaction between firms determines the productivity levels. Under a monopolistic competition market, the market share distribution, price dispersion and the effect of trade on productivity levels are mostly determined by the elasticity of substitution from the consumers' utility function, however, the interactions between firms are ignored because firms do not have enough market power to affect the market equilibrium. However, there are many industries that are dominated by only a few firms, and these firms have the market power and interact with each other strategically. By including the interactions between firms in a oligopolistic competition model, the effect of one firm's choice on the other firms can be captured with respect to their productivity levels, market share distribution, pricing strategies and their corresponding decisions after exposure to trade such as whether to exit, whether to export and whether to invest and improve their productivity levels.

This model also captures the endogenous relationship between productivity choice and quantity choice (and thus price choice) for firms. In all the other monopolistic competition papers such as Melitz and Ottaviano 2008, Helpman, Melitz and Yeaple (2004), Costantini and Melitz 2007 and Yeaple 2005, this endogenous relationship is hard to be incorporated into the analysis, and hence it is often assume that firm’s productivity is a random draw from a certain distribution. In the model of this chapter, I assume that there is a clear relationship between R&D investment and firm’s
productivity, which is different from the assumption in Bustos (2011). Therefore, firms are allowed to make their productivity choices and price choices endogenously by incurring different levels of R&D investment. This assumption also fits better in an oligopolistic competition market since firms with more market power are usually more likely to know a more deterministic relationship between their R&D investments and their productivity.

Besides analyzing the individual firms’ productivity choices before and after exposure to trade, the model in this chapter also discusses the ”self selection” effect of trade on the aggregate productivity through the exit of the least productive firms. This model can well capture the exit effect of trade on the aggregate productivity level of an industry that the least productive firms may choose to exit, as well as the effect that more productive firms self select into the export market.

In addition, the effects of trade on post-trade productivity difference of different types of firms, profit difference, profit change and social welfare change are more obvious with firms having the power to determine their productivity levels by choosing their optimal R&D investment level. Profit diverges more and declines more after exposure to trade due to pro-competitive effect and productivity improvement effect.

This chapter is organized as following. Section 2.1 gives a literature review on the related theoretical work. Section 2.2 introduces a basic Cournot oligopolistic competition model with two firms in the open economy. I extend the model to a four-firm Cournot competition in the open economy in section 2.3. A numerical example shows the comparison of the productivity choice and firm level’ profit between the closed economy case and the open economy case in both section 2.2 and 2.3. Section 2.4 lists the major conclusions.

2.1 Literature Review

The following four theoretical papers model the self selection of firms into export market and the self selection effect of trade on the aggregate productivity through the drop out of the least productive firms and the entry of the more productive firms. They analyzed the intra-industry
reallocation of market shares, firms’ sizes, profits, firms’ export decisions and aggregate productivity level after exposure to trade.

Bernard, Eaton, Jensen and Kortum 2003 develops a theoretical model to reconcile trade theory with plant-level export behavior and simulate this theoretical model with the data from U.S plants. A plant with higher efficiency is likely to have a higher markup, to export and to have a larger size.

Melitz 2003 introduces a dynamic industry model that incorporates firm level heterogeneity to analyze the impacts of international trade on the aggregate industry productivity and welfare through intra-industry reallocation of both market share and profit. The results from this model actually fit many empirical studies very well. The least efficient firms which can survive in the closed economy are driven out of the industry due to a higher cutoff productivity level required in the open economy; and the most efficient firms export and gain in both market share and profit. By this kind of intra-industry reallocation, the aggregate productivity of the industry is higher.

Melitz and Ottaviano 2008 then studies a monopolistically competitive model that predicts how a wide set of industry performance measures (productivity, size, price, and mark-up) responds to changes in the world trading environment. It incorporated heterogeneous firms (a random productivity draw for each firm) which is the same as Melitz 2003 and endogenous mark-ups that responded to the endogenous toughness of competition in a market. Market size and trade affect the toughness of competition, which feeds back into the selection of heterogeneous products and exporters in that market. Larger, more integrated markets exhibit tougher competition and thus higher productivity and lower mark-ups.

Helpman, Melitz and Yeaple 2004 are not only interested in whether a firm export but also whether a firm directly invest in a foreign market. The model in their paper achieves similar results as Melitz 2003, moreover, only the most productive firms in the industry will choose FDI in an open economy.

These four papers address issues around the "self-selection" effect of trade on the aggregate productivity of an industry through entry and exit when firms are exposed to trade. The model in
this chapter can capture this effect and come to the similar conclusions. The following two papers discuss the "self-selection" effect on individual firms’ productivity change after exposure to trade given different assumptions. The three theoretical models developed by Costantini and Melitz 2007, Yeaple 2005 and Bustos 2011 conclude that the self-selection effect also plays an important role on individual firms’ choices of their specific productivity levels.

Costantini and Melitz 2007 develop a theoretical model that can capture firms’ productivity choices after the announcement of trade liberalization - an open market to trade can encourage firms to innovate. The model captures the joint entry, exit, export, and innovation decisions (subject to sunk costs) of heterogeneous firms as they adjust to trade liberalization. Firm-level productivity evolves stochastically, and innovation involves a trade-off between its cost and a return in terms of a better distribution of future productivity draws.

Yeaple 2005 presents another kind of theoretical model. In the model presented in this paper, homogeneous firms face four types of decisions: (1) entry, (2) technology choice, (3) whether or not to export, and (4) type of worker to employ. The interaction between the characteristics of competing technologies with trade costs and with worker heterogeneity gives rise to a type of firm heterogeneity that is consistent with some of the stylized facts: Exporting firms are larger, employ more advanced technologies, pay higher wages, and appear to be more productive than firms that do not export. Second, the model shows that a reduction in trade frictions can induce firms to switch technologies, leading to an expansion of trade volumes, an increase in the wage premium paid to the most highly skilled workers and a decrease in the wage premium paid to moderately skilled workers.

Bustos 2011 extends Melitz 2003 model by introducing technology choice in the theoretical part. The joint treatment of the technology choice and the exporting decision shows that trade liberalization can induce exporters to upgrade technology. In this paper, Argentinian firm level data is used to test the impact of a regional free trade agreement, MERCOSUR, on technology upgrading by Argentinean firms.

The model in this chapter uses the idea in Costantini and Melitz working paper 2007 that
firms can improve their productivity levels by incurring some fixed cost, but applies Cournot com-
petition model to allow the productivity to be determined by firms’ choices of R&D investment
rather than a random draw. Firms know their abilities of R&D investment very well and choose
different productivity levels by choosing different levels of R&D investment. With this relationship
between R&D investment and productivity, firms’ interdependence can be well captured in their
decisions before and after exposure to trade.

2.2 Basic Model

In this basic model set-up, there are two countries $h$ and $f$ with the same domestic inverse
demand function which is given by

\[ P = \alpha - \beta X, \quad (2.1) \]

where $P$ stands for the price of the good and $X$ for the quantity. There is a monopoly firm in each
country. Firm $H$ is the domestic firm for Country $h$ and firm $F$ is the domestic firm for Country
$f$. In this model, I first analyze the closed economy situation and derive the equilibrium marginal
costs (productivity levels) and R&D investment levels for both firms. Then in the open economy,
with no trade cost, two firms will compete against each other under a Cournot competition model
and market demand function is the sum of the two countries’ demand functions. With changes in
both the market size and the toughness of competition in the open economy, two firms strategically
interact with each other and determine their new output levels, profits, R&D investments, and thus
productivity levels.

2.2.1 Closed Economy

In the closed economy, firm $H$ serves country $h$’s consumers with a linear inverse demand
function $P_h = \alpha - \beta X_h$ and firm $F$ serves country $f$’s consumers with an inverse demand function
$P_f = \alpha - \beta X_f$. Firm $H$’s marginal cost function is $c_H = \eta_H - \theta_H I_H^{\frac{1}{2}}$ which reveals the relationship
between firm $H$’s marginal cost $c_H$ and its R&D investment level $I_H$. Both $\eta_H$ and $\theta_H$ are positive,
with $\eta_H$ reflecting the base productivity (base marginal cost) of firm $H$ and $\theta_H$ showing firm $H$'s transformability from R&D investment to productivity improvement. With a higher R&D investment level, firm $H$'s marginal cost level is lower, which means the productivity level of the firm is higher. With more money invested in the R&D, the marginal cost is decreasing at a diminishing rate. Similarly, firm $F$'s marginal cost function is $c_F = \eta_F - \theta_F I_F^{\frac{1}{2}}$.

Firm $H$'s behavior can be analyzed independently in the closed economy. In this basic model, I assume that the demand is large enough for a monopoly firm to make an economic profit. Firm $H$ makes a two-stage decision to maximize its profit. In the first stage, firm $H$ determines its R&D investment level, and thus the marginal cost (productivity) is decided according to the marginal cost function. In the second stage, firm $H$ needs to choose its monopoly output and market price given the marginal cost level determined in the first stage. The optimal R&D investment level $I^C_H$, marginal cost level $c^C_H$, quantity $X^C_H$, price $P^C_H$ and profit $\pi^C_H$ can be derived by backward induction for this monopoly firm $H$. Superscript $C$ indicates that it is in a closed economy.

\[
I^C_H = \left( \frac{(\alpha - \eta_H) \theta_H}{4\beta - \theta_H^2} \right)^2,
\]
\[
c^C_H = \eta_H - \frac{(\alpha - \eta_H) \theta_H^2}{4\beta - \theta_H^2},
\]
\[
X^C_H = \frac{2(\alpha - \eta_H)}{4\beta - \theta_H^2},
\]
\[
P^C_H = \frac{2\beta (\alpha + \eta_H) - \alpha \theta_H^2}{4\beta - \theta_H^2},
\]
\[
\pi^C_H = \frac{(\alpha - \eta_H)^2}{4\beta - \theta_H^2}. \tag{2.2}
\]

In country $F$, analogous to county $H$, the optimal R&D investment level $I^C_F$, marginal cost level $c^C_F$, quantity $X^C_F$, price $P^C_F$ and profit $\pi^C_F$ are as following:

\[
I^C_F = \left( \frac{(\alpha - \eta_F) \theta_F}{4\beta - \theta_F^2} \right)^2,
\]
\[
c^C_F = \eta_F - \frac{(\alpha - \eta_F) \theta_F^2}{4\beta - \theta_F^2},
\]
\[
X^C_F = \frac{2(\alpha - \eta_F)}{4\beta - \theta_F^2},
\]
\[
P^C_F = \frac{2\beta (\alpha + \eta_F) - \alpha \theta_F^2}{4\beta - \theta_F^2},
\]
\[
\pi_F^C = \frac{(\alpha - \eta_F)^2}{4\beta - \theta_F^2}.
\] (2.3)

As I have assumed that the inverse demand functions of the two countries are the same (both with parameters \( \alpha \) and \( \beta \)), the difference in prices and quantities between the two countries only depends on the parameters in the marginal cost functions. \( \eta \) and \( \theta \) reflect the ability of a firm to transform R&D investment to productivity by reducing marginal cost. \( \eta \) represents the base productivity of a firm. A higher \( \eta \) indicates a base marginal cost and a lower base productivity level. Parameter \( \theta \) determines how fast productivity can be increased (marginal cost can be reduced) with the increase in the R&D investment. According to the marginal cost functions, firm with a larger \( \theta \) has a better ability to transform its R&D investment to a productivity increase. With a smaller \( \eta \) and a larger \( \theta \), a monopoly firm can be defined as ex-ante more efficient and it will choose a lower price and larger output, but with higher mark-up and profit. Moreover, this firm will invest more in R&D, and the marginal cost level will be lower (productivity level will be higher) due to its better transformability from R&D investment to productivity improvement and lower base marginal cost.

### 2.2.2 Open Economy

In the open economy, I assume there is a variable trade cost \( t \). Both firm \( H \) and firm \( F \) will incur the same unit trade cost if they choose to export to the other country. Two firms which sell homogeneous goods compete by choosing their optimal quantities (Cournot competition) in both countries. After exposure to trade, firms get the opportunity to export to a foreign market, while the domestic market is more competitive with two firms. Neither firm can make its decision independently by only focusing on the market demand function. They have to make choices to maximize their profits interdependently.

The inverse demand function of country \( h \) and \( f \) in the open economy are \( P = \alpha - \beta (X_{Hh} + X_{Fh}) \) and \( P = \alpha - \beta (X_{Hf} + X_{Ff}) \) respectively. Subscripts \( h \) and \( f \) stand for country \( h \) and country \( f \), and subscripts \( H \) and \( F \) indicate firm \( H \) and firm \( F \). It is also a two-stage game. Both firms need to choose their R&D investment levels to determine their marginal costs (productivity) first. Then they have to figure out their best response functions in the Cournot competition.
competition and hence determine their quantities, price and maximized profits.

By backward induction, supposing that both firms have decided their R&D investments and marginal costs, I can express the profit-maximizing quantities, price and profits as functions of their marginal costs. Superscript $O$ indicates the open economy case.

Quantities:

\[
X_{Oh}^O = \frac{1}{3\beta} \left( \alpha - 2c_H^O + c_F^O + t \right),
\]

\[
X_{Of}^O = \frac{1}{3\beta} \left( \alpha - 2c_H^O + c_F^O - 2t \right),
\]

\[
X_{Fh}^O = \frac{1}{3\beta} \left( \alpha - 2c_F^O + c_H^O - 2t \right),
\]

\[
X_{Ff}^O = \frac{1}{3\beta} \left( \alpha - 2c_F^O + c_H^O + t \right).
\] (2.4)

Price: (same in both country)

\[
P_h^O = P_f^O = \frac{1}{3} (\alpha + c_H^O + c_F^O + t).
\] (2.5)

Profits:

\[
\pi_H^O = \frac{1}{9\beta} (\alpha - 2c_H^O + c_F^O + t)^2 + \frac{1}{9\beta} (\alpha - 2c_H^O + c_F^O - 2t)^2 - I_H^O,
\]

\[
\pi_F^O = \frac{1}{9\beta} (\alpha - 2c_F^O + c_H^O + t)^2 + \frac{1}{9\beta} (\alpha - 2c_F^O + c_H^O - 2t)^2 - I_F^O.
\] (2.6)

In order to maximize the profit, it is easy to determine the optimal R&D investment levels and also calculate the marginal costs according to the cost functions.

\[
I_H^O = \left\{ \frac{4\theta_H \left[ (9\beta - 12\theta_F) \alpha - (18\beta - 12\theta_F^2) \eta_H + 9\beta \eta_F - (4.5\beta - 6\theta_F^2)t \right]}{(9\beta - 8\theta_F^2) (9\beta - 8\theta_H^2) - 16\theta_H^2 \theta_F^2} \right\}^2,
\]

\[
I_F^O = \left\{ \frac{4\theta_F \left[ (9\beta - 12\theta_H^2) \alpha - (18\beta - 12\theta_H^2) \eta_F + 9\beta \eta_H - (4.5\beta - 6\theta_H^2)t \right]}{(9\beta - 8\theta_H^2) (9\beta - 8\theta_F^2) - 16\theta_F^2 \theta_H^2} \right\}^2.
\] (2.7)

I can rewrite $I_H^O$ into this following form

\[
I_H^O = \left\{ \frac{4\theta_H \left[ 6\theta_F^2 t + (9\beta - 12\theta_F^2) \alpha - (18\beta - 12\theta_F^2) \eta_H + 9\beta \eta_F - 4.5\beta t \right]}{81\beta^2 - 72\beta \theta_F^2 - (72\beta - 48\theta_F^2) \theta_H^2} \right\}^2.
\] (2.8)

Since a larger $\theta_H$ makes the numerator larger and the denominator smaller, and $\eta_H$ only exists in a negative term on the numerator, firm $H$ will choose to invest more in its R&D investment to
increase its productivity if it is ex-ante more efficient with a lower base marginal cost and a higher R&D investment to productivity transformability. This shows that an ex-ante more efficient firm with a smaller $\eta$ and a larger $\theta$ will choose a higher R&D investment level in the open economy, and thus it will have a higher productivity, larger domestic market share, larger total output and higher profit.

When firm $H$ and firm $F$ have the same levels of base productivity and transformability from R&D investment to productivity, which means that the cost function are identical for two firms $c_H = c_F = \eta - \theta I^\frac{1}{2}$, the expression for optimal R&D investment for both firms without trade cost can be simplified to

$$I^O_H = I^O_F = \left( \frac{\alpha - \eta}{4\beta - \theta^2} \right)^2.$$

Under this symmetric with no trade cost case, the optimal R&D investment level in the open economy is higher than that in the closed economy which

$$I^C_H = I^C_F = \left( \frac{\alpha - \eta}{4\beta - \theta^2} \right)^2.$$

Hence, the productivity level is higher (marginal cost is lower) in the open economy.

According to the above four equilibrium quantity levels (Eq. 2.4), if the variable trade cost is low and cost functions of the two firms do not differ much, both firms will choose to export at the same time to serve their domestic market. When the trade cost or the difference between two cost functions gets larger, the firm with a more efficient marginal cost function (a smaller $\eta$ and a larger $\theta$) will choose to export and serve its domestic market at the same time, while the firm with a less efficient marginal cost function (a larger $\eta$ and a smaller $\theta$) will not export and it will also lose some of its domestic market share.

The variable trade cost $t$ has both direct effect and indirect effect on the export decision in this model. The two exporting quantities $X^O_{Hf}$ and $X^O_{Fh}$ both include a variable trade cost term $-2t$ which means that the trade cost has a negative effect on the exporting quantities directly. Higher trade cost is associated with lower exporting quantities for both firms. And this direct effect is the
same for both firms. The following chain shows the indirect effect of the trade cost on the exporting quantities: a higher trade cost reduces the optimal R&D investment level which will increase the corresponding marginal cost, then the marginal cost will affect the exporting quantities. A higher trade cost reduces the incentive to increase optimal R&D investment even more for a firm with a better transformability from R&D investment to productivity (a larger $\theta$). Combining these direct and indirect effects of the trade cost, a firm with a better transformability from R&D investment to productivity (an ex-ante more efficient cost function) is more sensitive to the trade cost when it makes its exporting quantity decision. However, if the ex-ante more efficient firm’s transformability from R&D investment to productivity is high enough to keep its marginal cost always at zero, the trade cost can no longer affect this firm’s R&D investment level, then the other firm with an ex-ante less efficient cost function will be more sensitive to the trade cost.

Compared to the closed economy case, the exposure to trade will make both firms reduce their marginal costs (increase their productivity) by incurring more R&D investments as long as these two firms’ abilities to transform R&D investment into productivity do not differ too much and the trade cost is not too high. Market price will decrease due to the more competitive market and the reduction in the marginal costs of both firms. Aggregate productivity will increase. Total output will increase and total profit of the two firms will decrease, and thus social welfare will increase.

2.2.3 A Numerical Example

Considering that the R&D investment and profit are affected by many parameters such as the market demand parameters ($\alpha$ and $\beta$), marginal cost function of firm H ($\eta_H$ and $\theta_H$) and marginal cost function of firm F ($\eta_F$ and $\theta_F$). I give a numerical example to show how firms change their R&D investment levels and profits after exposure to trade given different cost functions. In this example, the demand function is $P = 10 - 3X_i$, $i = H, F$, and the variable trade cost is set to be zero for the first two cases for simplicity. The third case in this numerical example shows how trade cost affects the exporting quantities for both firms in the open economy.
In the first case, I set the base productivity of these two firms at the same level $\eta_H = \eta_F = 2$, and check how different combinations of $\theta_H$ and $\theta_F$ (the transformability from R&D investment to productivity) will end up with different combinations of optimal R&D investment levels and maximized profits in both closed economy and open economy. $\theta_H$ increases from 0 to 1.5, while $\theta_F$ decreases from 1.5 to 0. The sum of $\theta_H$ and $\theta_F$ is constant at 1.5. Fig.2.1 shows the optimal marginal cost levels of both firms under the closed economy and open economy cases, while Fig.2.1 presents the maximized profits of these two firms. The dotted lines indicate the closed economy case and the solid lines represent the open economy case. The blue lines indicate firm $F$ (located in country $f$) and the red lines indicate firm $H$ (located in country $h$). Subscripts $H$ and $F$ indicate firm $H$ and firm $F$ respectively, and superscripts $C$ and $O$ denote the closed economy and the open economy respectively. These notations will be carried over to all other figures in this chapter.

Figure 2.1: 2-Firm Case: Optimal marginal costs ($c$) when $\eta_H = \eta_F = 2$, $\theta_F + \theta_H = 1.5$

In Fig.2.1, the marginal cost levels for two firms are the same when $\theta_H = \theta_F = 0.75$ in both closed economy and open economy. A higher $\theta_H$ makes the optimal marginal cost lower for firm $H$ because firm $H$ chooses to invest in R&D more. In the closed economy case, the optimal marginal cost level of firm $H$ is not related with $\theta_F$; it decreases only because of the increase in $\theta_H$ which
is shown by the declining dotted red line. In the open economy, the marginal cost level of firm $H$ decreases due to a decreasing $\theta_F$ as well as an increasing $\theta_H$. With a larger difference between $\theta_H$ and $\theta_F$, the marginal cost levels for two firms diverge even more in the open economy. If $\theta_H$ continues to increase, eventually the marginal cost of firm $H$ will reduce to zero and afterward firm $H$ will have no incentive to increase R&D investment and just keep its marginal cost at zero. After exposure to trade, both firms will increase their R&D investment levels and reduce their marginal costs as long as their $\theta$’s do not differ too much, since Fig.2.1 shows that the majority part of the solid line (open economy case) is lower than its corresponding part of the dotted line (closed economy case). This specific numerical case actually shows graphically that both firms are very likely to reduce their marginal costs (improve their productivity) by investing more after exposure to trade and the firm with a higher ability to transform its R&D investment into cost reduction will have a stronger incentive to invest even more to reduce its cost.

![Figure 2.2: 2-Firm Case: Maximized profits ($\pi$) when $\eta_H = \eta_F = 2$, $\theta_F + \theta_H = 1.5$](image)

As to profits, Fig.2.2 shows that the firm with a high $\theta$ ends up with a higher profit in the closed economy and only its own R&D to productivity transformability affects its pre-trade profit. After exposure to trade, two firms interact with each other so that either firm’s post-trade profit...
is affected by not only its own transformability but also the other firm’s transformability. When these two firms’ \( \theta \)'s are similar, both firms will choose to reduce their marginal costs, while the post-trade profits of both firms will decrease.

Two effects - pro-competitive effect and productivity-improvement effect cause the profits of both firms to decrease in the open economy. The pro-competitive effect happens here because when market becomes more competitive (2-firm Cournot competition VS. monopoly) two firms will produce more output and thus reduce the market price. The productivity-improvement effect can also be captured in this model because firms are allowed to choose their optimal R&D investment levels to determine their marginal costs (productivity). After exposure to trade, both firms increase their R&D investment levels to reduce their corresponding marginal costs as long as their ex-ante cost function difference is not too large, which will further increase the total output level in each country and reduce the market price. More consumers will be served in each country to the extent that the mark-up will also decrease. Hence, the profit of each firm will decrease again due to this productivity-improvement effect. This second effect actually increases the output, reduces the profit and increases the social welfare further more in the open economy.

Figure 2.3: 2-Firm Case: Decomposition of pro-competitive effect and productivity-improvement effect on profits
Fig.2.3 presents the decomposition of these two effects on the profit change from closed economy to open economy. Compared to Fig.2.2, Fig.2.3 has two more dashed lines which indicate the maximized profit levels in the open economy if marginal costs of the two firms are held at the same levels as those in the closed economy. The pro-competitive effect is described by the difference between the closed economy dotted lines and the open economy dashed lines. This effect is caused only by a more competitive market structure with no productivity change because two firms are forced to keep their closed-economy marginal costs for the profit decomposition case (two dashed lines). The difference between the open economy dashed lines and the open economy solid lines indicates the productivity-improvement effect which enhances the decrease in the profits after exposure to trade.

Figure 2.4: 2-Firm Case: Optimal marginal costs \( (c) \) when \( \theta_H = \theta_F = 0.75 \), \( \eta_F + \eta_H = 4 \)

In the second case, by setting the transformability from R&D investment to productivity constant and same for both firms \( \theta_H = \theta_F = 0.75 \) (the symmetric case from Fig.2.1 – 2.3), I show how different base productivity levels \( (\eta' \text{s}) \) will affect the pre-trade and post-trade marginal cost choices and profits for both firms. I make \( \eta_H \) increase from 1 to 3, at the same time \( \eta_F \) decreases from 3 to 1. The sum of two \( \eta' \text{s} \) is constant at 4. Fig.2.4 shows the numerical results of the marginal
costs before and after trade for both firms, while Fig. 2.5 presents the maximized profits. I can make similar conclusions as those of the first case with different $\eta$’s instead of $\theta$’s.

In the third case, I set the base productivity of two firms the same level $\eta_H = \eta_F = 2$ and the transformability $\theta_H = 1.1$ and $\theta_F = 0.4$. Then I check how the variable trade cost (from free trade zero to a relatively high level 3) will affect exporting decisions of the two firms in the open economy. In this case, firm $H$ has a more efficient cost function with a higher $\theta$. According to the upper part of Fig. 2.6, firm $H$ will keep its marginal cost at zero so that the variable trade cost will not affect its R&D investment level when the variable trade cost is really small (close to zero). An increase in the variable trade cost only has a direct effect on firm $H$’s exporting quantity. Firm $F$ is more sensitive to the variable trade cost increase when it makes its exporting quantity decision because the trade cost is affecting firm $F$’s exporting quantity both directly and indirectly through affecting its marginal cost (productivity) choice. The difference between firm $H$’s exporting quantity and firm $F$’s exporting quantity gets larger as the variable trade cost increases, which means firm $F$’s exporting quantity decreases at a faster speed than firm $H$’s. As the variable trade cost grows large enough to affect firm $H$’s R&D investment and therefore firm $H$ is going to have a positive marginal

Figure 2.5: 2-Firm Case: Maximized profits ($\pi$) when $\theta_H = \theta_F = 0.75, \eta_F + \eta_H = 4$
cost, firm $H$ becomes more sensitive to the trade cost increase afterward compared to firm $F$. The difference between firm $H$’s exporting quantity and firm $F$’s exporting quantity decreases as the variable trade cost increases further.

![Figure 2.6: 2-Firm Case: Direct and indirect effects of the variable trade cost ($t$) on the exporting quantities](image)

Fig. 2.6 clearly shows the direct and indirect effects of the variable trade cost on the exporting quantity decision of these two firms. When the variable trade cost level is low, the exporting quantity of firm $F$ decreases at a faster speed than that of firm $H$ as the trade cost increases, which will enlarge the difference between exporting quantities of these two firms. When the variable trade cost is at a relatively higher level, the exporting quantity of firm $H$ will decrease faster with an increase in the variable trade cost, the exporting quantity difference between these two firms will shrink accordingly.

Fig. 2.7 presents the self-selection effect - only high-productivity firm will self-select into the exporting market. In this third numerical case, firm $H$ has a higher productivity level (lower

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1 The upper part of Fig. 2.6 shows the how the variable trade cost affects the marginal cost choices of these two firms which indirectly affects their exporting quantity decision. The lower part of Fig. 2.6 shows the difference between these two firms’ exporting quantity after combining the direct and indirect effects of the variable trade cost.
marginal cost) both ex-ante and ex-post. When the variable trade cost gets large enough\(^2\) (graphically it is greater than 3.23), only firm \(H\) will choose to export to country \(f\), while firm \(F\) will choose to serve its domestic market only because firm \(F\) cannot afford the variable trade cost any more.

### 2.3 Extended Model

In this section, I introduce an extended model that includes more firms than the previous basic model so that I can capture the drop out phenomenon of low productivity firms after exposure to trade. There are two countries \(h\) and \(f\) with the same domestic inverse demand function which is \(P = \alpha - \beta X\) (same as Eq.2.1), where \(P\) stands for the price of the good and \(X\) for the quantity. In each country there are two firms competing against each other under a Cournot competition market. Firm 1 and 2 are the domestic firms for country \(h\) and firm 3 and 4 are the domestic firms for country \(f\). In this extended model, similar to the basic model section, I first analyze the closed economy equilibrium and then let four firms compete with each other with no trade cost in

\(^2\) I allow the variable trade cost to continue increasing to 4 in this figure.
the open economy. This section also includes a numerical example that could graphically show all firms’ R&D investment choices and profits before and after trade.

2.3.1 Closed Economy

In the closed economy, firm 1 and 2 are serving country $h$’s consumers with a linear inverse demand function $P_h = \alpha - \beta X_h$ in which $X_h = X_1 + X_2$ and firm 3 and 4 are serving country $f$’s consumers with an inverse demand function $P_f = \alpha - \beta X_f$ in which $X_f = X_3 + X_4$. Each firm’s marginal cost function is $c_i = \eta_i - \theta_i I_i^\frac{1}{2}$ ($i = 1, 2, 3, 4$) with both $\eta_i$ and $\theta_i$ positive.

Firm 1 and 2, whose decisions are not affected by country $f$’s firm 3 and 4, interact with each other in country $h$ in the closed economy. I still assume that the demand is large enough for these Cournot duopoly firms to make a positive economic profit. Both firms have to make a two-stage decision to maximize their profits interdependently. Again by backward induction, suppose that both firms have decided their R&D investments and marginal costs, their profit-maximizing quantities, price and profits can be expressed as a function of their marginal costs as following.

Quantities:

$$X^C_1 = \frac{1}{3\beta} (\alpha - 2c_1^C + c_2^C),$$
$$X^C_2 = \frac{1}{3\beta} (\alpha - 2c_2^C + c_1^C).$$ (2.9)

Price:

$$P^C_h = \frac{1}{3} (\alpha + c_1^C + c_2^C).$$ (2.10)

Profits:

$$\pi^C_1 = \frac{1}{9\beta} (\alpha - 2c_1^C + c_2^C)^2 - I_1^C,$$
$$\pi^C_2 = \frac{1}{9\beta} (\alpha - 2c_2^C + c_1^C)^2 - I_2^C.$$ (2.11)

In order to maximize the profit, it is easy to determine the optimal R&D investment levels and also calculate the marginal costs according to the cost functions.

$$I_1^C = \left\{ \frac{2\theta_1 \left[ (9\beta - 6\theta_2^2) \alpha - (18\beta - 6\theta_2^2) \eta_1 + 9\beta \eta_2 \right]}{(9\beta - 4\theta_1^2) (9\beta - 4\theta_2^2) - 4\theta_1^2 \theta_2^2} \right\}^2,$$
\[ I^C_2 = \left\{ \frac{2\theta_2 \left[ (9\beta - 6\theta_1^2) \alpha - (18\beta - 6\theta_1^2) \eta_2 + 9\beta \eta_1 \right]}{(9\beta - 4\theta_1^2) (9\beta - 4\theta_2^2) - 4\theta_1^2 \theta_2^2} \right\}^2, \]  

(2.12)

with

\[ c^C_1 = \eta_1 - \theta_1 \left( I^C_1 \right)^{\frac{1}{2}}, \]

\[ c^C_2 = \eta_2 - \theta_2 \left( I^C_2 \right)^{\frac{1}{2}}. \]  

(2.13)

Similar to the open economy case in the basic model section, a firm with a smaller \( \eta \) and a larger \( \theta \) will invest more in its R&D investment to increase its productivity in the closed economy. This firm will end up with a larger market share, and a higher profit.

I can derive analogous calculation and conclusions for country \( f \) with firm 3 and 4, simply replacing subscript \( h \) with \( f \), 1 with 2 and 3 with 4.

### 2.3.2 Open Economy

I still assume there is no variable trade cost in the open economy. There are four firms selling homogeneous goods and competing in the world market. The world demand equals the sum of the two countries’ demands which is

\[ P = \alpha - \beta \left( X_h + X_f \right) / 2 = \alpha - \beta \left( X_1 + X_2 + X_3 + X_4 \right) / 2. \]  

(2.14)

After exposure to trade, the market demand increases and the market is more competitive. All four firms need to make decisions to maximize their profits strategically and interdependently.

If all four firms have decided their R&D investments and marginal costs, their profit-maximizing quantities, price and profits can be expressed as a function of their marginal costs as following.

Quantities:

\[ X^O_i = \frac{2}{5\beta} \left( \alpha + \sum_{j=1}^{4} c^O_j - 5c^O_i \right), i = 1, 2, 3, 4. \]  

(2.15)

Prices: (same in both countries)

\[ P^O_h = P^O_f = \frac{1}{5} \left( \alpha + \sum_{j=1}^{4} c^O_j \right). \]  

(2.16)
Profits:

$$\pi^O_i = \frac{2}{25\beta} \left( \alpha + \sum_{j=1}^{4} c^O_j - 5c^O_i \right)^2 - I^O_i, \; i = 1, 2, 3, 4. \tag{2.17}$$

In order to maximize the profit, I use backward induction to determine the optimal R&D investment levels and calculate the marginal costs according to the cost functions. The optimal R&D investment levels are the results of the following system of equations with four variables and four equations. One can determine the corresponding marginal costs, quantities, price and profits from the R&D investment results.

\[
\begin{align*}
\left( \frac{25\beta}{8\theta_1} - 4\theta_1 \right) \left( I^O_1 \right)^{1/2} + \theta_2 \left( I^O_2 \right)^{1/2} + \theta_3 \left( I^O_3 \right)^{1/2} + \theta_4 \left( I^O_4 \right)^{1/2} &= \alpha - 4\eta_1 + \eta_2 + \eta_3 + \eta_4 \\
\theta_1 \left( I^O_1 \right)^{1/2} + \left( \frac{25\beta}{8\theta_2} - 4\theta_2 \right) \left( I^O_2 \right)^{1/2} + \theta_3 \left( I^O_3 \right)^{1/2} + \theta_4 \left( I^O_4 \right)^{1/2} &= \alpha + \eta_1 - 4\eta_2 + \eta_3 + \eta_4 \\
\theta_1 \left( I^O_1 \right)^{1/2} + \theta_2 \left( I^O_2 \right)^{1/2} + \left( \frac{25\beta}{8\theta_3} - 4\theta_3 \right) \left( I^O_3 \right)^{1/2} + \theta_4 \left( I^O_4 \right)^{1/2} &= \alpha + \eta_1 + \eta_2 - 4\eta_3 + \eta_4 \\
\theta_1 \left( I^O_1 \right)^{1/2} + \theta_2 \left( I^O_2 \right)^{1/2} + \theta_3 \left( I^O_3 \right)^{1/2} + \left( \frac{25\beta}{8\theta_4} - 4\theta_4 \right) \left( I^O_4 \right)^{1/2} &= \alpha + \eta_1 + \eta_2 + \eta_3 - 4\eta_4
\end{align*}
\]

A firm with a smaller $\eta$ and a larger $\theta$ will invest more in its R&D investment to increase its productivity (reduce its marginal cost) in the open economy. This firm will end up with a larger market share (more output) and a higher profit level. In the open economy, as long as their abilities to transform R&D investment to productivity do not differ too much, all firms will reduce their marginal costs (increase their productivity) by incurring more R&D investments compared to the closed economy case, the market price will decrease due to the more competitive market and the reduction in the marginal costs of all firms. Total output will increase and total profit of all the firms will decrease, and thus social welfare will increase. Besides these similar conclusions I have presented in the basic model open economy subsection, firms with very inefficient cost functions (large $\eta$ and small $\theta$) will choose to exit the world market when they realize that their revenues cannot cover their costs. When it is very inefficient for a firm to transform its R&D investment to productivity, the market share drops dramatically after exposure to trade, which will further discourage the firm to invest in R&D. Higher marginal cost and lower market share together may lead to a negative profit in the open economy, which makes this firm better exit the market.
2.3.3 A Numerical Example – Cont’d

I continue using the numerical example in the previous section to present how firms will change their R&D investment levels and profits and whether the least productive firms will choose to exit the market after exposure to trade given different pairs of cost functions. Like the previous example, the demand function for each country is $P = 10 - 3X_i$, $i = h, f$.

![Diagram](image)

Figure 2.8: 4-Firm Case: Optimal marginal costs ($c_i$) when $\eta_i = 2$, $\theta_{1(3)} + \theta_{2(4)} = 1.5$

Similar to the previous example, the base productivity levels of four firms are at the same level $\eta_1 = \eta_2 = \eta_3 = \eta_4 = 2$, and I want to check how different $\theta$’s (transformability from R&D investment to productivity) will affect the optimal R&D investment levels and different profits in both closed economy and open economy. In order to present the results on a 2-dimensional graph, I make $\theta_1 = \theta_3$ and let them increase from 0 to 1.5; at the same time, $\theta_2 = \theta_4$ and they decrease from 1.5 to 0. The sum of $\theta_1$ ($\theta_3$) and $\theta_2$ ($\theta_4$) is constant at 1.5. Fig.2.8 shows the optimal marginal costs of all firms in both closed and open economy; and Fig.2.9 presents the maximized profit levels. The dotted lines show the closed economy case and the solid lines show the open economy case. The blue lines indicate firm 2 and 4 (one in country $h$ and the other in country $f$) and the red lines indicate firm 1 and 3 (one in country $h$ and the other in country $f$). Subscripts 1, 2, 3, 4 indicate
firm 1 to firm 4 respectively, and superscripts C and O denote closed economy and open economy respectively. Each line can represent two firms in either closed economy or open economy due to the symmetry of firm 1 and 3 (and the symmetry of firm 2 and 4).

Figure 2.9: 4-Firm Case: Maximized profits ($\pi$) when $\eta_i = 2$, $\theta_{1(3)} + \theta_{2(4)} = 1.5$

In Fig.2.8, a firm with a higher $\theta$ will choose a higher R&D investment level and therefore a lower marginal cost in both closed economy and open economy. With a larger difference in $\theta$’s, the marginal costs for two types of firms diverge even more in the open economy compared with the closed economy. Both types of firms will reduce their marginal costs as long as their $\theta$’s do not differ too much after exposure to trade. The conclusion from Fig.2.8 is very similar to that from Fig.2.1: all four firms are very likely to improve their productivity (reduce the marginal costs) by investing more after exposure to trade and firms with higher ability to transform R&D investment into cost reduction will have an incentive to invest even more to reduce their marginal costs.

Fig.2.9 shows that firms with a higher $\theta$ will eventually earn higher profits in both closed economy and open economy. The post-trade profits of two types of firms drop much more due to the pro-competitive effect and the productivity improvement effect. In the open economy, the profits of firm 1 and 3 increase as $\theta_1 = \theta_3$ increases and $\theta_2 = \theta_4$ decreases, while the profits of firm
2 and 4 decline, which is similar to the 2-firm open economy case in the basic model.

Figure 2.10: 4-Firm Case: Output quantities for 2 types of firms when $\eta = 2$, $\theta_1(3) + \theta_2(4) = 1.5$

In order to show the drop-out effect in the open economy that the least productive firms may choose to exit the market, I change the choke price parameter $\alpha$ to 5 and keep all the other parameters the same. Individual firms’ output quantity choices can show that when the productivity difference of two types of firms gets too large ($(\theta_1 = \theta_3) < 0.125$ or $(\theta_1 = \theta_3) > 1.125$), the least productive firms (both firm 2 and firm 4 in this example) will be driven out of the market due to their inefficient ex-ante marginal cost functions. Fig.2.10 clearly describes this post-trade drop-out effect for the least productive firms. Compared to the basic model, this extended model includes more competing firms in both closed economy and open economy so the market competitiveness gets much tougher in the open economy, which makes the least productive firms more likely to exit the market.

2.4 Concluding Remarks

In this chapter both the basic model and the extended model demonstrate the relationship between trade and productivity. After exposure to trade, firms with better ability to transform
the R&D investment to productivity improvement or better base productivity level will choose to invest in the R&D much more and improve their productivity much more. At the same time firms with less efficient cost function may also choose to invest more in their R&D. Although both types of firms are very likely to improve their productivity, the ex-post productivity difference between these two types of firms will still be enlarged in the open economy.

In the open economy, firms with more efficient cost function will self select into exporting market and end up with a larger market share, while firms with a really inefficient cost function will choose to exit when their revenues cannot cover their costs. The total market output will be higher, leading a lower market price. The total profits of firms will decrease, and thus the social welfare will increase.

The post-trade aggregate productivity of the whole international market will increase due to two types of effects. First, individual firms will choose to improve their productivity by investing more in their R&D after exposure to trade. Second, firms with the least efficient cost function may choose to exit, which only leaves the high-productivity firms surviving and competing in the international market. This second effect will further enhance the first effect because these surviving firms will increase their productivity even more with fewer competitors in this international market.

The productivity difference of different types of firms will diverge even more in the open economy. The models (both basic and extended) in this chapter predict a much larger decrease in the total post-trade profits due to both the pro-competitive effect and the productivity improvement effect.
Chapter 3

Exporting, Licensing, FDI and Productivity Choice

Multinational firms have played a more and more important role in the world economy with both international trade and foreign direct investment being fast growing economic activities. Many developing countries have liberalized their economies to attract foreign direct investment (FDI) and licenses of foreign technology. On the other hand, firms also face the problem that how they should sell their products in a more liberalized world market. This is the mode choice for a firm. The mode choice means that a firm may choose one of the following ways to serve the foreign market: exporting, licensing, or foreign direct investment$^1$. A firm’s optimal mode choice not only affects the profits of itself and its competitors, but also has a large impact on the social welfare and technology improvement. The role that multinational firms play in the technological development has raised a lot of research interests and has been studied theoretically and empirically through both self-selection channel and learning by exporting channel to reveal the relationship between trade behaviors and productivity.

This chapter focuses on firms’ behaviors in the open economy. I develop a theoretical model that combines mode choice with productivity choice of multinational firms. In the open economy, firms can choose their R&D investment levels and thus productivity levels to maximize their combined profits from domestic and foreign markets. At the same time, mode choice between exporting, licensing and foreign direct investment (FDI) is also made. Foreign direct investment in this chapter refers to “horizontal” FDI which means that a firm acquires a subsidiary in a foreign

$^1$ FDI in this chapter indicates horizontal foreign direct investment.
country to produce a final product purchased directly by consumers.

The existing theoretical work on the mode choice and productivity choice favors two types of models. Monopolistic competition models which reveal the relationship between productivity and mode choice usually assume that different productivity levels are exogenously given (Helpman, Melitz and Yeaple 2004). Oligopolistic competition models which apply Cournot competition use knowledge capital or human capital to differentiate firms (Horstmann and Markusen 1987, Ethier and Markusen 1996) or allow firms to change R&D investment levels to determine their productivity (Saggi 1999, Ghosh and Saha 2008). These oligopolistic competition models usually focus on the competition in the country that has relatively lower productivity firms or has no human capital.

In this chapter, I introduce two heterogeneous firms (firm $H$ and firm $F$) located in different countries (country $h$ and country $f$). Firms are heterogeneous in their cost function efficiency parameters (R&D investment to cost reduction transformability $\theta$ and base marginal cost $\eta$) which influence the returns from the R&D investment to the reduction of marginal cost. Without loss of generality, I assume firm $H$ is the firm with a more efficient cost function (lower base marginal cost and/or higher transformability from R&D investment to cost reduction). The model is a three-stage game. In the first stage, firm $H$ which has a more efficient cost function makes its mode choice (exporting, licensing or FDI). Firm $F$ with a less efficient marginal cost function accepts firm $H$’s mode choice according to the assumptions in the model. Under the exporting choice, both firms choose to serve both markets (country $h$ and country $f$) and bear a symmetric variable trade cost when exporting. If firm $H$ prefers licensing, firm $F$ gets firm $H$’s technology and competes against firm $H$ in both markets$^2$. Neither firm $H$ nor firm $F$ is isolated from competition in either market (country $h$ or country $f$). Under the FDI choice, firm $H$ pays a fixed cost and acquires a subsidiary in country $f$ to avoid any other trade cost, while firm $F$ exports to country $h$ and still bears the variable trade cost. Then in the second stage, two firms determine their corresponding

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$^2$ I assume licensing cannot block any output competition in either country. It is trivial that both firms will get the highest profits and prefer licensing if I allow no-competition clause since both firms can have monopoly power within its own country. In addition, no-competition clause is not very credible assumption because among all three mode choices that a firm chooses to serve a foreign market, licensing is usually considered to give the licensor having the least control over the usage of its technology.
ex-post marginal costs by choosing their optimal R&D investment levels endogenously. In the last stage (third stage) two firms compete against each other by choosing their optimal output levels (Cournot duopoly competition) in both their domestic and foreign markets in the open economy.

With a productivity level (marginal cost) endogenously chosen by the firm, this model captures the relationship between productivity and mode choice in a more sophisticated way compared to most monopolistic competition literature. Different from most oligopolistic competition literature which only analyzes the effect of the mode choice on the host country, the model in this chapter is more realistic in considering the effect on the whole international market (both host country and source country). This chapter illustrates a model that combines the features from some existing monopolistic competition and oligopolistic competition literature that includes intra-industry trade, endogenously productivity choice and mode choice.

The model in this chapter emphasizes the joint determination of productivity and mode choice of firms in the open economy by allowing firms to choose their ex-post marginal cost (productivity) endogenously. The ex-ante difference between two firms is the difference in their cost functions. Firm $H$ has a more efficient cost function with a lower base marginal cost and/or higher transformability from R&D investment to reduction in marginal cost than firm $F$. If the ex-ante cost functions are similar for two firms, firm $H$ is more likely to prefer licensing and the ex-post productivity difference of two firms disappears because licensing will make both firms share the same ex-ante cost functions. With an intermediate ex-ante difference in cost functions of two firms, firm $H$ prefers exporting most when it makes the mode choice and the ex-post productivity difference determined by two firms’ productivity choices is enlarged compared with the ex-ante difference. When the ex-ante difference in cost functions of two firms gets large, firm $H$ is more likely to choose FDI and the ex-post productivity difference of two firms is even larger than that in the exporting mode. The interaction between productivity choice and mode choice studied in this chapter offers a more complete analysis of this relationship than most of the monopolistic competition literature.

This chapter studies a bilateral trade that allows firms to compete in both domestic and foreign markets. Firm $F$ with a less efficient cost function can still choose to export and its pro-
ductivity level under different mode choices that firm $H$ chooses. Under this assumption, different from most oligopolistic competition literature, firm $H$ has to consider a more complex competition effect caused by different mode choices because it cannot exclude competition in its domestic market. Firm $F$ always prefers licensing to the other two mode choices because licensing can offer this ex-ante less efficient firm a higher ex-post productivity level and a larger market share; however, licensing is not always firm $H$’s best mode choice since the choice of licensing creates a most challenging ex-post competitor for firm $H$ in both countries. The total industry profit from two countries for two firms is not always the highest under the licensing choice though I assume that firm $H$ can exact the entire extra profit that firm $F$ can earn as licensing fee in the model. This is due to the dramatic market price drop under this non-cooperative output competition game. By considering the competition in both domestic market and foreign market, firm $H$ may choose any of the modes under different circumstances.

The mode choice is not only interacted with the ex-post productivity choice but also affected by the relative market demand size. This chapter also includes a market size effect on productivity and mode choices of firms by holding the world market size constant and changing the relative size of two countries. Given the ex-ante cost efficiency difference is not too large or too small to dominate the mode choice, the firm with better ex-ante cost efficiency parameters (firm $H$) in a relatively smaller country (country $h$) will probably choose to license its technology to the other firm (firm $F$) located in a bigger market (country $f$). The extra profit that firm $F$ can earn under the licensing choice (endogenous licensing fee) is larger than firm $H$’s profit loss due to a larger trade cost saving effect for a larger market size of country $f$. With the relative market size of country $h$ increasing to an intermediate level, FDI has a larger chance to occur for two reasons combined together. First, country $f$’s market size is still large enough to make the variable exporting trade cost outweigh the fixed FDI cost so that the FDI choice is preferred to the exporting choice. Second, the trade cost saving effect of country $f$ decreases and the trade cost of exporting to country $h$ increases under the licensing choice, and hence licensing is no longer the optimal choice. As the relative market size of country $h$ continues increasing, firm $H$ is more likely to directly export to
the relative smaller market of country $f$ because it is no longer worth spending a fixed FDI cost to avoid the smaller amount of the variable trade cost.

The following section (section 3.1) studies the interaction between productivity choice and mode choice by holding the market demand sizes of two countries the same. The initial (ex-ante) difference in cost functions of two firms will end up with different productivity choices, different mode choices, and different welfare situations for two countries. The assumption of same market demand size is relaxed in section 3.2 so that relative market size of two countries is allowed to be different. I use one numerical example with different assumptions to separate the ex-ante efficiency effect by holding market sizes the same (section 3.1) from the market size effect by fixing the cost functions (section 3.2) on the productivity choice and mode choice. The last section (section 3.3) gives a brief conclusion of this chapter.

### 3.1 Ex-ante Efficiency Effect

#### 3.1.1 Model Set up

There are two countries $h$ and $f$ with the same domestic inverse demand function which is

$$P = \alpha - \beta X,$$  \hspace{1cm} (3.1)

where $P$ stands for the price of the good and $X$ for the quantity. In each country there is a monopoly firm. Firm $H$ is the domestic firm for Country $h$ and firm $F$ is the domestic firm for Country $f$. In order to maximize its profit, each firm chooses its R&D investment level first and then determines its marginal cost level by its given cost function. Firm $H$’s marginal cost function is

$$c_H = \eta_H - \theta_H I_H^{\frac{1}{2}},$$  \hspace{1cm} (3.2)

which captures the relationship between firm $H$’s marginal cost $c_H$ and its R&D investment level $I_H$ with both $\eta_H$ and $\theta_H$ positive. $\eta_H$ is the base marginal cost (productivity) of firm $H$ and $\theta_H$ indicates the R&D investment to productivity transformability. The cost function is more efficient
if it has a smaller $\eta_H$ and a larger $\theta_H$. With a higher R&D investment level, firm $H$’s ex-post marginal cost level is lower, which means the productivity level of the firm is higher. With more money invested in the R&D, the marginal cost is decreasing at a diminishing rate. Similarly, firm $F$’s marginal cost function is

$$c_F = \eta_F - \theta_F I_F^{1/2}. \tag{3.3}$$

In the open economy, firm $H$ and $F$ which sell homogeneous goods compete by choosing their optimal quantities (Cournot competition) in both country $h$ and country $f$. I assume firm $H$ has a more efficient cost function (smaller $\eta$ and larger $\theta$) compared with firm $F$ without loss of generality. There is a symmetric variable trade cost which equals $t$ if either firm chooses to export to the other country$^3$. Firm $F$ can pay a licensing fee ($L$) to firm $H$ to get the same marginal cost function as firm $H$ and thus choose its own marginal cost (productivity) which is going to be the same as firm $H$’s marginal cost in the equilibrium. Firm $H$ can choose to incur a fixed investment $D$ (horizontal FDI) in country $f$ so that it can sell goods to country $f$ directly without the variable trade cost. Suppose this fixed investment is large enough so that firm $F$ cannot afford the FDI cost due to its less efficient cost function.

There are three possible cases that might end up as an equilibrium.$^4$ First, both firms choose to export to the other country with no licensing or FDI. In this situation, both firms choose their optimal R&D investment levels interdependently and have different marginal cost levels. Second, firm $H$ chooses to do FDI to get rid of the variable trade cost while firm $F$ chooses to export. In this case, they also have different cost levels due to their different choices of R&D investment. Third, firm $H$ accepts the offer from firm $F$ and licenses its production technology (more efficient marginal cost function) to firm $F$. The licensing in this chapter does not block any competition so that both firms will compete in both markets (country $h$ and country $f$). After paying the licensing fee, firm $F$ gets the same marginal cost function from firm $H$. Hence both firms will choose the

---

$^3$ The total marginal cost for firm $H$ to export one unit of its goods to country $f$ is $c_H + t$.

$^4$ In the theoretical model, it is possible that more productive firm $H$ acquires less productive firm $F$ and becomes a monopolist in the world market (both country $h$ and country $f$). However, in real life there are usually either legal or political restrictions on M&A to exclude the possibility of this situation, so this potential equilibrium will not be considered in this model.
same R&D investment level and enjoy the same ex-post marginal cost.

In order to solve this model, I use a three-step backward induction process. In the first step, I derive the intra-industry allocation results including output quantities, market prices, profits and social welfare levels of two firms in two countries under all these three cases given marginal costs of two firms ($c_H$ and $c_F$). In the second step, I maximize the profits of two firms by choosing their corresponding optimal R&D investment levels and thus determine the marginal costs under different cases. In the third step, the mode choice of firm $H$ can be determined by comparing the profits of these three cases.

3.1.1.1 Case 1 (Exporting):

Both firms compete against each other by choosing their optimal R&D investment in country $h$ and $f$ separately. Firm $H$ has to incur a variable trade cost $t$ if it exports to country $f$, while firm $F$ has to incur the same amount of trade cost $t$ if it sells in country $h$. The model reduces to a two-stage game given the mode choice is given as exporting. Both firms need to choose their R&D investment levels and thus marginal costs first. Then they have to figure out their best response functions in the Cournot competition and hence determine their quantities, price and maximized profits.

By backward induction, suppose that both firms have decided their R&D investments and marginal costs, their profit-maximizing quantities, price, mark-ups and profits can be expressed as a function of their marginal costs as following. Superscript $E$ stands for the exporting mode choice, and subscripts $H$ and $F$ indicate firm $H$ and firm $F$, while subscripts $h$ and $f$ stand for country $h$ and $f$.

Quantities:

$$X^E_{Hh} = \frac{1}{3\beta} \left( \alpha - 2c^E_H + c^E_F + t \right),$$
$$X^E_{Hf} = \frac{1}{3\beta} \left( \alpha - 2c^E_H + c^E_F - 2t \right),$$
$$X^E_{Fh} = \frac{1}{3\beta} \left( \alpha - 2c^E_F + c^E_H - 2t \right),$$
\[ X_{Ef}^F = \frac{1}{3\beta} (\alpha - 2c_E^F + c_H^E + t) . \] (3.4)

Prices: (same in both countries)

\[ P_h^E = P_f^E = \frac{1}{3} (\alpha + c_H^E + c_F^E + t) . \] (3.5)

Profits:

\[ \pi_H^E = \frac{1}{9\beta} (\alpha - 2c_H^E + c_F^E + t)^2 + \frac{1}{9\beta} (\alpha - 2c_H^E + c_F^E + 2t)^2 - I_{EH}^E, \]
\[ \pi_F^E = \frac{1}{9\beta} (\alpha - 2c_F^E + c_H^E + t)^2 + \frac{1}{9\beta} (\alpha - 2c_F^E + c_H^E + 2t)^2 - I_{EF}^E. \] (3.6)

Welfare levels:

\[ w_h^E = \frac{1}{18\beta} (2\alpha - c_H^E - c_F^E - t)^2 + \frac{1}{9\beta} (\alpha - 2c_H^E + c_F^E + t)^2 + \frac{1}{9\beta} (\alpha - 2c_H^E + c_F^E + 2t)^2 - I_{EH}^E, \]
\[ w_f^E = \frac{1}{18\beta} (2\alpha - c_F^E - c_H^E - t)^2 + \frac{1}{9\beta} (\alpha - 2c_F^E + c_H^E + t)^2 + \frac{1}{9\beta} (\alpha - 2c_F^E + c_H^E + 2t)^2 - I_{EF}^E. \] (3.7)

In order to maximize the profit, it is easy to determine the optimal R&D investment levels and also calculate the marginal costs according to the cost functions.

\[ I_{EH}^E = \frac{4\theta_H \left[ (9\beta - 12\theta_F^2) \alpha - (18\beta - 12\theta_F^2) \eta_H + 9\beta \eta_F - (4.5\beta - 6\theta_F^2)t \right]}{(9\beta - 8\theta_F^2) (9\beta - 8\theta_H^2) - 16\theta_H^2 \theta_F^2} \] \[ I_{EF}^E = \frac{4\theta_F \left[ (9\beta - 12\theta_H^2) \alpha - (18\beta - 12\theta_H^2) \eta_F + 9\beta \eta_H - (4.5\beta - 6\theta_H^2)t \right]}{(9\beta - 8\theta_H^2) (9\beta - 8\theta_F^2) - 16\theta_H^2 \theta_F^2} \] (3.8)

And marginal costs are

\[ c_H^E = \eta_H - \theta_H \sqrt{I_{EH}^E}, \]
\[ c_F^E = \eta_F - \theta_F \sqrt{I_{EF}^E}. \] (3.9)

\textbf{3.1.1.2 Case 2 (FDI):}

Firm $H$ chooses to do FDI by itself. It incurs a fixed exogenous FDI cost $D$ and sets up a subsidiary in country $f$. In this case, firm $H$ does not have the variable trade cost when it sells goods in country $f$. Since I assume that this fixed FDI cost is too large for less productive firm $F$ to afford, firm $F$ can only export to country $h$. The intra-industry allocation results for this
FDI case are shown below with superscript $M$ standing for the existence of the multinational firm. Letter $D$ stands for the fixed FDI cost.

Quantities:

\[
X_{Hh}^M = \frac{1}{3\beta} \left( \alpha - 2c_H^M + c_F^M + t \right),
\]
\[
X_{Hf}^M = \frac{1}{3\beta} \left( \alpha - 2c_H^M + c_F^M \right),
\]
\[
X_{Fh}^M = \frac{1}{3\beta} \left( \alpha - 2c_F^M + c_H^M - 2t \right),
\]
\[
X_{Ff}^M = \frac{1}{3\beta} \left( \alpha - 2c_F^M + c_H^M \right). \tag{3.10}
\]

Prices:

\[
P_{Hh}^M = \frac{1}{3} \left( \alpha + c_H^M + c_F^M + t \right),
\]
\[
P_{Ff}^M = \frac{1}{3} \left( \alpha + c_H^M + c_F^M \right). \tag{3.11}
\]

Profits:

\[
\pi_H^M = \frac{1}{9\beta} \left( \alpha - 2c_H^M + c_F^M + t \right)^2 + \frac{1}{9\beta} \left( \alpha - 2c_H^M + c_F^M \right)^2 - I_H^M - D,
\]
\[
\pi_F^M = \frac{1}{9\beta} \left( \alpha - 2c_F^M + c_H^M \right)^2 + \frac{1}{9\beta} \left( \alpha - 2c_F^M + c_H^M - 2t \right)^2 - I_F^M. \tag{3.12}
\]

Welfare levels:

\[
w_h^M = \frac{1}{18\beta} \left( 2\alpha - c_H^M - c_F^M - t \right)^2 + \frac{1}{9\beta} \left( \alpha - 2c_H^M + c_F^M + t \right)^2 + \frac{1}{9\beta} \left( \alpha - 2c_H^M + c_F^M \right)^2 - I_H^M - D,
\]
\[
w_f^M = \frac{1}{18\beta} \left( 2\alpha - c_H^M - c_F^M \right)^2 + \frac{1}{9\beta} \left( \alpha - 2c_F^M + c_H^M \right)^2 + \frac{1}{9\beta} \left( \alpha - 2c_F^M + c_H^M - 2t \right)^2 - I_F^M. \tag{3.13}
\]

The optimal R&D investment levels will be

\[
I_H^M = \left\{ \frac{4\theta_H \left[ (9\beta - 12\theta_H^2) \alpha - (18\beta - 12\theta_H^2) \eta_H + 9\beta \eta_F + 4.5\beta t \right]}{(9\beta - 8\theta_H^2) (9\beta - 8\theta_H^2 - 16\theta_H^2 \theta_F^2)} \right\}^2,
\]
\[
I_F^M = \left\{ \frac{4\theta_F \left[ (9\beta - 12\theta_H^2) \alpha - (18\beta - 12\theta_H^2) \eta_F + 9\beta \eta_H - (9\beta - 6\theta_H^2) t \right]}{(9\beta - 8\theta_F^2) (9\beta - 8\theta_H^2) - 16\theta_H^2 \theta_F^2} \right\}^2. \tag{3.14}
\]

And marginal cost levels are

\[
c_H^M = \eta_H - \theta_H \sqrt{I_H^M},
\]
\[
c_F^M = \eta_F - \theta_F \sqrt{I_F^M}. \tag{3.15}
\]
3.1.1.3 Case 3 (Licensing):

There are four assumptions in this model related with the licensing mode choice that needs to be stated. I have already mentioned the first assumption that firm $H$ is the firm with a more efficient cost function without loss of generality, which means that firm $H$ has a smaller $\eta$ and a larger $\theta$. If there is the optimal mode choice is licensing, firm $H$ should be the licensor that licenses its production technology (more efficient cost function) to firm $F$ which is the licensee.

The second assumption of the licensing case in this model is that firm $H$ licenses its more efficient cost function to firm $F$ and firm $F$ can determine how to make use of this production technology by choosing its optimal R&D investment level. With this assumption, firm $F$ will naturally choose the same R&D investment as firm $H$ ($I^O_H = I^O_F$)\(^5\) so that the marginal cost (productivity level) of these two firms under the licensing case is the same which is $c^O_H = \eta_H - \theta_H \sqrt{I^O_H} = c^O_F$. This second assumption tries to capture the fact that less productive firm can learn the production technology by paying a licensing fee and getting a license from more productive firm, but it still needs to choose how to utilize the more efficient production technology by choosing how much effort it is willing to make. The effort making choice of the licensee (firm $F$) in this model is to decide its own R&D investment level according to the more efficient cost function.

Moreover, the third assumption lets firm $H$ have all the bargaining power to determine the licensing fee.\(^6\) Under this assumption, firm $H$ will choose such a licensing fee $L$ that firm $F$ will gain exactly zero extra profit from the licensing compared to its second best choice. If the exporting profit is greater than the FDI profit for firm $H$, the licensing fee will be the entire extra profit firm $F$ can earn under this case compared with the profit in the exporting case which can be expressed by $L = \pi^{BO}_F - \pi^E_F$. However, if the FDI profit is greater than the exporting profit for firm $H$, firm $H$ will charge the extra profit of firm $F$ compared with the profit in the FDI case ($L = \pi^{BO}_F - \pi^M_F$). Superscript $O$ stands for the licensing case and $B$ indicates before licensing fee paid. The licensing case will happen only when firm $H$ can get the highest profit among all three cases.

---

\(^5\) Letter $O$ stands for the licensing (international outsourcing) case in this chapter.

\(^6\) If I relax the licensing fee bargaining power assumption which can allow firm $F$ does not completely give away its extra profit gain, this will not change the mode choice decision qualitatively as long as the licensing fee is not zero.
The fourth assumption is that the licensing mode choice cannot block any output competition, which means that firm $H$ cannot set up a pre-licensing contract with firm $F$ to exclude the possibility of firm $F$ using its production technology to compete against it in either country $h$ or country $f$. This assumption is realistic and to some extent can capture the fact that the parent firm usually has the least control of the technology spill-over under the licensing case among all three mode choices.

If the licensing case turns out to be the equilibrium in the open economy, both firms will enjoy the same marginal cost (productivity) level by choosing the same R&D investment according to the second assumption. The equilibrium will be the same as the symmetric situation under the exporting case. I calculate the prices, outputs, profits before licensing fee is paid by using results derived from the exporting case.

Quantities:

$$X^O_{Hh} = \frac{1}{3\beta} \left( \alpha - c^O_H + t \right),$$
$$X^O_{Hf} = \frac{1}{3\beta} \left( \alpha - c^O_H - 2t \right),$$
$$X^O_{Fh} = \frac{1}{3\beta} \left( \alpha - c^O_H - 2t \right),$$
$$X^O_{Ff} = \frac{1}{3\beta} \left( \alpha - c^O_H + t \right).$$

(3.16)

Prices: (same in both countries)

$$P^O_h = P^O_f = \frac{1}{3} \left( \alpha + 2c^O_H + t \right).$$

(3.17)

Profits: (before licensing fee paid)

$$\pi^BO_H = \frac{1}{9\beta} \left( \alpha - c^O_H + t \right)^2 + \frac{1}{9\beta} \left( \alpha - c^O_H - 2t \right)^2 - I^O_H,$$
$$\pi^BO_F = \frac{1}{9\beta} \left( \alpha - c^O_H + t \right)^2 + \frac{1}{9\beta} \left( \alpha - c^O_H - 2t \right)^2 - I^O_H.$$

(3.18)

Licensing fee will be all the extra profit that firm $F$ can gain through this licensing transaction according to the third assumption, which is

$$L = \pi^BO_F - \pi^E_F, \text{ if } \pi^E_F \geq \pi^M_F;$$
$$L = \pi^BO_F - \pi^M_F, \text{ if } \pi^E_F < \pi^M_F.$$

(3.19)
After the licensing fee is determined, the profits of two firms after licensing fee paid and welfare levels of two countries can be expressed as following.

Profits: (after licensing fee paid)

\[
\pi_H^O = \frac{1}{9\beta} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta} (\alpha - c_H^O - 2t)^2 - I_H^O + L, \\
\pi_F^O = \frac{1}{9\beta} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta} (\alpha - c_H^O - 2t)^2 - I_H^O - L. \tag{3.20}
\]

Welfare levels:

\[
w_H^O = \frac{1}{18\beta} (2\alpha - 2c_H^O - t)^2 + \frac{1}{9\beta} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta} (\alpha - c_H^O - 2t)^2 - I_H^O + L, \\
w_F^O = \frac{1}{18\beta} (2\alpha - 2c_H^O - t)^2 + \frac{1}{9\beta} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta} (\alpha - c_H^O - 2t)^2 - I_H^O - L. \tag{3.21}
\]

The optimal R&D investment (same for both firms) is

\[
I_H^O = I_F^O = \left\{\frac{\theta_H (\alpha - \eta_H - 0.5t)}{\frac{9}{4} \beta - \theta_H^2} \right\}^2, \tag{3.22}
\]
with the marginal cost level

\[
c_H^O = \eta_H - \theta_H \sqrt{I_H^O} = c_F^O. \tag{3.23}
\]

### 3.1.2 Mode Choice Decision

I have assumed that FDI fixed cost \((D)\) is high enough to exclude firm \(F\) to choose FDI as its best choice in the FDI case. Whether firm \(F\) will end up in the exporting case or the firm \(H\) FDI case is actually completely determined by firm \(H\). Due to the third assumption in the licensing case, firm \(H\) will choose a licensing fee which will make firm \(F\) feel indifferent between licensing and its second best choice (either exporting case or firm \(H\) FDI case). This model simplifies the mode choice decision to firm \(H\)’s profit maximization choice. In order to see how firm \(H\) will make its decision, I just need to compare the profits of firm \(H\) that are yielded by these three cases.

Exporting case:

\[
\pi_H^E = \frac{1}{9\beta} \left( \alpha - 2\eta_H + \eta_F + t + 2\theta_H \sqrt{I_H^E} - \theta_F \sqrt{I_F^E} \right)^2, \\
\quad + \frac{1}{9\beta} \left( \alpha - 2\eta_H + \eta_F - 2t + 2\theta_H \sqrt{I_H^E} - \theta_F \sqrt{I_F^E} \right)^2 - I_H^E.
\]
\[ I^E_H = \left\{ \frac{4\theta_H \left[ (9\beta - 12\theta_F^2) \alpha - (18\beta - 12\theta_F^2) \eta_H + 9\beta \eta_F - (4.5\beta - 6\theta_F^2) t \right]}{(9\beta - 8\theta_F^2) (9\beta - 8\theta_H^2) - 16\theta_H^2 \theta_F^2} \right\}^2, \]

\[ I^E_F = \left\{ \frac{4\theta_F \left[ (9\beta - 12\theta_H^2) \alpha - (18\beta - 12\theta_H^2) \eta_F + 9\beta \eta_H - (4.5\beta - 6\theta_H^2) t \right]}{(9\beta - 8\theta_F^2) (9\beta - 8\theta_H^2) - 16\theta_H^2 \theta_F^2} \right\}^2. \]  

(3.24)

FDI case:

\[ \pi^M_H = \frac{1}{9\beta} \left( \alpha - 2\eta_H + \eta_F + t + 2\theta_H \sqrt{I^M_H - \theta_F \sqrt{I^M_F}} \right)^2 \]

\[ + \frac{1}{9\beta} \left( \alpha - 2\eta_H + \eta_F + 2\theta_H \sqrt{I^M_H - \theta_F \sqrt{I^M_F}} \right)^2 - I^M_H - D, \]

\[ I^M_H = \left\{ \frac{4\theta_H \left[ (9\beta - 12\theta_F^2) \alpha - (18\beta - 12\theta_F^2) \eta_H + 9\beta \eta_F + 4.5\beta t \right]}{(9\beta - 8\theta_F^2) (9\beta - 8\theta_H^2) - 16\theta_H^2 \theta_F^2} \right\}^2, \]

\[ I^M_F = \left\{ \frac{4\theta_F \left[ (9\beta - 12\theta_H^2) \alpha - (18\beta - 12\theta_H^2) \eta_F + 9\beta \eta_H - (4.5\beta - 6\theta_H^2) t \right]}{(9\beta - 8\theta_F^2) (9\beta - 8\theta_H^2) - 16\theta_H^2 \theta_F^2} \right\}^2. \]  

(3.25)

Licensing case:

\[ \pi^O_H = \frac{1}{9\beta} \left( \alpha - \eta_H + t + \theta_H \sqrt{I^O_H} \right)^2 \]

\[ + \frac{1}{9\beta} \left( \alpha - \eta_H + 2t + \theta_H \sqrt{I^O_H} \right)^2 - I^O_H - L \]

\[ I^O_H = I^O_F = \left\{ \frac{\theta_H (\alpha - \eta_H - 0.5t)}{9\beta - \theta_H^2} \right\}^2. \]  

(3.26)

Given firm F’s cost function efficiency parameters \( \eta_F \) and \( \theta_F \), the mode choice of firm H can be expressed as following.

First, given firm H’s base marginal cost \( \eta_H \), with an increase in firm H’s R&D investment to productivity transformability \( \theta_H \), licensing is the optimal mode choice when \( \theta_H \) is relatively small; exporting mode choice is the best when \( \theta_H \) is getting bigger to a medium level; and FDI choice will dominate both licensing and exporting when \( \theta_H \) is relatively large.

Second, given firm H’s R&D investment to productivity transformability \( \theta_H \), with a decrease in firm H’s base marginal cost \( \eta_H \), the optimal mode choice is licensing when \( \eta_H \) is relatively large; when \( \eta_H \) decreases to a medium level, the best mode choice is exporting; and FDI choice will dominate both licensing and exporting when \( \eta_H \) is relatively small.

Licensing turns out to have the largest profit when the difference between two firms’ ex-ante cost function efficiency parameters is small and the variable trade cost is high. When the ex-ante
cost functions' difference is small, the extra market share that firm \( H \) can gain will yield a smaller increase in profit than the licensing fee. Firm \( H \) will choose licensing when it only has a small advantage in its ex-ante cost function. In addition, a high variable trade cost can encourage firm \( H \) to choose licensing instead of exporting because firm \( H \) has a small trade volume under the licensing choice than that under the exporting choice.

Exporting will be the dominant strategy for firm \( H \) when the variable trade cost is low and the cost function difference between two firms is in the medium range. If the ex-post productivity level that firm \( H \) chooses is high enough for it to enjoy a larger market share so that the profit increase due to the productivity advantage is greater than the licensing fee that firm \( F \) can afford, exporting will yield a higher profit than licensing. Accompanied with the low variable trade cost, there is very little incentive for firm \( H \) to do FDI. Exporting will be the best choice for firm \( H \).

FDI will be the optimal choice when the variable trade cost is high, the FDI cost is low and the cost function difference between these two firms is large. When the large difference of ex-ante cost function leads to an even larger ex-post productivity difference, it is easy for firm \( H \) to have a large enough market share so that the trade cost caused by exporting will be greater than a fixed FDI cost and therefore firm \( H \) will choose FDI. Higher trade cost and lower FDI cost will also make it easier for the variable trade cost (under the exporting choice) to outweigh the FDI cost (under the FDI choice).

Although firm \( H \) can successfully grab the entire extra profit that firm \( F \) can earn under the licensing choice, licensing is still not always the optimal choice for firm \( H \). There are a few reasons for this phenomenon. First, Licensing does make the marginal cost of firm \( F \) (ex-ante less efficient firm) lower, but it reduces the incentive of firm \( H \) (ex-ante more efficient firm) to further decrease its marginal cost by increasing R&D investment because firm \( H \) does not need to compete against firm \( F \) in order to win a larger market share. Second, a smaller market share and a higher marginal cost for firm \( H \) will make its before-licensing-fee profit lower compared to the exporting and FDI choices. Last but not least, firm \( F \) becomes a more challenging competitor after it gets licensed with a more efficient cost function in both country \( h \) and country \( f \), which will lower the market
price and enlarge the market output for both countries. Firm $F$’s before-licensing-fee profit will increase due to its productivity increase under the licensing choice, however, this increase could be smaller than firm $H$’s before-licensing fee profit decrease due to higher marginal cost, lower market share and much lower market price for firm $H$ especially when the ex-ante cost function difference between firm $H$ and firm $F$ gets large enough. Whenever the extra profit firm $F$ can gain from licensing cannot make up the profit loss of firm $H$, firm $H$ will search for the other two choices - either exporting or FDI as its optimal mode choice.

### 3.1.3 Welfare Analysis

The incentive for firm $H$ to conduct R&D investment is largest under the FDI choice because it needs to compete against firm $F$ to win a larger market share and zero variable trade cost with a FDI facility enhances its advantage in this competition. The R&D investment of firm $H$ in the licensing case is the lowest among these three mode choices since firm $H$ does not have the competition mechanism to gain a larger market share by reducing its marginal cost.

The results are quite different for market prices and market outputs because the market prices in both counties are determined by the average marginal costs (average productivity levels) of the two firms. Although firm $H$ chooses the highest productivity (lowest marginal cost) under the FDI case, the market prices are still the highest due to a low productivity firm $F$ chooses. The market price is lowest under the licensing case because higher productivity for firm $F$ encourages both firms to produce more in the Cournot competition. According to the linear demand function that is assumed in the model, the market output has an inverse relationship with the market price, which is the smallest under the FDI case and the largest under the licensing case.

Due to a low price (high output) under the licensing case, consumer surplus is the largest. So are the profits if firm $H$ chooses licensing as the optimal mode choice. The total welfare is largest under the licensing case. When there is a shift from licensing choice to exporting or FDI choice, the profits should be the same at the shifting point for both firms; however consumer surplus will have a large decrease because the market price goes higher and the market output decreases with
the mode choice change. The same type of welfare change will also happen if there is a shift from exporting choice to FDI choice but in a smaller magnitude.\footnote{The model in this chapter is a static model which only considers the current period welfare, the welfare is the highest under the licensing mode choice in the current period. However, the R&D investment level and therefore the productivity level of firm $H$ is the lowest under the licensing mode choice. If the model can be extended to a dynamic one including multiple periods, there should be a trade-off between the current period welfare and the long-run productivity.}

### 3.1.4 A Numerical Example

Considering that the R&D investment level and firm $H$’s profit are affected by many parameters in the open economy such as the market demand parameters $(\alpha, \beta)$, the parameters of firm $H$’s cost function $(\eta_H, \theta_H)$ and the parameters of firm $F$’s cost function $(\eta_F, \theta_F)$, a numerical example is helpful for us to see how these parameters will affect the equilibrium decision and the welfare levels of the two countries.

In this example, the market inverse demand function for both countries is $P = 15 - 2X_i$, $i = h, f$. I set the cost function of firm $F$ to be $c_F = 6 - 0.1I_F^{\frac{1}{2}}$ and also fix the base productivity level of firm $H$ to be 1 ($\eta_H = 1$). This example can check how different $\theta_H$ (transformability from R&D investment to productivity of firm $H$) will affect the exporting, licensing and FDI decision in the open economy. $\theta_H$ increases from 0.1 to 0.45. The variable trade cost $t$ is 0.3, and the FDI cost $D$ is 1.35. This FDI cost is set to be high enough so that firm $F$ will never choose to FDI in country $h$.

In all the figures in this chapter, red (solid) line indicates the exporting case (case 1), the black (long dashed) line shows the FDI case (case 2) and blue (dashed) line indicates the licensing case (case 3). These figures start from the equilibrium mode choice decision of firm $H$. After the optimal mode choice is determined, the rest of the graphs show the optimal R&D investment levels, market prices and welfare levels.

Fig.3.1 shows the exporting, licensing and FDI decision (the mode choice) made by firm $H$. Given the variable trade cost and FDI cost in this specific numerical example, when firm $H$ has a relatively smaller advantage in its R&D investment to productivity transformability (smaller
Figure 3.1: Ex-ante Efficiency effect: Exporting, Licensing and FDI choice

difference between $\theta_H$ and $\theta_F$), it will choose to license its more efficient cost function to firm $F$ because the fixed licensing fee income will benefit firm $H$ more than a small increase in the market share with its small advantage in its ex-ante cost function. When firm $H$ has a relatively larger advantage in the cost function efficiency parameter $\theta_H$, licensing choice will be dominated by either exporting or FDI because the licensing fee can no longer cover the profit loss of firm $H$ due to the market share decrease, marginal cost increase and market price decrease under the licensing case. When firm $H$ is very efficient in transforming R&D investment to productivity, it will choose to conduct foreign direct investment because it can gain a large foreign market share and hence forgoing a fixed FDI cost can make it get rid of the high variable trade cost. Firm $H$ will just choose to export to country $F$ when R&D investment to productivity transformability is at the medium level, which means that larger the market share, higher the market price and lower the marginal cost together is better than the fixed licensing fee while the foreign market share is not large enough for the variable trade cost to outweigh the fixed FDI cost.

The following two figures (Fig.3.2 and Fig.3.3) present the R&D investment choices for two firms under different optimal mode choices. FDI case is associated with the highest R&D investment
Figure 3.2: Ex-ante Efficiency effect: R&D investment of firm $H$

Figure 3.3: Ex-ante Efficiency effect: R&D investment of firm $F$
choice for firm $H$ while the licensing case relates to the lowest investment choice for firm $H$, which is just the opposite to the choices of firm $F$. Firm $F$’s R&D investment, which is the same as firm $H$’s under the licensing choice, is much larger than the R&D investment under the other two mode choices. Fig.3.3 only has two segments for exporting and FDI for firm $F$ in order to graph a more clear trend of these two mode choices. In Fig.3.2, there are two jumps - both happen when there is a mode choice shift. The first jump happens when firm $H$ shifts from licensing to exporting, accompanied by a cost function change of firm $F$. Licensing actually discourages firm $H$ to reduce its marginal cost compared to exporting or FDI because there is no such competition mechanism for firm $H$ to invest more R&D in order to win a larger market share. The second jump shows up when firm $H$ starts to choose FDI instead of exporting. The magnitude of this jump is much smaller than that of the previous one since the competition mechanism to win a larger market share is the same for both exporting and FDI cases. The elimination of the variable trade cost for firm $H$ due to FDI enhances the easiness for firm $H$ to win a larger market share in country $f$ and therefore induces this upward R&D investment jump.

Fig.3.4 and Fig.3.5 show the market prices in each country. In this model, prices are the same for both countries under the licensing and exporting choices. And consumers in country $f$ enjoy a lower market price than those in country $h$ under the FDI choice because the elimination of the variable trade cost only happens in country $f$ when firm $H$ sells its product in country $f$. The market price is the highest under the exporting case and the lowest under the licensing case for both countries. The price jump caused by the shift from licensing choice to exporting choice is large in magnitude for both countries because the increase in the productivity level (decrease in the marginal cost) of firm $F$ under the licensing choice enhances the competitiveness in this duopoly market, enlarges the total market output and thus reduces the market price a lot. The jump between exporting and FDI choices is relatively smaller with an even less obvious change in country $h$ because the price decrease under FDI choice is mainly caused by the higher productivity choice of firm $H$ and FDI can only happen in country $f$ by firm $H$ so that consumers in country $f$ benefit more with a larger price decrease and a larger market output increase.
Figure 3.4: Ex-ante Efficiency effect: Market price in country $h$

Figure 3.5: Ex-ante Efficiency effect: Market price in country $f$
Figure 3.6: Ex-ante Efficiency effect: Welfare in country $h$

Figure 3.7: Ex-ante Efficiency effect: Welfare in country $f$
Fig.3.6 and Fig.3.7 show the welfare levels under the optimal mode choice determined by firm $H$. Similar to the previous figures, there are also two jumps of welfare levels in both countries showing up at the mode choice shifting points. The first large welfare decrease is from the licensing choice to the exporting choice. Welfare is the highest for both countries under the licensing choice because the lower price and the higher output largely increase the consumer surplus. At this first mode choice shifting point, the profits generated under the licensing choice and exporting choice are the same, so the decrease in total welfare is completely caused by the loss in the consumer surplus due to an increase in market price (a decrease in market output) shown by Fig.3.4 and Fig.3.5. Welfare increases when there is a shift from exporting choice to FDI choice for both country $h$ and country $f$, and the welfare increase for country $h$ from this mode choice change is very small. At the mode choice shifting point, again there is no profit change for either firm $H$ or firm $F$. Consumers in country $h$ still have to bear the variable trade cost so that their consumer surplus gain is small which is purely caused by a higher productivity choice of firm $H$. Welfare has a more obvious increase from this second mode choice change for country $f$ because besides a higher productivity choice of firm $H$, the consumers no longer need to pay any variable trade cost in country $f$.

3.2 Market Size Effect

3.2.1 Model Set up

In this section, I release the symmetric demand assumption to allow two countries $h$ and $f$ to have different domestic inverse demand functions which are

$$P_i = \alpha - \beta_i X_i, \ i = h, f,$$

(3.27)

where $P_i$ stands for the price of the good in country $i$ and $X_i$ for the market quantity of country $i$. The consumers of both countries have the same choke price for the good which is $\alpha$. At the same price, the price elasticities of demand for both demand curves are also the same. Different $\beta$ indicates different market demand size (no. of consumers). A smaller $\beta$ is associated with a larger
market demand size.

In the open economy, the optimal R&D investment levels, marginal costs, market outputs, prices, profits and welfare levels under different mode choices will have the following results. The notations have the same meanings as those in the previous section.

### 3.2.1.1 Case 1 (Exporting):

R&D investments:

\[
I_H^E = \left\{ \frac{4\theta_H \left( (4.5B - 3\theta_F^2) \alpha - (9B - 3\theta_F^2) \eta_H + 4.5B\eta_F - (4.5B(2\beta_h - \beta_f) - 3\theta_F^2)2\beta_h)\eta/(\beta_f + \beta_h) \right)}{(9B - 4\theta_F^2) (9B - 4\theta_H^2) - 4\theta_H^2 \theta_F^2} \right\}^2,
\]

\[
I_F^E = \left\{ \frac{4\theta_F \left( (4.5B - 3\theta_H^2) \alpha - (9B - 3\theta_H^2) \eta_F + 4.5B\eta_H - (4.5B(2\beta_f - \beta_h) - 3\theta_H^2)2\beta_f)\eta/(\beta_f + \beta_h) \right)}{(9B - 4\theta_F^2) (9B - 4\theta_H^2) - 4\theta_H^2 \theta_F^2} \right\}^2,
\]

(3.28)

where:

\[
B = \frac{\beta_h \beta_f}{\beta_h + \beta_f}.
\]

Marginal costs:

\[
c_H^E = \eta_H - \theta_H \sqrt{I_H^E},
\]

\[
c_F^E = \eta_F - \theta_F \sqrt{I_F^E}.
\]

(3.29)

Quantities:

\[
X_{HH}^E = \frac{1}{3\beta_h} \left( \alpha - 2c_H^E + c_F^E + t \right),
\]

\[
X_{HF}^E = \frac{1}{3\beta_f} \left( \alpha - 2c_F^E + c_H^E - 2t \right),
\]

\[
X_{FH}^E = \frac{1}{3\beta_h} \left( \alpha - 2c_F^E + c_H^E - 2t \right),
\]

\[
X_{FF}^E = \frac{1}{3\beta_f} \left( \alpha - 2c_F^E + c_H^E + t \right).
\]

(3.30)

Prices: (same in both countries)

\[
P_h^E = P_f^E = \frac{1}{3} \left( \alpha + c_H^E + c_F^E + t \right).
\]

(3.31)
Profits:

\[ \pi^E_H = \frac{1}{9\beta_h} (\alpha - 2c^E_H + c^E_F + t)^2 + \frac{1}{9\beta_f} (\alpha - 2c^E_H + c^E_F - 2t)^2 - I^E_H, \]

\[ \pi^E_F = \frac{1}{9\beta_f} (\alpha - 2c^E_H + c^E_F + t)^2 + \frac{1}{9\beta_h} (\alpha - 2c^E_H + c^E_F - 2t)^2 - I^E_F. \]  

(3.32)

Welfare levels:

\[ w^E_h = \frac{1}{18\beta_h} (2\alpha - c^E_H - c^E_F - t)^2 + \frac{1}{9\beta_h} (\alpha - 2c^E_H + c^E_F + t)^2 + \frac{1}{9\beta_f} (\alpha - 2c^E_H + c^E_F - 2t)^2 - I^E_H, \]

\[ w^E_f = \frac{1}{18\beta_f} (2\alpha - c^E_H - c^E_F - t)^2 + \frac{1}{9\beta_f} (\alpha - 2c^E_H + c^E_F + t)^2 + \frac{1}{9\beta_h} (\alpha - 2c^E_H + c^E_F - 2t)^2 - I^E_F. \]  

(3.33)

3.2.1.2 Case 2 (FDI):

R&D investments:

\[ I^M_H = \left\{ \frac{4\theta_H \left[ (4.5B - 3\theta_F^2) \alpha - (9B - 3\theta_F^2) \eta_H + 4.5B\eta_F + (4.5B/\beta_h - 2\theta_F^2/\beta_h + 2\theta_F^2/\beta_f)Bt \right]}{(9B - 4\theta_F^2) (9B - 4\theta_F^2) - 4\theta^2_H \theta^2_F} \right\}^2, \]

\[ I^M_F = \left\{ \frac{4\theta_F \left[ (4.5B - 3\theta_H^2) \alpha - (9B - 3\theta_H^2) \eta_F + 4.5B\eta_H - (9B/\beta_f - 4\theta_H^2/\beta_f + \theta_H^2/\beta_h)Bt \right]}{(9B - 4\theta_H^2) (9B - 4\theta_H^2) - 4\theta^2_H \theta^2_F} \right\}^2, \]  

(3.34)

where:

\[ B = \frac{\beta_h \beta_f}{\beta_h + \beta_f}. \]

Marginal costs:

\[ c^M_H = \eta_H - \theta_H \sqrt{I^M_H}, \]

\[ c^M_F = \eta_F - \theta_F \sqrt{I^M_F}. \]  

(3.35)

Quantities:

\[ X^M_{He} = \frac{1}{3\beta_h} (\alpha - 2c^M_H + c^M_F + t), \]

\[ X^M_{Fe} = \frac{1}{3\beta_f} (\alpha - 2c^M_H + c^M_F), \]
\[ X^M_{p_h} = \frac{1}{3\beta_h} \left( \alpha - 2c^M_F + c^M_H - 2t \right), \]
\[ X^M_{p_f} = \frac{1}{3\beta_f} \left( \alpha - 2c^M_F + c^M_H \right). \]  \hfill (3.36)

Prices:
\[ P^M_h = \frac{1}{3} \left( \alpha + c^M_H + c^M_F + t \right), \]
\[ P^M_f = \frac{1}{3} \left( \alpha + c^M_H + c^M_F \right). \]  \hfill (3.37)

Profits:
\[ \pi^M_H = \frac{1}{9\beta_h} \left( \alpha - 2c^M_H + c^M_F + t \right)^2 + \frac{1}{9\beta_f} \left( \alpha - 2c^M_H + c^M_F \right)^2 - I^M_H - D, \]
\[ \pi^M_F = \frac{1}{9\beta_f} \left( \alpha - 2c^M_F + c^M_H \right)^2 + \frac{1}{9\beta_f} \left( \alpha - 2c^M_F + c^M_H - 2t \right)^2 - I^M_F. \]  \hfill (3.38)

Welfare levels:
\[ w^M_h = \frac{1}{18\beta_h} \left( 2\alpha - c^M_H - c^M_F - t \right)^2 + \frac{1}{9\beta_h} \left( \alpha - 2c^M_H + c^M_F + t \right)^2 + \frac{1}{9\beta_f} \left( \alpha - 2c^M_H + c^M_F \right)^2 - I^M_H - D, \]
\[ w^M_f = \frac{1}{18\beta_f} \left( 2\alpha - c^M_H - c^M_F \right)^2 + \frac{1}{9\beta_f} \left( \alpha - 2c^M_F + c^M_H \right)^2 + \frac{1}{9\beta_h} \left( \alpha - 2c^M_F + c^M_H - 2t \right)^2 - I^M_F. \]  \hfill (3.39)

### 3.2.1.3 Case 3 (Licensing):

R&D investments:
\[ I^O_H = I^O_F = \left( \frac{\theta_H \left( \alpha - \eta_H - \left( \frac{2}{\beta_f} - \frac{1}{\beta_h} \right)Bt \right)}{\frac{9}{2}B - \theta^2_H} \right)^2, \]  \hfill (4.40)

where:
\[ B = \frac{\beta_h \beta_f}{\beta_h + \beta_f}. \]

Marginal costs:
\[ c^O_H = \eta_H - \theta_H \sqrt{I^O_H} = c^O_F. \]  \hfill (4.41)

Quantities:
\[ X^O_{Hh} = \frac{1}{3\beta_h} \left( \alpha - c^O_H + t \right), \]
\begin{align*}
X_{Hf}^O &= \frac{1}{3\beta_f} (\alpha - c_H^O - 2t), \\
X_{Fh}^O &= \frac{1}{3\beta_h} (\alpha - c_H^O - 2t), \\
X_{Ff}^O &= \frac{1}{3\beta_f} (\alpha - c_H^O + t). \\
\text{(3.42)}
\end{align*}

Prices: (same in both countries)

\begin{align*}
P_h^O &= P_f^O = \frac{1}{3} (\alpha + 2c_H^O + t). \\
\text{(3.43)}
\end{align*}

Profits: (before licensing fee paid)

\begin{align*}
\pi_{H}^{BO} &= \frac{1}{9\beta_h} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta_f} (\alpha - c_H^O - 2t)^2 - I_H^O, \\
\pi_{F}^{BO} &= \frac{1}{9\beta_f} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta_h} (\alpha - c_H^O - 2t)^2 - I_H^O. \\
\text{(3.44)}
\end{align*}

Licensing fee:

\begin{align*}
L &= \pi_{F}^{BO} - \pi_{F}^{E}, \text{ if } \pi_{F}^{E} \geq \pi_{F}^{M}; \\
L &= \pi_{F}^{BO} - \pi_{F}^{M}, \text{ if } \pi_{F}^{E} < \pi_{F}^{M}. \\
\text{(3.45)}
\end{align*}

Profits: (after licensing fee paid)

\begin{align*}
\pi_{H}^O &= \frac{1}{9\beta_h} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta_f} (\alpha - c_H^O - 2t)^2 - I_H^O + L, \\
\pi_{F}^O &= \frac{1}{9\beta_f} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta_h} (\alpha - c_H^O - 2t)^2 - I_H^O - L. \\
\text{(3.46)}
\end{align*}

Welfare levels:

\begin{align*}
w_{h}^O &= \frac{1}{18\beta_h} (2\alpha - 2c_H^O - t)^2 + \frac{1}{9\beta_h} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta_f} (\alpha - c_H^O - 2t)^2 - I_H^O + L, \\
w_{f}^O &= \frac{1}{18\beta_f} (2\alpha - 2c_H^O - t)^2 + \frac{1}{9\beta_f} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta_h} (\alpha - c_H^O - 2t)^2 - I_H^O - L. \\
\text{(3.47)}
\end{align*}

3.2.2 A Numerical Example - Continued

Considering that the R&D investment level and profit are affected by even more parameters in the open economy if we allow market demand size to differ for country $h$ and country $f$, a numerical
example is necessary for us to see how market demand size affects the mode choice decision of the firm with a higher productivity level (firm H).

In this example, the market inverse demand function is \( P_i = 15 - \beta_i X_i \), \( i = h, f \), for country \( h \) and country \( f \) respectively. The sum of \( 1/\beta_h \) and \( 1/\beta_f \) equals 1, which means the world market demand size is constant. I set the marginal cost function of firm H to be \( c_H = 1 - 0.35 \frac{1}{\beta_h} \) and the marginal cost function of firm F to be \( c_F = 6 - 0.11 \frac{1}{\beta_f} \). This example can check how different combinations of \( 1/\beta_h \) and \( 1/\beta_f \) (relative market demand size) will affect the exporting, licensing and FDI decision in the open economy. \( 1/\beta_h \) increases from 0.25 to 0.75, at the same time \( 1/\beta_f \) decreases from 0.75 to 0.25. A larger \( 1/\beta \) is associated with a larger market demand size. The trade cost \( t \) is 0.3, and the FDI cost \( D \) is 1.35. FDI cost is set to be high enough so that firm F will never choose to FDI in country \( h \).

The symmetric market demand size situation in the example when \( 1/\beta_h = 1/\beta_f = 0.5 \) is exactly the same situation in the previous ex-ante efficiency effect example when \( \theta_H = 0.35 \). Under this symmetric situation, firm H will choose exporting instead of licensing or FDI. I intentionally fix marginal cost function of firm H at this level because it is easier to observe the transitions among different mode choices of firm H with different relative market demand size. If the R&D investment to productivity transformability of firm H (\( \theta_H \)) is chosen to be too large or too small, the optimal mode choice will be dominated by the ex-ante efficiency effect analyzed in the previous section so that market size effect cannot change firm H’s mode choice decision.

Same as the previous ex-ante efficiency effect example, in all the following figures, red (solid) line indicates the exporting case (case 1), the black (long dashed) line shows the FDI case (case 2) and blue (dashed) line indicates the licensing case (case 3). These figures start from the optimal mode choice decision of firm H (Fig.3.8). Whenever the mode choice is determined by firm H, the following figures (from Fig.3.9 to Fig.3.16) will show the R&D investment levels, market prices and welfare levels of the two firms and two countries.

According to Fig.3.8, when country \( h \) is as large as country \( f \) with \( 1/\beta_h = 1/\beta_f = 0.5 \), the optimal mode choice is exporting which is the same as the previous ex-ante efficiency effect.
Figure 3.8: Market Size Effect: Exporting, Licensing and FDI choice

example if $\theta_H$ is set to be 0.35 shown by Fig.3.1. In this example, there is some ex-ante cost function difference between two firms but not very large.

When country $h$ has a relatively smaller market demand size than country $f$, firm $H$ will choose to license its technology to firm $F$. The extra profit firm $H$ can extract from firm $F$’s profit gain as a licensing fee is greater than the profit firm $H$ can earn by competing against firm $F$ to win the extra market share because a large amount of variable trade cost can be saved due to the relatively large market demand size of country $f$.

With country $h$’s market demand size increasing and country $f$’s market demand size decreasing, FDI will be the optimal mode choice for two reasons. First, country $f$’s relative market demand size reduces so that the licensing fee determined by the extra profit firm $F$ can earn cannot make up the profit loss incurred through both domestic market share (country $h$) loss and foreign market share (country $f$) loss for firm $H$. Intuitively, the variable trade cost saving due to relatively large market demand size of country $f$ is not large enough to cover the profit decrease of firm $H$ through licensing. Second, country $f$’s market demand size is still large enough to make the variable trade cost outweigh the fixed FDI cost for firm $H$. 

Exporting will turn out to be the optimal mode choice selected by firm \( H \) when country \( h \)'s relative market size continues growing. Firm \( H \) will not choose licensing because country \( f \)'s market size is so small that the only a small amount of variable trade cost can be saved under the licensing choice and firm \( F \) cannot pay enough amount of licensing fee. In addition, firm \( H \) will not choose FDI because the FDI cost is larger than the variable trade cost it will incur under the exporting choice.

As the relative market demand size of country \( h \) increases, the profits of firm \( H \) under the exporting choice, FDI choice and licensing choice will all increase. As country \( f \)'s market demand size decreases, FDI will save smaller and smaller amount of variable trade cost for firm \( H \). When country \( f \)'s market size is relatively large initially, the larger before-licensing-fee paid profit of firm \( F \) will compensate firm \( H \)'s profit loss in the form of licensing fee under the licensing choice. This compensation will decrease due to smaller amount of variable trade cost saving as country \( f \)'s relative market demand size shrinks. The profit of firm \( H \) will increase at the fastest speed under exporting choice and at the slowest speed under the licensing choice, and therefore the optimal mode choice will change as the relative market demand size changes shown in Fig.3.8.

Fig.3.9 presents the optimal R&D investment levels of firm \( H \). As to firm \( H \) who has more efficient cost function in the example, the optimal R&D investment increases as its domestic relative market demand size (country \( h \)) increases under all mode choices shown by Fig.3.9. When there is an optimal mode choice shift from licensing to FDI, there is a large upward jump for R&D investment of firm \( H \) though there is no market size change at the shifting point. This upward jump can be explained by the existence of a competition mechanism that firm \( H \) has to increase its productivity level (reduce its marginal cost) to win a larger market share under the FDI choice but not the licensing choice. Similarly there is a downward jump in R&D investment when firm \( H \) changes from FDI choice to exporting choice. This downward jump is smaller in magnitude than the previous upward jump from licensing to FDI because the competition mechanism for firm \( H \) to win a larger domestic and foreign market share still exists under the exporting choice. This downward jump is mainly due to the disadvantage in gaining market share in a foreign market.
Figure 3.9: Market Size Effect: R&D investment of firm $H$

Figure 3.10: Market Size Effect: R&D investment of firm $F$
(country $f$) under the exporting choice due to the varibale trade cost for firm $H$ compared with the FDI case.

Fig.3.10 shows the R&D investment choice of firm $F$ under exporting and FDI choices. I do not include the licensing case in this figure because firm $F$ incurs just as much R&D investment as firm $H$ which can be shown in Fig.3.9 and is much larger than the R&D investment levels under the other two mode choices for firm $F$. At the shifting point from FDI case to exporting case, there is an upward jump in R&D investment level for firm $F$ because the disadvantage in gaining market share in its domestic market (country $f$) is lessened under the exporting choice.

Fig.3.11 and Fig.3.12 show the market prices in country $h$ and country $f$. With the same price elasticity of demand for country $h$ and country $f$, both countries will have the same market price under either exporting choice or licensing choice. Under FDI case, the price is lower in country $f$ than that in country $h$ because FDI can only happen in country $f$ and save the variable trade cost for consumers in that country. Similar to the ex-ante efficiency effect example, market price is determined by the average marginal cost of firm $H$ and $F$. When optimal mode choice shifts from licensing to FDI, the decrease in productivity level of firm $F$ is larger compared with the increase in productivity level of firm $H$ so that there is a large price increase in both countries though the relative market demand size of these two counties does not change at the shifting point. When firm $H$ chooses exporting instead of FDI at the second shifting point, the market prices jump upward for both countries because the productivity decrease of firm $H$ is larger compared to the productivity increase of firm $F$. This jump is more obvious for country $f$ due to the variable trade cost saving effect of FDI in country $f$. Market price has an inverse relationship with market output. By looking at Fig.3.11 and Fig.3.12, the market outputs in both countries will just have the opposite trends to the market prices. Licensing choice ends up with highest output level while exporting has the lowest output level.
Figure 3.11: Market Size Effect: Market price in country $h$

Figure 3.12: Market Size Effect: Market price in country $f$
Fig.3.13 and Fig.3.14 are the total welfare levels of country $h$ and country $f$. As relative market demand size gets larger for country $h$ and smaller for country $f$, the total welfare has a clear increasing trend for country $h$ and a decreasing trend for country $f$ no matter what mode choice is chosen by firm $H$. At each mode choice shifting point (no change in relative market demand size) from licensing to FDI and from FDI to exporting, there is a total welfare decrease for country $h$ and country $f$ due to market price increase and market output decrease. However, this decrease in total welfare is quickly recovered by the increase in the relative market demand size for country $h$; and for country $f$ this decrease is enhanced by the relative market demand size decrease.

In order to see how relative market size will affect welfare per capita, I use total welfare of each country divided by its corresponding $(1/\beta)$ to indicate its welfare per capita. The following two figures (Fig.3.15 and Fig.3.16) describe the market size effect on welfare per capita for both countries in this example.

In Fig.3.15 and Fig.3.16, the downward jump at each shifting point caused by mode choice change can still be observed as in Fig.3.13 and Fig.3.14. However, welfare per capita of a country has a general downward trend as the relative market demand size of this country increases. In this numerical example, I have assumed that the sum of two countries’ market demand sizes is constant at 1 which means that the entire world market demand size won’t change. The market size change actually refers to relative market demand size change. If a firm in a relatively smaller country sells its product to a relatively larger country in the world market, the profit of this firm will increase a lot, while the relative market size only affects the individual consumer a little through the marginal cost channel. In this case, the welfare per capita will be larger for relatively smaller country. As Fig.3.15 shows, as the relative market demand size of country $h$ gets larger and larger, the welfare per capita for country $h$ has a decreasing trend in each mode choice, while welfare per capita in country $f$ has exactly the opposite trend because the relative market demand size of country $f$ decreases with the increase of $1/\beta_h$. 
Figure 3.13: Market Size Effect: Total welfare in country \( h \)

Figure 3.14: Market Size Effect: Total welfare in country \( f \)
Figure 3.15: Market Size Effect: Welfare per capita in country $h$

Figure 3.16: Market Size Effect: Welfare per capita in country $f$
3.3 Concluding Remarks

By holding market size the same for both countries to analyze the interaction between productivity choice and mode choice, I can get the following conclusions. As to mode choice, licensing is the optimal mode choice for firm $H$ when ex-ante difference between cost functions of two firms is small while FDI is the best when this ex-ante difference is large. Although firm with a more efficient cost function can successfully extract the entire extra profit that firm with a less efficient marginal cost function can earn under the licensing case, licensing is still not always the optimal mode choice because licensing reduces the incentive of ex-ante more efficient firm to decrease its marginal cost by increasing R&D investment and ex-ante less efficient firm becomes a more challenging competitor in both markets after it gets licensed with a more productive production technology. As to productivity choice, the ex-post productivity levels of two firms shrinks to zero under the choice of licensing when the ex-ante difference in cost functions is small; the medium ex-ante difference in cost functions leads to a simultaneous exporting choice and an enlarged ex-post productivity difference; the ex-post productivity difference is even larger associated with the choice of FDI when this ex-ante difference is also large.

Mode choice is also affected by the market demand size. I fix the marginal cost functions of two firms and the world market demand size constant in section 3.2. If the difference between two firms’ ex-ante cost functions is not too large or too small to make one mode choice dominant, larger relative domestic market demand size (smaller relative foreign market demand size) will encourage ex-ante more efficient firm to choose exporting directly, while smaller relative domestic market demand size (larger relative foreign market demand size) will make licensing choice more attractive. When this relative market demand size is in the middle range, FDI will become the optimal mode choice.

The mode choice interacts with the ex-post productivity choices and affects the welfare levels. The incentive of the firm with a more efficient cost function to conduct R&D investment is the largest is associated with the choice of FDI and the lowest with the choice of licensing. Due to a
low price (high output) under the licensing case, consumer surplus is the largest. So are the profits if firm $H$ chooses licensing as its mode choice. The total welfare is the largest under the licensing case in both countries. The choice of FDI will have the lowest total welfare mostly due to the large decrease in consumer surplus.
Chapter 4

Choosing a Target Firm to Implement FDI or Licensing

The decision process for any firm to serve a foreign market is complicated and includes multiple steps. The first step of the decision process is whether a firm will serve a foreign market or not given the productivity of its competitors and itself.

After a firm decides to serve a foreign market in the first step, the second step of the decision process is which mode choice it is going to make to serve the foreign market – exporting directly, licensing its technology to a foreign firm or FDI in a foreign country.\(^1\)

The third step of the decision process is how to choose a target firm to implement FDI or licensing in a host country if a parent firm has already made its mode choice in the second step. In order to set up a foreign direct investment, the parent firm can choose to do a greenfield investment or cross-border merger and acquisition. And interestingly, cross-border M&A is a more prevalent form of multinational entry compared with greenfield investment in some countries. In addition, the parent firm can also choose to acquire a more productive host-country firm or a less productive one under the cross-border acquisition choice. As to the licensing decision, the licensor firm also have the choice of licensing its technology to a more productive host-country firm or a less productive one.

Up to now, the existing literature has addressed the first two steps of the decision process both theoretically and empirically, for example, BEJK 2003, Melitz 2003, Melitz and Ottaviano

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\(^1\) In the previous two chapters, I have analyzed the first two steps of choices by a Cournot oligopolistic competition model. Only the most productive firms self-select to serve the foreign market, while less productive firms only sell their products domestically. Among these very productive firms which self-select to serve foreign markets, the most productive firms prefer FDI and the least productive ones prefer licensing.
2008, Yeaple 2005, Bustos 2011 for the first step and Helpman, Melitz, and Yeaple 2004, Horstmann and Markusen 198), Ethier and Markusen 1996 for the second step. However, little is known about the economic determinants driving the FDI and licensing target choices for firms to implement FDI or licensing in the host country. Noeke and Yeaple 2007, 2008 have distinguished the differences between the greenfield investment and the cross-border acquisition according to the characteristics of the parent firm, which do not consider alternative host-country acquisition targets.

The model developed in this chapter is to try to find some theoretical explanations for different FDI or licensing implementation target choices. I use a Cournot oligopolistic competition model which includes three firms competing against each other in the host country. Firms are heterogeneous in their productivity levels reflected by their constant marginal costs, with the most productive firm (firm M) located in another country choosing its FDI or licensing target firm in the host country. The other two firms, more productive firm H and the least productive firm L, are the domestic firms for this host country.

As to FDI, there are three different host-country targets for firm M to implement FDI – a new subsidiary (greenfield investment), the more productive firm H (cross-border acquisition) and firm L (cross-border acquisition). Different from most existing trade literature, in my model it is not always optimal for the parent firm to choose to acquire a more productive firm\(^2\). Also different from some corporate finance merger literature such as Lichtenberg and Siegel 1992 and Jovanovic and Rousseau 2002, the parent firm has more incentive to acquire a less productive firm because it is cheaper. The model in this chapter captures a trade-off between the FDI set-up costs\(^3\) and the parent firm’s ex-post market share under different FDI target choices. The parent firm’s optimal FDI target choice is different given different levels of heterogeneity among all firms and different market demand characteristics. If the profitability in the market for a certain industry is relatively low, it will be optimal for the parent firm to choose to acquire a more productive host-country

\(^2\) Guadalupe, Kuzmina and Thomas 2010 uses a monopolistic competition model to analyze the different acquisition targets in the host country and concludes that the parent firm always chooses a more productive host-country firm to acquire.

\(^3\) In this chapter, I assume that setting up a new subsidiary (greenfield investment) has the lowest the FDI set-up cost, while acquiring a more productive host-country firm is the most expensive target for the parent firm.
firm, which might be the case for the traditional industries with more mature markets. When the market profitability is very high (some high-tech emerging industries), setting up a new subsidiary by greenfield investment becomes most profitable for the parent firm to implement FDI. Acquisition of a less productive firm is the best choice when the profitability of the market is at the medium level.

There are two potential targets for firm M (licensor) to implement its licensing mode choice – a more productive firm (firm H) and a less productive firm (firm L). The trade-off of choosing a licensee for the licensor is between the potential licensing fee and the ex-post market share of the licensor. Similar results are derived as the FDI mode choice. The optimal licensing choice is to license its technology to a more productive host-country firm with a relatively low profitability in the market, while licensing to a less productive local firm is the best response for firm M when the market profitability is high.

This chapter is organized with four sections. In section 4.1 I introduce the basic model assumptions and model setup for the analysis of FDI and licensing implementation choices. I use a Cournot oligopolistic competition model with three firms in this chapter. Optimal FDI implementation choices and licensing choices are analyzed in section 4.2 and 4.3 respectively. Section 4.4 lists the major conclusions.

4.1 Set up of the Model

The whole world can be simplified into two parts – the host country and the other country. The host country has an inverse linear market demand function

\[ P = \alpha - \beta X. \] (4.1)

Parameter \( \alpha \) is the choke price which indicates the highest level of willingness to pay in a certain market if demand still exists. Parameter \( \beta \) is an inverse indicator of market size. \( P \) is the market price of the good, and \( X \) is the quantity.
4.1.1 Firms

There are three firms (firm M, firm H and firm L). Firm M is the most productive firm which is located in the other country; firm H and firm L are two less productive firms which compete under Cournot duopoly market in the host country in the closed economy. In the open economy, firm M can join the host-country market without any variable trade cost and these three firms compete against each other under Cournot oligopolistic market in the host country. In this chapter, I simply assume that three firms are having constant marginal cost $c_i \ (i = M, H, L)$ in order to make the model more tractable. I also normalize the marginal cost of firm M to be zero ($c_M = 0$) and the marginal cost of firm H to be $c$ ($c_H = c$), and assume that firm L is the least productive firm with the marginal cost $\sigma c$ and $\sigma > 1$ without loss of generality.

There is no entry and exit concern under this basic model set up, which implicitly assume that given $\sigma > 1$ the least productive firm L can still earn a positive profit in the open economy.

4.1.2 FDI Choices or Licensing Choices

In the previous chapters, I have studied that what type of firm is able to serve foreign market in the open economy and how it is going to serve foreign market (mode choice). In this chapter, I will temporarily put these two questions away by assuming that first all three firms are productive enough to survive given the host-country’s market demand in the open economy. Second, the most productive firm (firm M) located in the other country has already made its mode choice to serve the host-country market. Given the above assumptions, it is possible to study each mode choice (FDI or licensing) in a more detailed way – how firm M is going to implement FDI or licensing.

If firm M has already chosen FDI as its mode choice, there are two ways for it to implement FDI, one is to conduct greenfield FDI, the other is to acquire a host-country firm (either firm H or firm L). As to the acquisition, firm M is still facing the question of which host-country firm to acquire – the more productive firm H or the less productive firm L. Put it into simpler words, there are three choices for firm M to implement its FDI mode choice – greenfield investment, acquisition
of a more productive host-country firm or acquisition of a less productive host-country firm. The costs of implementing different FDI choices are also different. Firm M has to pay a fixed cost $F$ to set up a new subsidiary in the case of greenfield FDI which later is assumed to be zero ($F = 0$) for simplicity. In order to acquire a host-country domestic firm, firm M has to pay either firm H or firm L’s potential profit to buy out one of these firms. The acquisition prices for these two host-country firms are the potential profits they might earn under firm M’s greenfield FDI choice. After the cross-border acquisition, one of the host-country will become firm M’s subsidiary, enjoy firm M’s productivity level ($c_M = 0$) and compete against the other host-country firm.\footnote{Theoretically it is possible for firm M to acquire both firm H and firm L and become a monopolist in the world market. However, in real life there are usually either legal or political restrictions on M&A to exclude the possibility of this situation, so this potential equilibrium will not be considered in this model.}

Similarly, after firm M makes the mode choice of licensing, there are still two choices for it to implement the licensing mode choice – licensing its marginal cost ($c_M = 0$) to a more productive local firm (firm H) or licensing to a less productive firm (firm L). Same as the previous chapter, firm M has all the bargaining power over how much licensing fee it can charge. The licensing fee is the entire extra profit firm H or firm L can earn after it gets licensed compared with the case that firm M chooses to export to the host-country market directly. I also exclude the possibility that firm M can license its marginal cost to both firms; and firm M still compete against firm H and L in the host country after licensing (no change in the number of competitors after licensing).

4.2 Greenfield FDI, Acquisition of a more productive firm or Acquisition of a less productive firm

According to the assumptions and derivations (see appendix C.1), given different value ranges of $\sigma$ which indicates the relative productivity difference of the least productive firm (firm L) compared to firm M and firm H, there are two equilibrium chains.

When $\sigma \leq 4$, with the increase of the choke price parameter $\alpha$, the optimal FDI choice has a chain as: Acquisition of a more productive firm $\rightarrow$ Acquisition of a less productive firm $\rightarrow$
When $\sigma > 4$, with the increase of the choke price parameter $\alpha$, the optimal FDI choice has a chain as: Acquisition of a less productive firm $\rightarrow$ Greenfield FDI.

4.2.1 Costs of Different FDI Choices

In the model I assume that the fixed cost of setting up a new subsidiary (greenfield FDI) is zero and the cost of acquisition is the potential profit of the acquired firm under the greenfield FDI case. Under these assumptions, greenfield FDI has the lowest set-up cost for firm M which is zero, while acquisition of a more productive firm (firm H) has the highest set-up cost which is $\frac{[\alpha + (\sigma - 3)c]^2}{16\beta}$. And acquisition of a less productive firm (firm L) has an intermediate set-up cost which is $\frac{[\alpha + (1 + 3\sigma)c]^2}{16\beta}$.

4.2.2 Benefits of Different FDI Choices

The market share under the acquisition of a more productive firm case is the highest and the market price is also the highest for firm M because this reduces the toughness of competition (from the point view of firm M) most not only by reducing the number of its competitors but also by eliminating a more challenging competitor (firm H). Meanwhile, greenfield FDI can usually be considered with the smallest market share with the lowest market price for firm M because there are more competitors in the market. The toughness of competition of the market from the point view of firm M is intermediate when firm M chooses to acquire a less productive firm (firm L), it reduces the number of competitors, however, it still leaves a more productive competitor (firm H) in the market. The profits that firm M can earn under these three choices are respectively:

$$\pi^M_G = \frac{[\alpha + (1 + \sigma)c]^2}{16\beta},$$  \hspace{1cm} (4.2)

$$\pi^M_H = \frac{(\alpha + \sigma c)^2}{9\beta},$$  \hspace{1cm} (4.3)

$$\pi^M_L = \frac{(\alpha + c)^2}{9\beta}. \hspace{1cm} (4.4)$$
Superscripts \( G, H, L \) stand for greenfield FDI, acquisition of a more productive firm and acquisition of a less productive respectively; superscript \( b \) stands for before corresponding costs paid for the acquisition choices; and subscripts \( M, H, L \) indicate firm \( M \), firm \( H \) and firm \( L \) respectively.

### 4.2.3 Comparing Benefits with Costs

In order to determine which FDI choice is the optimal for firm \( M \), costs need to be subtracted from their corresponding benefits, the net profits for firm \( M \) under difference FDI choices are as following:

\[
\pi^G_M = \frac{[\alpha + (1 + \sigma)c]^2}{16\beta}, \quad (4.5)
\]

\[
\pi^H_M = \frac{(\alpha + \sigma c)^2}{9\beta} - \frac{[\alpha + (\sigma - 3)c]^2}{16\beta}, \quad (4.6)
\]

\[
\pi^L_M = \frac{(\alpha + c)^2}{9\beta} - \frac{[\alpha + (1 - 3\sigma)c]^2}{16\beta}. \quad (4.7)
\]

Comparing the net profits above under three different FDI implementation choices, I can get the following relations:\(^5\)

If \( \sigma \leq 4 \)

\( \pi^H_M \) is max when

\[
3\sigma - 2 < \frac{\alpha - c}{c} \leq \frac{11}{5}\sigma + \frac{6}{5};
\]

\( \pi^L_M \) is max when

\[
\frac{11}{5}\sigma + \frac{6}{5} < \frac{\alpha - c}{c} < 15\sigma - 2;
\]

\( \pi^G_M \) is max when

\[
\frac{\alpha - c}{c} \geq 15\sigma - 2.
\]

---

\(^5\) The implicit assumption that the least productive firm \( L \) will not be driven out of the market in the open economy (zero profit boundary for all firms) is also included in the following results, which reveals a relationship between the choke price and the marginal costs of the firms: \( a > (3\sigma - 1)c \).
If $\sigma > 4$

$\pi_{M}^{L}$ is max when

$$3\sigma - 2 < \frac{\alpha - c}{c} < 15\sigma - 2;$$

$\pi_{M}^{G}$ is max when

$$\frac{\alpha - c}{c} \geq 15\sigma - 2.$$

Fig.4.1 and Fig.4.2 show the above results graphically. Solid (blue) line indicates the profit of firm M under the case of acquiring a more productive firm (firm H), dotted (black) line is firm M’s profit under the acquisition of a less productive firm (firm L), and the dashed (red) line refers to the profit of firm M with greenfield FDI. When the level of heterogeneity among firms is relatively low (smaller $\sigma$) illustrated by Fig.4.1, with the increase in the market average profitability, the choice of acquiring a more productive host-country firm dominates first, followed by acquisition of a less productive firm and then greenfield investment. When the level of heterogeneity among firms is high (larger $\sigma$) shown by Fig.4.2, acquisition of a more productive local firm is never the optimal choice, acquisition of a less productive firm is the best response with lower average market profitability and greenfield investment yields the highest profit for the investing firm (firm M) with higher average market profitability.

According to the above relations, the FDI implementation choice depends on the level of firms’ heterogeneity $\sigma$ and the market demand characteristic – maximum willingness to pay $\alpha$. Taking first order derivatives with respect to $\alpha$ for Eq.4.5 – 4.7, how fast profits are increasing with the choke price can be shown as following:

$$d\pi_{M}^{G} \over d\alpha = \frac{1}{72\beta} (9\alpha + 9c + 9\sigma c), \quad (4.8)$$

$$d\pi_{M}^{H} \over d\alpha = \frac{1}{9\beta} (2\alpha + 2\sigma c) - \frac{1}{16\beta} (2\alpha - 6c + 2\sigma c) = \frac{1}{72\beta} (7\alpha + 27c + 7\sigma c), \quad (4.9)$$

$$d\pi_{M}^{L} \over d\alpha = \frac{1}{9\beta} (2\alpha + 2c) - \frac{1}{16\beta} (2\alpha + 2c - 6\sigma c) = \frac{1}{72\beta} (7\alpha + 7c + 27\sigma c). \quad (4.10)$$
Figure 4.1: $\sigma \leq 4$: Firm M’s profits ($\pi_M$) under different FDI implementation choices

Figure 4.2: $\sigma > 4$: Firm M’s profits ($\pi_M$) under different FDI implementation choices
When the choke price $\alpha$ is relatively low compared to firms’ marginal costs, according to Eq. 4.5 – 4.7, it is most profitable for firm M to acquire a more productive host-country firm (firm H), because among three FDI implementation choices, acquisition of firm H generates the highest benefit$^6$, while the cost differences$^7$ among these choices are relatively small. By comparing Eq. 4.8 – 4.10, with an increase in the choke price $\alpha$, acquisition of a less productive firm (firm L) enjoys the highest profit increasing rate since $\sigma > 1$ when the choke price $\alpha$ is in the middle range. As the choke price continues to increase, the profit increasing rate is the largest under the greenfield FDI choice.

There is a trade-off between the costs of different FDI choices and the profitability of an industry. When the choke price $\alpha$ is low relative to the firms’ marginal costs in a certain industry which leaves only a small per unit profit margin (low mark-up) for all the firms, the host-country market is very tough for all firms. Firm M has more incentive to acquire a more productive host-country firm (firm H) because first, under this tough market situation, buying out a more productive firm (firm H) is not much more expensive than buying a less productive firm (firm L), both the costs of cross-border acquisition choices are small. Second, the benefit differences between these three choices with a low choke price $\alpha$ are most significant in the percentage term compared to the cases with the high choke price $\alpha$. So acquiring a more challenging competitor (firm H) is optimal for firm M to maximize its profit by winning the largest market share and increasing the market price (increasing the mark-up) most.

When the choke price $\alpha$ is higher (but not very high) relative to the firms’ marginal costs, the per unit market profit also gets higher but the market profitability is not very large, acquiring a less productive host-country firm (firm L) can be the most attractive choice because getting rid of one competitor by cross-border acquisition is still more profitable (a relatively larger market share a higher market price compared to the greenfield FDI), however, the more productive firm (firm H) turns out to be too expensive to be acquired since its potential profit level is too high under a

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$^6$ See section 4.2.2.

$^7$ See section 4.2.1.
higher choke price case. Comparing the two cross-border acquisition choices when the choke price $\alpha$ is increasing, both the benefits and costs of these two choices are increasing and diverging, with two costs diverging at faster speed than the benefits, which makes the profit of acquiring firm L increases at a faster than the profit of acquiring firm H. Since the market profitability is not very large, the profit of greenfield FDI still increases at a slower speed than the profit of acquiring firm L with the increase of $\alpha$.

When the choke price $\alpha$ is high enough (high market profitability case) which leaves a very high per unit profit margin to firm M even under the most competitive greenfield FDI choice, reducing the toughness of competition in the market through cross-border acquisition can no longer lead to a significant increase (in percentage term) in the market price, mark-up or market share for firm M. Meanwhile, acquisition costs for either more productive firm H or less productive firm L increases with the increase in the market profitability because their corresponding potential profits increase. Under this situation, the profit under greenfield FDI increases fastest and the choice of greenfield FDI will be preferred since it is not worthwhile by incurring a large acquisition cost to gain a small increase in market price, mark-up and market share.

Note: When $\sigma > 4$, the choice of acquiring a more productive firm (firm H) does not exist in the equilibrium chain. This is because when $\sigma$ gets very large and firm L still can survive in the greenfield FDI choice of firm M, it already guarantees a higher per unit profit in this market. The market is at least under the medium market profitability case, so it is not a surprising result that acquisition of more productive firm (firm H) is never the optimal choice.

### 4.3 Licensing to a More Productive Firm or a Less Productive Firm

If firm M has already made the mode choice to license its marginal cost ($c_M = 0$) to either firm H or firm L, we compare the profits of firm M under these two licensing cases, given different ranges of $\sigma$, there are also two equilibrium chains shown in the following. Please see appendix C.2 for the derivations.
When $\sigma \leq 5$, with the increase of the choke price parameter $\alpha$, the optimal licensing choice has a chain as Licensing to a more productive firm $\rightarrow$ Licensing to a less productive firm.

When $\sigma > 5$, with the increase of the choke price parameter $\alpha$, the optimal licensing choice is Licensing to a less productive firm.

### 4.3.1 Licensing Fees

The licensing fees are actually the benefits for firm M to license its technology (low marginal cost) to one of the host-country firm. The amount of licensing fee depends on how much extra profit the licensee firm can get. Licensing to a less productive firm leads to a higher licensing fee, while licensing to a more productive firm is related to a smaller amount of licensing fee. Given the assumption that firm M can enjoy all the extra profit that the licensee can earn, the licensing fees under these two licensing choices are as following.

Licensing to a more productive firm (firm H):

$$L^H = \frac{3c}{16\beta} (2\alpha + 2\sigma c - 3c).$$ (4.11)

Licensing to a less productive firm (firm L):

$$L^L = \frac{3\sigma c}{16\beta} (2\alpha + 2c - 3\sigma c).$$ (4.12)

### 4.3.2 Market Share Loss and Market Price Decrease

The major costs for firm M to license out its more efficient marginal cost are the loss in its market share and also the decrease in the market price (decrease in the mark-up). Since firm M still competes against the other two host-country firms (firm H and firm L) after licensing in this model assumption, different from the cross-border acquisition, licensing increases the toughness of competition from the point of view of firm M in the market because the number of competitors does not change but licensing makes the licensee firm (either firm H or firm L) more productive and competitive in the market. Licensing to a more productive firm (firm H) will decrease the market
price and reduce the market share of firm M in a relatively smaller amount than licensing to a less productive firm (firm L) because firm L is less productive compared to firm H before licensing.

### 4.3.3 Comparing Benefits with Costs

The licensing decision between these two choices can be made by comparing the profits that firm M can earn after getting the licensing fees. The profits of firm M under these two licensing choices are respectively:

\[
\pi_{H_{Ml}} = \left(\frac{\alpha + \sigma c}{16\beta}\right)^2 + \frac{3c}{16\beta} (2\alpha + 2\sigma c - 3c),
\]

\[
\pi_{L_{Ml}} = \left(\frac{\alpha + c}{16\beta}\right)^2 + \frac{3\sigma c}{16\beta} (2\alpha + 2c - 3\sigma c),
\]

where subscript \(l\) stands for the licensing mode choice case and all the other notations have the same meanings as the FDI mode choice case.

Firm M will make its optimal licensing choice according to the following profits comparison results:

If \(\sigma \leq 5\):

\(\pi_{H_{Ml}}\) is max when

\[
3\sigma - 1 < \frac{\alpha - c}{c} \leq \frac{5(\sigma - 1)}{2};
\]

\(\pi_{L_{Ml}}\) is max when

\[
\frac{\alpha - c}{c} > \frac{5(\sigma - 1)}{2}.
\]

If \(\sigma > 5\):

\(\pi_{L_{Ml}}\) is always max.

Fig.4.3 and Fig.4.4 show the optimal licensing choices. Solid (blue) line and dotted (black) line indicate the profits of firm M under the choice of licensing to a more productive firm (firm H) and the choice of licensing to a less productive firm (firm L) respectively. When the level
Figure 4.3: $\sigma \leq 5$: Firm M’s profits ($\pi_M$) under different licensing implementation choices

Figure 4.4: $\sigma > 5$: Firm M’s profits ($\pi_M$) under different licensing implementation choices
of heterogeneity among firms is relatively low (smaller \( \sigma \)) in Fig. 4.3, with the increase in the market profitability (increase in \( \alpha \)), licensing to a more productive host-country firm dominates first, followed by licensing to a less productive firm. When the level of heterogeneity among firms is high (larger \( \sigma \)) as in Fig. 4.4, licensing to a less productive firm is always the best response regardless of the profitability in the market.

The choice of licensing has a similar economic implication as the FDI choices. When the choke price is low relative to the firms’ marginal costs in a certain industry which leaves only a small per unit profit margin for all the firms, this industry has a relatively tough market with low profitability level, firm M has more incentive to give its license to a more productive host-country firm (firm H) since now keeping its market share and making the market price stay at a relatively high level are more important than getting a higher licensing fee. Licensing to a less productive firm (firm L) will make the competition in the market tougher and cause larger reductions in firm M’s own market share, market price level and mark-up. However, the licensing fee firm M can charge from the extra profit firm L can earn is not much more than the choice of licensing to firm H, that is, either licensee (firm H or firm L) is not able to earn much more extra profit due to the low market profitability.

When the choke price is high compared to the firms’ marginal costs, licensing to a less productive local firm (firm L) can be more attractive because increasing the toughness of competition in the market for firm M won’t decrease firm M’s market share or the market price a lot due to the high market profitability. Moreover, the licensing fee it can earn from this less productive firm is much larger under this higher choke price situation.

Note: when \( \sigma > 5 \), firm M will not choose to license to a more productive firm. When \( \sigma \) gets very large and firm L still can survive in the 3-firm Cournot competition, it already guarantees a high profitability level in this market. So licensing to a more productive firm is never optimal.
4.4 Concluding Remarks

The optimal FDI and licensing implementation choices depend on the level of heterogeneity between firms and different market profitability in this model. There are three ways for the parent firm to implement FDI – greenfield, acquisition of more productive host-country firm or acquisition of less productive host-country firm. If the market profitability of a certain industry is relatively low, it will be optimal for the parent firm to choose to acquire a more productive host-country firm, which might be the case for the traditional industries with more mature markets. When the average profitability in the market is very high (some high-tech emerging industries), greenfield investment becomes most profitable for the parent firm to implement FDI. Acquisition of a less productive firm is the best choice when the profitability in the market is in the middle range.

As to licensing, there are two ways for the most productive firm (licenser) to implement its licensing mode choice – licensing to a more productive firm or licensing to a less productive firm. Similar results are derived as the FDI mode choice. The optimal licensing choice is to license its technology to a more productive host-country firm when the market profitability is relatively low, while licensing to a less productive host-country firm is the best response for the licenser firm when the market has a high profitability.
Chapter 5

Foreign Linkages & Productivity Advantage: Evidence from Chilean Data

Many developing countries have liberalized their economies to attract foreign direct investment (FDI) and licensing of foreign technology. The role that multinational firms play in the technological development of the host country has raised a lot of research interests and has been studied theoretically and empirically through both self-selection channel and learning by exporting channel. Although there are some controversial results according to the previous studies, such liberalization policies are usually accompanied by some benefits for host countries - social welfare increase, domestic productivity increase, and etc.

On the other hand, firms with better technology also face the problem that how they should sell their products in the more liberalized host countries. This is the mode choice for a firm. As I have mentioned in the previous chapter, a firm can choose to export directly, license its technology to the host country or do foreign direct investment. How firms choose their optimal mode choice not only affects the profit of the decision-making firms, but also has a large impact on the welfare and productivity of the host country.

There are quite a few empirical papers focusing on the interactions between exporting decision, mode choice and firm-level productivity. Clerides, Lach and Tybout (1998), Pavcnik (2002), Helpman, Melitz and Yeaple (2004), Javorcik (2004), De Loecker (2007), Aw, Roberts and Xu (2008) and Bustos (2011) have studied the effect of ex-ante firm-level productivity on the exporting decision and mode choice (FDI or exporting) and the impact of exporting decision and mode choice (FDI) on firms’ ex-post productivity levels in different ways. Due to the lack of licensing information in
most data sets, licensing choice hasn’t been well studied in the existing empirical literature.

In this empirical chapter, I use the Chilean plant-level panel data from 2001 to 2007 to study two sets of empirical hypotheses that can support some of the theoretical predictions from chapter 3.¹ This data includes more than 5000 plants belonging to 111 different ISIC 4-digit manufacturing industries each year and the information of both foreign linkages – licensing and FDI, which allows me to give a comparison of the effects on productivity and intra-industry allocations of different foreign linkages. In addition, under what circumstance licensing or FDI will end up to be the optimal mode choice can be studied.

As to the first set of empirical hypotheses, foreign linkages including FDI and licensing are positively correlated with the total factor productivity of a plant. Foreign subsidiaries and domestic licensees on average show a higher productivity level than plants with no access to foreign linkages. Moreover, foreign subsidiaries have an even higher average productivity level compared to domestic licensees. Together with the basic productivity advantage associated with foreign linkages, plants with access to foreign linkages (foreign subsidiaries and domestic licensees) on average are also larger in size and have a larger market share with respect to three plant-level dependent variables – total sales, value added and total employment. Similarly, this intra-industry allocation effect of FDI is also larger than that of licensing.

According to the second set of empirical hypotheses, what determines the mode choice is not the absolute productivity level of the more productive firm, but the productivity difference between more productive foreign firms and less productive domestic firms. A larger average productivity difference between domestic Chilean plants and foreign subsidiaries within an industry, which indicates a larger productivity advantage of relatively more productive foreign firms, is associated with more foreign direct investment behaviors in the data. If the productivity advantage of more productive foreign firms is smaller in an industry, more licensing transactions are observed.

In section 5.1, I use the Levinsohn-Petrin method to estimate the total factor productivity

¹ There is neither R&D investment variable nor enough switching observations from domestic plants to foreign subsidiaries or licensees in the data. Unfortunately I cannot observe/estimate a difference between the ex-ante and the ex-post productivity as the theory part states in chapter 3.
of each individual plant by industries and categorize these plants by four different groups. Three sets of regressions are analyzed in the three following sections. Whether foreign linkages (either FDI or licensing) are associated with higher productivity is the question in section 5.2. Section 5.3 discusses whether foreign linkages affect the size of a specific plant. These two sections (5.2 and 5.3) are testing the effects of different mode choice on the productivity and intra-industry allocations in Chile. In section 5.4, I cluster the plant-level data into 4-digit industry level to see the relationship between the domestic and foreign productivity difference and the mode choice decision. I give a brief conclusion summary for this chapter in the last section (section 5.5).

5.1 Total Factor Productivity Estimation

There are 111 4-digit level manufacturing industries in the data. I cluster the data to 2-digit industry level to calculate total factor productivity by using Levinsohn-Petrin method. Except “manufacture of office” industry, accounting and computing machinery which only has 15 observations in seven years, the rest 19 2-digit industries all have enough observations. Table 5.1 shows the descriptive data of these twenty 2-digit industries.

Using Levinsohn-Petrin method to estimate total factor productivity corrects the problem that arises from the correlation between the unobservable productivity shocks and input levels. Using intermediate inputs as proxy can solve this simultaneity problem. Levinsohn-Petrin method also works well for this Chilean data which has some zeros in the capital stock. In the Levinsohn-Petrin regressions, I use number of skilled labor and number of unskilled labor as freely variable inputs, and I use electricity consumption (thousands of kWh) as the proxy variable. Table 5.2 reports the coefficients from the Levinsohn-Petrin regressions, and the ones with bold letters are significant at (at least) 10% level.

In order to analyze the productivity between different types of plants in Chile, I categorize all of the Chilean private plants into 4 different groups. The first group (group 1) includes domestic no-licensing no-exporting plants. Plants in this group do not have any access to foreign linkages
Table 5.1: ISIC 2-digit industry codes and descriptions

<table>
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<tr>
<th>ISIC2</th>
<th>No. of Obs.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>11240</td>
<td>Manufacture of food products and beverages</td>
</tr>
<tr>
<td>17</td>
<td>1790</td>
<td>Manufacture of textiles</td>
</tr>
<tr>
<td>18</td>
<td>1873</td>
<td>Manufacture of wearing apparel, dressing and dyeing of fur</td>
</tr>
<tr>
<td>19</td>
<td>956</td>
<td>Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear</td>
</tr>
<tr>
<td>20</td>
<td>2462</td>
<td>Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials</td>
</tr>
<tr>
<td>21</td>
<td>1082</td>
<td>Manufacture of paper and paper products</td>
</tr>
<tr>
<td>22</td>
<td>1836</td>
<td>Publishing, printing and reproduction of recorded media</td>
</tr>
<tr>
<td>24</td>
<td>2192</td>
<td>Manufacture of chemicals and chemical products</td>
</tr>
<tr>
<td>25</td>
<td>2332</td>
<td>Manufacture of rubber and plastics products</td>
</tr>
<tr>
<td>26</td>
<td>1940</td>
<td>Manufacture of other non-metallic mineral products</td>
</tr>
<tr>
<td>27</td>
<td>999</td>
<td>Manufacture of basic metals</td>
</tr>
<tr>
<td>28</td>
<td>2802</td>
<td>Manufacture of fabricated metal products, except machinery and equipment</td>
</tr>
<tr>
<td>29</td>
<td>2203</td>
<td>Manufacture of machinery and equipment n.e.c.</td>
</tr>
<tr>
<td>30</td>
<td>15</td>
<td>Manufacture of office, accounting and computing machinery</td>
</tr>
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<td>31</td>
<td>577</td>
<td>Manufacture of electrical machinery and apparatus n.e.c.</td>
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<td>32</td>
<td>58</td>
<td>Manufacture of radio, television and communication equipment and apparatus</td>
</tr>
<tr>
<td>33</td>
<td>223</td>
<td>Manufacture of medical, precision and optical instruments, watches and clocks</td>
</tr>
<tr>
<td>34</td>
<td>582</td>
<td>Manufacture of motor vehicles, trailers and semi-trailers</td>
</tr>
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<td>35</td>
<td>365</td>
<td>Manufacture of other transport equipment</td>
</tr>
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<td>36</td>
<td>1780</td>
<td>Manufacture of furniture; manufacturing n.e.c.</td>
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Table 5.2: Coefficients from Levinsohn-Petrin TFP estimating regressions

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<th>Sector code</th>
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<th>17</th>
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<th>19</th>
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<th>22</th>
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<td>1862</td>
<td>940</td>
<td>2426</td>
<td>1080</td>
<td>1825</td>
<td>2165</td>
<td>2326</td>
<td>1908</td>
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<td>ln(skilled labor)</td>
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<td>0.57</td>
<td>0.65</td>
<td>0.46</td>
<td>0.43</td>
<td>0.56</td>
<td>0.65</td>
<td>0.53</td>
<td>0.42</td>
</tr>
<tr>
<td>ln(unskilled labor)</td>
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<td>0.28</td>
<td>0.27</td>
<td>0.3</td>
<td>0.15</td>
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<td>0.02</td>
</tr>
<tr>
<td>ln(capital)</td>
<td>0.04</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.02</td>
<td>0.01</td>
<td>0.05</td>
<td>0.05</td>
<td>0.07</td>
<td>0.02</td>
</tr>
<tr>
<td>Sum of coefficients</td>
<td>0.60</td>
<td>1.01</td>
<td>0.88</td>
<td>1.00</td>
<td>0.63</td>
<td>0.55</td>
<td>0.82</td>
<td>0.75</td>
<td>0.82</td>
<td>0.46</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sector code</th>
<th>27</th>
<th>28</th>
<th>29</th>
<th>30</th>
<th>31</th>
<th>32</th>
<th>33</th>
<th>34</th>
<th>35</th>
<th>36</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of observations</td>
<td>961</td>
<td>2796</td>
<td>2194</td>
<td>15</td>
<td>575</td>
<td>58</td>
<td>222</td>
<td>579</td>
<td>364</td>
<td>1767</td>
</tr>
<tr>
<td>ln(skilled labor)</td>
<td>0.18</td>
<td>0.57</td>
<td>0.61</td>
<td>1.75</td>
<td>0.6</td>
<td>0.43</td>
<td>0.63</td>
<td>0.88</td>
<td>0.53</td>
<td>0.71</td>
</tr>
<tr>
<td>ln(unskilled labor)</td>
<td>0.02</td>
<td>0.26</td>
<td>0.25</td>
<td>0.4</td>
<td>0.24</td>
<td>0.36</td>
<td>0.13</td>
<td>0.28</td>
<td>0.28</td>
<td>0.37</td>
</tr>
<tr>
<td>ln(capital)</td>
<td>0.01</td>
<td>0.05</td>
<td>0.01</td>
<td>0.98</td>
<td>0.07</td>
<td>0</td>
<td>0.2</td>
<td>0.15</td>
<td>0.03</td>
<td>0.04</td>
</tr>
<tr>
<td>Sum of coefficients</td>
<td>0.21</td>
<td>0.88</td>
<td>0.87</td>
<td>3.13</td>
<td>0.91</td>
<td>0.79</td>
<td>0.96</td>
<td>1.31</td>
<td>0.84</td>
<td>1.12</td>
</tr>
</tbody>
</table>

Table 5.3: Logarithm of total factor productivity by groups

<table>
<thead>
<tr>
<th>Type of firm (50% capital share foreign plants)</th>
<th>no. of Obs</th>
<th>Mean</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic no licensing no exporting (Group1)</td>
<td>27834</td>
<td>9.871</td>
<td>9.810</td>
</tr>
<tr>
<td>Domestic licensee (Group 2)</td>
<td>1398</td>
<td>11.171</td>
<td>10.956</td>
</tr>
<tr>
<td>Foreign subsidiary(Group 3)</td>
<td>1762</td>
<td>11.776</td>
<td>11.525</td>
</tr>
<tr>
<td>Domestic no licensing exporter (Group 4)</td>
<td>5508</td>
<td>11.154</td>
<td>10.981</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of firm (10% capital share foreign plants)</th>
<th>no. of Obs</th>
<th>Mean</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic no licensing no exporting (Group1)</td>
<td>27692</td>
<td>9.864</td>
<td>9.806</td>
</tr>
<tr>
<td>Domestic licensee (Group 2)</td>
<td>1360</td>
<td>11.124</td>
<td>10.885</td>
</tr>
<tr>
<td>Foreign subsidiary(Group 3)</td>
<td>2075</td>
<td>11.783</td>
<td>11.563</td>
</tr>
<tr>
<td>Domestic no licensing exporter (Group 4)</td>
<td>5375</td>
<td>11.132</td>
<td>10.957</td>
</tr>
</tbody>
</table>
to affect their productivity and do not export either. This group indicates the low-end domestic productivity level in Chile. The second group (group 2) includes all domestic licensees (both exporters and non exporters). Plants in this group get access to more productive foreign firms through licensing, which would increase their own productivity. The third group (group 3) is the foreign subsidiary group. These plants are foreign subsidiaries and get production technology directly from their corresponding parent firms. These plants are usually associated with the highest productivity in their specific industries. The last group (group 4) indicates domestic no-licensing exporters. The plants in this group do not have any foreign linkage either; however, they still have the competitiveness in the world market so that they can export their products to foreign markets. I consider the plants in this group have the highest pure domestic productivity. The cut-off for domestic and foreign plants in this empirical setting is 50% (or 10%) capital share.\textsuperscript{2} If more than 50% (or 10%) of the plant is owned by foreign countries, this plant is considered to be a foreign plant; otherwise it is a domestic plant. Table 5.3 shows the mean and median productivity level of each group by two different foreign subsidiary definitions. As the theory predicts\textsuperscript{3}, group 1 has the lowest productivity and group 3 has the highest. The average productivity levels of domestic licensees and domestic no-licensing exporters are in the middle range and are quite similar. According to this data summary, there is not much difference under the two different foreign subsidiary capital share definitions.

Fig. 5.1 shows the Kernel density of the natural log of total factor productivity by different groups given the 50% capital share foreign subsidiary definition. Graphically group 1 (domestic no-licensing no-exporting plants) has a larger proportion in low-productivity plants and a smaller proportion in high-productivity plants indicated by the solid line, while group 3 (foreign plants) has a smaller proportion in low-productivity plants and a larger proportion in high-productivity plants.

\textsuperscript{2} 50% capital share is a commonly accepted ratio for the majority ownership of a firm; and 10% capital share is a widely accepted definition for foreign subsidiaries in the multinational literature. In this chapter, I will test all the hypotheses associated with foreign subsidiaries with both definitions.

\textsuperscript{3} See chapter 2 for the support for the productivity difference between group 1 and group 4 that exporters are more productive than non-exporters. And refer to chapter 3 for the theoretical explanations for the productivity difference among group 1, group 2 and group 3 that both FDI and licensing can bring better technology to the host country with the effect of FDI even stronger.
Figure 5.1: Total factor productivity by groups

(long dashed line). Group 2 (dashed line) which includes all domestic licensees has a distribution in the middle, which is very similar to group 4 (domestic exporters with no foreign license) indicated by the dotted line. Fig.5.1 is consistent with the results shown in Table 5.3.

5.2 Foreign Linkages and Productivity

Question 1: Do foreign plants or domestic licensees exhibit higher productivity compared with domestic plants without any foreign linkages?

FDI subsidiaries and licensee plants in Chile can reflect the corresponding productivity levels of their parent firms or licensors. According to the theory, domestic licensees (group 2 plants) are associated with a higher productivity level than domestic no-licensing no-exporting plants (group 1 plants); and FDI subsidiaries (group 3 plants) have the highest productivity levels. Table 5.4 presents the results for the following regression equation. In the following equation, \( i \) stands for plant index, \( j \) stands for industry, \( r \) stands for region, and \( t \) stands for time:
\[ \ln(TFP_{it}) = \alpha + \beta_1 \ast FDI_{it} + \beta_2 \ast Licensee_{it} + \gamma_1 \ast Industrydummies_j + \gamma_2 \ast Regiondummies_r + \gamma_3 \ast Timedummies_t + \mu_i + \omega_{it}. \] (5.1)

The dependent variable is the natural log of the total factor productivity for each plant, and the key independent variables are FDI dummy and Licensee dummy. FDI dummy variable equals one if the plant belongs to the foreign subsidiary group (group 2) and zero otherwise. Licensee dummy variable here only considers the domestic licensees that it equals one if the plant is domestic and pays a positive licensing fee. These two dummy variables are mutually exclusive.

Table 5.4: Foreign linkages (FDI and licensing) and plant-level TFP

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>50% capital share – foreign plant</th>
<th>10% capital share – foreign plant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>FDI dummy</td>
<td>0.396***</td>
<td>0.407***</td>
</tr>
<tr>
<td></td>
<td>(0.048)</td>
<td>(0.048)</td>
</tr>
<tr>
<td>Licensee Dummy</td>
<td>0.156***</td>
<td>0.161***</td>
</tr>
<tr>
<td></td>
<td>(0.023)</td>
<td>(0.023)</td>
</tr>
<tr>
<td></td>
<td>(0.113)</td>
<td>(0.492)</td>
</tr>
</tbody>
</table>

I use random effect model in this regression. The first four columns show the regression results using the 50% capital share foreign subsidiary definition, and the last four columns are associated with the 10% capital share foreign subsidiary definition. All eight regressions include both time controls and region controls. Column 1, 2, 5, 6 have 4-digit industry controls, while column
3, 4, 7, 8 have industry controls at 2-digit level. Column 2, 4, 6, 8 also include some other controls: time-region control (population), time-industry control (average effective tariff rate) and plant-level control (capital labor ratio). The coefficients of FDI and Licensee are both positive and significant and quite robust in both significance and magnitude among different foreign subsidiary definitions with different control variables. Compared to pure domestic plant with no foreign linkages (the benchmark group in these regressions), being a foreign subsidiary on average has a higher natural log of total factor productivity (by about 0.4), and getting access to foreign license increases the natural log of total factor productivity by around 0.16. This means that foreign subsidiaries are about 4% more productive and domestic licensees are about 1.5% more productive than the domestic plants with no foreign linkages at the mean or medium level. Moreover, the coefficient of FDI is significantly larger in magnitude than the coefficient of Licensee (more than doubled). Whether a plant is a foreign subsidiary affects this plant’s total factor productivity more than whether a plant is a domestic licensee.

5.3 Foreign Linkages and Market Share

Question 2: Do foreign plants or domestic licensees have larger size (larger market share) compared to domestic firms without any foreign linkages?

According to the theoretical model in chapter 3, foreign subsidiaries (Group 3) on average are larger in size than domestic licensees (Group 2), and domestic licensees are larger than domestic no-licensing no-exporting plants (Group 1). Three dependent variables (yi,it) reflecting market share are tested in the following: first is the logarithm of real total sales (Table 5.5), second is the logarithm of real value added (Table 5.6), and third is the logarithm of total employment (Table 5.7). Taking the logarithm of any potential dependent variable and putting industry dummy variables on the right hand side actually mean that these dependent variables are also market share indicators. The following regression is the general form for all the three regressions with different dependent
variables:

\[
ln(y_{it}) = \alpha + \beta_1 * FDI_{it} + \beta_2 * Licensee_{it} + \gamma_1 * Industrydummies_j + \\
\gamma_2 * Regiondummy + \gamma_3 * Timedummies_t + \mu_i + \omega_{it}. \quad (5.2)
\]

I expect that both \( FDI \) and \( Licensee \) dummy variables have positive and significant coefficients on any market share dependent variables, and the coefficient of FDI is larger than that of licensee. Table 5.5, 5.6 and 5.7 present the results of three random effect regressions. Similar to table 5.4, the first four columns of each table report the regression results under the 50% capital share foreign subsidiary definition, and the last four columns show the regression results under the 10% capital share foreign subsidiary definition. All regressions include both time controls and region controls. In each table, column 1, 2, 5, 6 have 4-digit industry controls, while column 3, 4, 7, 8 have industry controls at 2-digit level. Column 2, 4, 6, 8 also include some other controls: time-region control (population), time-industry control (average tariff rate) and plant-level control (capital labor ratio). All of the three tables with different market share dependent variables show the results consistent with the theoretical predictions. Both the coefficients of \( FDI \) dummy and \( Licensee \) dummy are positive and significant at 1% level which indicates that plants with foreign linkages are significantly larger (have significantly larger market share) than pure domestic plants belonging to group 1 or group 4. In addition, the magnitude of the coefficient of \( FDI \) dummy is significantly larger than that of \( Licensee \) dummy, which means that foreign subsidiaries are larger (have larger market share) than domestic licensees.

At around mean or medium level of each dependent variables, compared to domestic plants with no foreign linkages, foreign subsidiaries on average are 5% – 6% larger and domestic licensees are about 1.7% larger in the logarithm of real total sales; foreign subsidiaries are 3.3% larger and domestic licensees are 1.7% larger in the logarithm of real value added; foreign subsidiaries are 5% larger and domestic licensees are 2.5% larger in the logarithm of total employment.

Comparing Table 5.5 to Table 5.6, the coefficients of \( Licensee \) are very similar in magnitude, while the coefficients of \( FDI \) are larger in magnitude under the total sales dependent variable (Ta-
Table 5.5: Foreign linkages (FDI and licensing) and plant size (market share) – Total Sales

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>50% capital share -- foreign plant</th>
<th>10% capital share -- foreign plant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>FDI dummy</td>
<td>0.649***</td>
<td>0.654***</td>
</tr>
<tr>
<td></td>
<td>(0.160)</td>
<td>(0.160)</td>
</tr>
<tr>
<td>Licensee Dummy</td>
<td>0.212***</td>
<td>0.214***</td>
</tr>
<tr>
<td></td>
<td>(0.060)</td>
<td>(0.060)</td>
</tr>
<tr>
<td>Constant</td>
<td>13.33***</td>
<td>10.48***</td>
</tr>
<tr>
<td></td>
<td>(0.898)</td>
<td>(1.677)</td>
</tr>
</tbody>
</table>

Number of plants 8,212   8,210   8,212   8,210   8,212   8,210   8,212   8,210
Industry Control 4-digit 4-digit  2-digit 2-digit  4-digit 4-digit  2-digit 2-digit
Time Control Yes Yes Yes Yes Yes Yes Yes Yes
Region Control Yes Yes Yes Yes Yes Yes Yes Yes
Other Controls Yes Yes Yes Yes Yes Yes Yes Yes

Other controls include population (region-year), average tariff rate (industry-year) and capital labor ratio (plant).
Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 5.6: Foreign linkages (FDI and licensing) and plant size (market share) – Value Added

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>50% capital share -- foreign plant</th>
<th>10% capital share -- foreign plant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>FDI dummy</td>
<td>0.406***</td>
<td>0.418***</td>
</tr>
<tr>
<td></td>
<td>(0.053)</td>
<td>(0.053)</td>
</tr>
<tr>
<td>Licensee Dummy</td>
<td>0.201***</td>
<td>0.206***</td>
</tr>
<tr>
<td></td>
<td>(0.026)</td>
<td>(0.026)</td>
</tr>
<tr>
<td>Constant</td>
<td>12.77***</td>
<td>10.84***</td>
</tr>
<tr>
<td></td>
<td>(0.232)</td>
<td>(0.580)</td>
</tr>
</tbody>
</table>

Observations 36,502  36,486  36,502  36,486  36,502  36,486  36,502  36,486
Number of plants 8,180   8,178   8,180   8,178   8,180   8,178   8,180   8,178
Industry Control 4-digit 4-digit  2-digit 2-digit  4-digit 4-digit  2-digit 2-digit
Time Control Yes Yes Yes Yes Yes Yes Yes Yes
Region Control Yes Yes Yes Yes Yes Yes Yes Yes
Other Controls Yes Yes Yes Yes Yes Yes Yes Yes

Other controls include population (region-year), average tariff rate (industry-year) and capital labor ratio (plant).
Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1
ble 5.5) than under the value added dependent variable (Table 5.6). This is very likely to be caused by the high value-added intermediate inputs purchase of foreign subsidiaries from their parent firms that reduce their total value added. However, even there is a different in the magnitudes of the coefficients of FDI under these two sets of regressions, the larger market share effect still exists for the foreign subsidiary group.

Table 5.7: Foreign linkages (FDI and licensing) and plant size (market share) – Total Employment

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>50% capital share – foreign plant</th>
<th>10% capital share – foreign plant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lnemp 1</td>
<td>lnemp 2</td>
</tr>
<tr>
<td>FDI dummy</td>
<td>0.170***</td>
<td>0.174***</td>
</tr>
<tr>
<td></td>
<td>(0.028)</td>
<td>(0.028)</td>
</tr>
<tr>
<td>Licensee Dummy</td>
<td>0.080***</td>
<td>0.079***</td>
</tr>
<tr>
<td></td>
<td>(0.018)</td>
<td>(0.019)</td>
</tr>
<tr>
<td>Constant</td>
<td>3.623***</td>
<td>3.072***</td>
</tr>
<tr>
<td></td>
<td>(0.314)</td>
<td>(0.455)</td>
</tr>
</tbody>
</table>

Observations: 36,845
Number of plants: 8,210
Industry Control: 4-digit
Time Control: Yes
Region Control: Yes
Other Controls: Yes

Other controls include population (region-year), average tariff rate (industry-year) and capital labor ratio (plant)
Robust standard errors in parentheses

5.4 Productivity Difference and Mode Choice

Question 3: Is FDI more likely to happen when the productivity difference between foreign plants and domestic firms is plants? Is licensing more likely to happen when this difference is low?

I use both plant-level data and 4-digit industry aggregate data to test this hypothesis. The plant-level test is using a probit regression to see how productivity difference between foreign firms and domestic firms will affect the mode choice of FDI decision or licensing decision. At the 4-digit
industry level, I test how this foreign-domestic productivity difference relates to the total numbers of FDI plants or domestic licensees and how it relates to the total industry-level foreign share or total industry-level licensing fee paid. The regression results are shown by Table 5.8 (probit regressions at plant-level), Table 5.9 (poisson MLE regressions of number of FDI plants or number of domestic licensees at 4-digit industry level) and Table 5.10 (total foreign share or total licensing fee at 4-digit industry level).

The key independent variable in both the plant-level probit regressions and the industry-level regressions is the foreign-domestic productivity difference. In order to construct this variable, weighted average total factor productivity by groups are calculated by weighting their real value of total sales at each 4-digit industry ($T_{FP}^{ijt} = \frac{\sum_{i} \text{sales}_{ijt} \ast T_{FP}^{ijt}}{\text{sales}_{ijt}}$). According to the theoretical explanations from chapter 2, domestic no-licensing exporters (group 4) should indicate the highest level of domestic productivity, and foreign subsidiaries (group 3) can represent the highest foreign productivity. And therefore this independent variable can be indicated by the difference between the natural log of weighted average industry-level productivity of group 3 and that of group 4. This productivity difference can be expressed by $\ln(T_{FP}^{3}) - \ln(T_{FP}^{4})$ where superscripts 3 and 4 indicate the group number (3 for foreign subsidiary and 4 for domestic no-licensing exporter). I further simplify this domestic-foreign productivity difference with notation $\ln(T_{FP}^{3}/T_{FP}^{4})$.

The probit regression is expressed by the following equation:

$$ y_{it} = \alpha + \beta \ast \ln(T_{FP}^{3}/T_{FP}^{4})_{jt} + \gamma_{1} \ast Industrydummies_{j} + \gamma_{2} \ast Regiondummies_{r} + \gamma_{3} \ast Timedummies_{t} + \gamma_{4} \ast Othercontrols + \epsilon_{it}, \quad (5.3) $$

in which, $y_{it}$ is either $FDI$ dummy (shown by column 1, 3, 5, 7 in Table 5.8) or $Licensee$ dummy (shown by column 2, 4, 6, 8 in Table 5.8). 2-digit industry controls, time controls and region controls are also included in these regressions. In addition, other controls include population (region-year level), average tariff rate (industry-year level) and capital labor ratio (plant level). Similar to the regressions in the previous sections, 50% capital share foreign plants definition (first four columns in Table 5.8) and 10% capital share foreign plants definition (last four columns in Table 5.8) are
Table 5.8: Foreign linkages (FDI and licensing) and productivity difference – plant level

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>(1) fdi50</th>
<th>(2) license1</th>
<th>(3) fdi50</th>
<th>(4) license1</th>
<th>(5) fdi10</th>
<th>(6) license2</th>
<th>(7) fdi10</th>
<th>(8) license2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ln(TFP3/TFP4)</td>
<td>0.037***</td>
<td>-0.040***</td>
<td></td>
<td></td>
<td>-0.0054</td>
<td>-0.061***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.012)</td>
<td>(0.012)</td>
<td>(0.009)</td>
<td></td>
<td></td>
<td>(0.010)</td>
<td>(0.010)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lagged 1 period ln(TFP3/TFP4)</td>
<td>0.034***</td>
<td>-0.034***</td>
<td>-0.013</td>
<td>-0.056***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.013)</td>
<td>(0.014)</td>
<td>(0.010)</td>
<td></td>
<td></td>
<td>(0.011)</td>
<td>(0.011)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>28,510</td>
<td>28,432</td>
<td>22,194</td>
<td>22,194</td>
<td>29,361</td>
<td>29,309</td>
<td>22,869</td>
<td>22,869</td>
</tr>
<tr>
<td>Industry Control</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Time Control</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Region Control</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Other Controls</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Other controls include population (region-year), average tariff rate (industry-year) and capital labor ratio (plant)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard errors in parentheses</td>
<td>*** p&lt;0.01, ** p&lt;0.05, * p&lt;0.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Moreover, I use both current period productivity difference $ln(TFP3/TFP4)_{jt}$ (column 1, 2, 5, 6) and lagged one period productivity difference $ln(TFP3/TFP4)_{j(t-1)}$ (column 3, 4, 7, 8) as the independent variable, and the results are very similar. Most results are consistent with the theoretical prediction that with a larger productivity difference between these two types of plants, FDI is more likely to take place and licensing is less likely to happen. The coefficients of $ln(TFP3/TFP4)$ for the FDI regressions are positive and significant (column 1 and 3); and the coefficients of $ln(TFP3/TFP4)$ are all negative and significant (column 2, 4, 6, 8). The productivity difference effect is not strong enough to show up at 10% capital share foreign plants definition set-up probably because the decision of majority ownership does matter to some extent when the parent firm sets up a foreign subsidiary abroad.

In order to test the industry-level effect of this hypothesis, I aggregate the plant-level data into 4-digit industry level. There are two sets of dependent variables which are testable and interesting. First set is the total number of foreign plants or total number of domestic licensees at 4-digit industry level. Since these two dependent variables are both count data, it is natural to use Poisson MLE reported by Table 5.9. Second set of dependent variables is the total industry-level
foreign share or total industry-level licensing fee paid shown by Table 5.10. Both these two variables are weighted by the real value of sales of each plant. The regression equation is:

\[ y_{jt} = \alpha + \beta_1 \cdot \ln(\text{TFP}3/\text{TFP}4)_{jt} + \beta_2 \cdot 4\text{digitIndustrySize} + Y_1 \cdot \text{Industrydummies}_{jt} + Y_3 \cdot \text{Timedummies}_{it} + \epsilon_{jt}, \] (5.4)

where \( y_{jt} \) can be

1. No. of FDI plants (Poisson MLE regression),
2. No. of domestic licensees (Poisson MLE regression),
3. weighted average foreign share \( \left( \sum_{i} \frac{\text{sales}_{ijt}}{\text{sales}_{ijt}} \cdot \text{foreignshare}_{ijt} \right) \) (Pooled OLS regression),
4. logarithm of weighted average licensing fee \( \ln \left( \sum_{i} \frac{\text{sales}_{ijt}}{\text{sales}_{ijt}} \cdot \text{licensingfee}_{ijt} \right) \) (Pooled OLS regression).

The industry controls are at 2-digit, so I also include a 4-digit industry size control variable in these regressions. The 4-digit industry size control variable is the total number of plants in Table 5.9 with dependent variable (1) and (2); and it is the logarithm of industry total sales in Table 5.10 with dependent variable (3) and (4).

Table 5.9 and Table 5.10 report the results consistent with the theoretical predictions and plant-level regressions (Table 5.8). The coefficients of foreign-domestic productivity variable are all positive and significant under all regressions with dependent variable FDI dummy (column 1 and 3 in both Table 5.9 and Table 5.10). And the coefficients are negative and significant under all regressions with dependent variable Licensing dummy (column 2 and 4 in both Table 5.9 and Table 5.10). If the productivity advantage is larger for foreign plants, there are more foreign subsidiaries and fewer domestic licensees.
Table 5.9: Foreign linkages (No. of foreign plants and No. of domestic licensees) and productivity difference – 4-digit industry level

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>50% capital share -- FDI</th>
<th>10% capital share -- FDI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>No. of FDIs</td>
<td>0.0645**</td>
<td>-0.0772***</td>
</tr>
<tr>
<td></td>
<td>(0.033)</td>
<td>(0.025)</td>
</tr>
<tr>
<td>No. of Plants</td>
<td>0.00147***</td>
<td>0.00197***</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>Observations</td>
<td>385</td>
<td>291</td>
</tr>
<tr>
<td>Industry Control</td>
<td>2-digit</td>
<td>2-digit</td>
</tr>
<tr>
<td>Time Control</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
| Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 5.10: Foreign linkages (average foreign shares and average licensing fee) and productivity difference – 4-digit industry level

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>50% capital share -- FDI</th>
<th>10% capital share -- FDI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>ln(TFP3/TFP4)</td>
<td>7.452***</td>
<td>-0.170</td>
</tr>
<tr>
<td></td>
<td>(1.347)</td>
<td>(0.134)</td>
</tr>
<tr>
<td>ln(total sales)</td>
<td>-1.516</td>
<td>0.588**</td>
</tr>
<tr>
<td></td>
<td>(1.904)</td>
<td>(0.277)</td>
</tr>
<tr>
<td>Observations</td>
<td>385</td>
<td>291</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.545</td>
<td>0.306</td>
</tr>
<tr>
<td>Industry Control</td>
<td>2-digit</td>
<td>2-digit</td>
</tr>
<tr>
<td>Time Control</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
| Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1
5.5 Concluding Remarks

In this chapter, I find some empirical supports from Chilean plant-level panel data with respect to two sets of the theoretical predictions from chapter 3. First, foreign linkages (licensing and FDI) are associated with higher plant-level productivity compared with domestic plants with no access to foreign linkages. Foreign subsidiaries are even more productive than domestic licensees. The foreign linkage effect also carries to plant size (market share) that both foreign subsidiaries and domestic licensees are larger in size than pure domestic plants. Second, a larger productivity difference between more productive foreign plants and less productive domestic plants encourages FDI and discourages licensing. A smaller productivity difference will have the opposite effect on the mode choice.
Bibliography


Appendix A

Derivations for Chapter 2

A.1 Basic Model

A.1.1 Closed Economy

In country \( h \), firm \( H \) is a monopoly firm under the closed economy facing a linear inverse market demand:

\[
P_h = \alpha - \beta X_h. \tag{A.1}
\]

Firm \( H \)'s marginal cost function is

\[
c_H = \eta_H - \theta_H I_H^\frac{1}{2} \tag{A.2}
\]

which reveals the relationship between firm \( H \)'s marginal cost \( c_H \) and its R&D investment level \( I_H \).

Both \( \eta_H \) and \( \theta_H \) are positive, with \( \eta_H \) reflecting the base productivity (base marginal cost) of firm \( H \) and \( \theta_H \) showing firm \( H \)'s transformability from R&D investment to productivity improvement. A smaller \( \eta_H \) and/or a larger \( \theta_H \) indicate a more efficient ex-ante cost function for firm \( H \).

Firm \( H \) makes a two-stage decision to maximize its profit. In the first stage, firm \( H \) determines its R&D investment level, and thus the marginal cost (productivity) is decided according to the marginal cost function. In the second stage, firm \( H \) needs to choose its monopoly output and market price given the marginal cost level determined in the first stage. The closed economy model can be solved by backward induction for this monopoly firm (firm \( H \)).

Step 1: In the second stage, assume that the marginal cost of firm \( H \) has already determined at \( c_H^C \) with the optimal R&D investment at \( I_H^C \).
The profit function of firm $H$ is

$$
\pi^C_H = (\alpha - \beta X^C_H) X^C_H - c^C_H X^C_H - I^C_H. \tag{A.3}
$$

In order to maximize the profit of firm $H$, the first order condition is

$$
\alpha - 2\beta X^C_H = c^C_H. \tag{A.4}
$$

Thus, in equilibrium, firm $H$’s output is

$$
X^C_H = \frac{\alpha - c^C_H}{2\beta}, \tag{A.5}
$$

and market price in country $h$ is

$$
P^C_h = \frac{\alpha + c^C_H}{2}. \tag{A.6}
$$

By plugging output $X^C_H$ (A.5) and market price $P^C_h$ (A.6) into the profit function (A.3), the profit of firm $H$ can be expressed as a function of its marginal cost $c^C_H$ and R&D investment $I^C_H$:

$$
\pi^C_H = \frac{(\alpha - c^C_H)^2}{4\beta} - I^C_H. \tag{A.7}
$$

Step 2: In the first stage, allow R&D investment of firm $H$ to change to maximize its profit (A.7), the first order condition with respect to $I^C_H$ is

$$
\frac{\partial \pi^C_H}{\partial I^C_H} = \frac{(c^C_H - \alpha)}{2\beta} \cdot \frac{\partial c^C_H}{\partial I^C_H} - 1 = 0. \tag{A.8}
$$

Plugging $c^C_H$ in (A.2) and $\frac{\partial c^C_H}{\partial I^C_H} = -\frac{1}{2} \theta^2_H I^C_H$, the optimal R&D investment in the closed economy for firm $H$ is

$$
I^C_H = \left( \frac{\alpha - \eta_H}{4\beta - \theta_H^2} \right)^2.
$$

Accordingly,

$$
I^C_H = \left( \frac{\alpha - \eta_H}{4\beta - \theta_H^2} \right)^2,
$$

$$
c^C_H = \eta_H - \frac{(\alpha - \eta_H) \theta^2_H}{4\beta - \theta_H^2},
$$
Similarly, in country $f$ with market demand $P_f = \alpha - \beta X_f$ and a monopoly firm (firm $F$) having the cost function $c_F = \eta_F - \theta F I_F^2$, the optimal R&D investment level $I_C^F$, marginal cost level $c_C^F$, quantity $X_C^F$, price $P_C^F$, and profit $\pi_C^F$ are as following:

\[
I_C^F = \left(\frac{(\alpha - \eta F) \theta F}{4\beta - \theta^2_F}\right)^2,
\]

\[
c_C^F = \eta_F - \frac{(\alpha - \eta F) \theta^2_F}{4\beta - \theta^2_F},
\]

\[
X_C^F = \frac{2(\alpha - \eta F)}{4\beta - \theta^2_F},
\]

\[
P_C^F = \frac{2\beta (\alpha + \eta F) - \alpha \theta^2_F}{4\beta - \theta^2_F},
\]

\[
\pi_C^F = \frac{(\alpha - \eta F)^2}{4\beta - \theta^2_F}.
\]

(A.10)

A.1.2 Open Economy

In the open economy, there is a variable trade cost $t$. Both firm $H$ and firm $F$ will incur the same unit trade cost if they choose to export to the other country.

The inverse demand function of country $h$ and $f$ in the open economy are

\[
P = \alpha - \beta (X_{Hh} + X_{Fh})
\]

\[
P = \alpha - \beta (X_{Hf} + X_{Ff})
\]

(A.11)

respectively. It is also a two-stage game. Both firms need to choose their R&D investment levels to determine their marginal costs (productivity) first. Then they have to figure out their best response functions in the Cournot competition and hence determine their quantities, price and maximized profits.

Step 1: Suppose that both firms have decided their R&D investments and marginal costs.
The profit functions of firm $H$ and firm $F$ are

$$\pi^O_H = \left[ \alpha - \beta \left( X^O_{Hh} + X^O_{Fh} \right) - c^O_H \right] X^O_{Hh} + \left[ \alpha - \beta \left( X^O_{Hf} + X^O_{Ff} \right) - c^O_H - t \right] X^O_{Hf} - I^O_H,$$

$$\pi^O_F = \left[ \alpha - \beta \left( X^O_{Hh} + X^O_{Fh} \right) - c^O_F - t \right] X^O_{Fh} + \left[ \alpha - \beta \left( X^O_{Hf} + X^O_{Ff} \right) - c^O_F \right] X^O_{Ff} - I^O_F. \quad (A.12)$$

By deriving the first order conditions of the above two profit functions with respect to $X^O_{Hh}$, $X^O_{Hf}$, $X^O_{Fh}$ and $X^O_{Ff}$ respectively, in the equilibrium,

Quantities:

$$X^O_{Hh} = \frac{1}{3\beta} \left( \alpha - 2c^O_H + c^O_F + t \right),$$

$$X^O_{Hf} = \frac{1}{3\beta} \left( \alpha - 2c^O_H + c^O_F - 2t \right),$$

$$X^O_{Fh} = \frac{1}{3\beta} \left( \alpha - 2c^O_F + c^O_H - 2t \right),$$

$$X^O_{Ff} = \frac{1}{3\beta} \left( \alpha - 2c^O_F + c^O_H + t \right). \quad (A.13)$$

Price: (same in both country)

$$P^O_h = P^O_f = \frac{1}{3} \left( \alpha + c^O_H + c^O_F + t \right). \quad (A.14)$$

Profits:

$$\pi^O_H = \frac{1}{9\beta} \left( \alpha - 2c^O_H + c^O_F + t \right)^2 + \frac{1}{9\beta} \left( \alpha - 2c^O_F + c^O_H + t \right)^2 - I^O_H,$$

$$\pi^O_F = \frac{1}{9\beta} \left( \alpha - 2c^O_F + c^O_H + t \right)^2 + \frac{1}{9\beta} \left( \alpha - 2c^O_F + c^O_H - 2t \right)^2 - I^O_F. \quad (A.15)$$

Step 2: In order to maximize the profit, by deriving the first order conditions with respect to $I^O_H$ and $I^O_F$ of (A.15), the optimal R&D investment levels are determined:

$$I^O_H = \left\{ \frac{4\theta_H \left[ \left( 9\beta - 12\theta^2_F \right) \alpha - \left( 18\beta - 12\theta^2_F \right) \eta_H + 9\beta \eta_F - (4.5\beta + 6\theta^2_F) t \right]}{(9\beta - 8\theta^2_H)(9\beta - 8\theta^2_F) - 16\theta^2_H \theta^2_F} \right\}^2,$$

$$I^O_F = \left\{ \frac{4\theta_F \left[ \left( 9\beta - 12\theta^2_H \right) \alpha - \left( 18\beta - 12\theta^2_H \right) \eta_F + 9\beta \eta_H - (4.5\beta + 6\theta^2_H) t \right]}{(9\beta - 8\theta^2_F)(9\beta - 8\theta^2_H) - 16\theta^2_H \theta^2_F} \right\}^2. \quad (A.16)$$

By plugging (A.16) into the marginal cost functions of firm $H$ and firm $F$ and (A.13) – (A.15), the intra-industry allocations between two firms in the open economy can be expressed as functions of the demand parameters ($\alpha$ and $\beta$), the trade cost parameter ($t$) and the cost function parameters ($\eta_H$, $\theta_H$, $\eta_F$ and $\theta_F$).
A.2 Extended Model

In this extended model, there are two firms competing against each other under a Cournot competition market in each country. Firm 1 and 2 are the domestic firms for country \( h \) and firm 3 and 4 are the domestic firms for country \( f \).

A.2.1 Closed Economy

In the closed economy, firm 1 and 2 are serving country \( h \)’s consumers with a linear inverse demand function

\[
P_h = \alpha - \beta X_h
\]  

(A.17)

in which \( X_h = X_1 + X_2 \) and firm 3 and 4 are serving country \( f \)’s consumers with an inverse demand function

\[
P_f = \alpha - \beta X_f
\]  

(A.18)

in which \( X_f = X_3 + X_4 \). Each firm’s marginal cost function is

\[
c_i = \eta_i - \theta_i I_i^\frac{3}{2}, \quad i = 1, 2, 3, 4
\]  

(A.19)

with both \( \eta_i \) and \( \theta_i \) positive.

Step 1: In country \( h \), assume that firm 1 and firm 2’s R&D investment levels \( I_1^C \) and \( I_2^C \) are determined. Thus the marginal costs \( (c_1^C \text{ and } c_2^C) \) are also known. The profit functions for firm 1 and firm 2 are

\[
\pi_1^C = \left[ \alpha - \beta (X_1^C + X_2^C) \right] X_1^C - c_1^C X_1^C - I_1^C,
\]

\[
\pi_2^C = \left[ \alpha - \beta (X_1^C + X_2^C) \right] X_2^C - c_2^C X_2^C - I_2^C.
\]

(A.20)

By taking first order derivatives with respect to \( X_1^C \) and \( X_2^C \), the first order conditions are

\[
\alpha - 2\beta X_1^C - \beta X_2^C - c_1^C = 0,
\]

\[
\alpha - \beta X_1^C - 2\beta X_2^C - c_2^C = 0.
\]

(A.21)
Firm 1 and firm 2’s profit-maximizing quantities, price and profits can be expressed as a function of their marginal costs as following.

Quantities:

\[
X^C_1 = \frac{1}{3\beta} \left( \alpha - 2c^C_1 + c^C_2 \right), \\
X^C_2 = \frac{1}{3\beta} \left( \alpha - 2c^C_2 + c^C_1 \right). 
\]  
(A.22)

Price:

\[
P^C_h = \frac{1}{3} \left( \alpha + c^C_1 + c^C_2 \right). 
\]  
(A.23)

Profits:

\[
\pi^C_1 = \frac{1}{9\beta} \left( \alpha - 2c^C_1 + c^C_2 \right)^2 - I^C_1, \\
\pi^C_2 = \frac{1}{9\beta} \left( \alpha - 2c^C_2 + c^C_1 \right)^2 - I^C_2. 
\]  
(A.24)

Step 2: In order to maximize the profits, the optimal R&D investment levels and also the marginal costs according can be determined by deriving the first order conditions of (A.24) with respect to \( I^C_1 \) and \( I^C_2 \). \( I^C_1 \) and \( I^C_2 \) can be solved and \( c^C_1 \) and \( c^C_2 \) can be determined.

\[
I^C_1 = \left\{ \frac{2\theta_1 \left[ (9\beta - 6\theta_2^2) \alpha - (18\beta - 6\theta_1^2) \eta_1 + 9\beta \eta_2 \right]}{(9\beta - 4\theta_1^2) (9\beta - 4\theta_2^2) - 4\theta_1^2 \theta_2^2} \right\}^2, \\
I^C_2 = \left\{ \frac{2\theta_2 \left[ (9\beta - 6\theta_1^2) \alpha - (18\beta - 6\theta_2^2) \eta_2 + 9\beta \eta_1 \right]}{(9\beta - 4\theta_1^2) (9\beta - 4\theta_2^2) - 4\theta_1^2 \theta_2^2} \right\}^2. 
\]  
(A.25)

By replacing \( I^C_1 \) and \( I^C_2 \) with (A.25) in firm 1 and firm 2’s marginal cost functions and their corresponding intra-industry allocations (A.22) – (A.24), the closed economy model in country \( h \) is solved.

The closed economy model in country \( f \) with firm 3 and firm 4 can be solved in the same way with very similar results as those in country \( h \), by simply replacing subscript \( h \) with \( f \), 1 with 2 and 3 with 4.
A.2.2 Open Economy

There is no variable trade cost in the open economy. There are four firms selling homogeneous goods and competing in the world market. The world demand equals the sum of the two countries’ demands which is

\[ P = \alpha - \beta (X_h + X_f) / 2 = \alpha - \beta (X_1 + X_2 + X_3 + X_4) / 2. \]  

(A.26)

Step 1: Assume that four firms’ R&D investment levels \( I^O_i \) \((i = 1, 2, 3, 4)\) are determined. Thus their marginal costs \((c^O_i)\) are also known. The profit functions for these four firms are

\[
\begin{align*}
\pi^O_1 &= \left[ \alpha - \frac{\beta}{2} (X^O_1 + X^O_2 + X^O_3 + X^O_4) \right] X^O_1 - c^O_1 X^O_1 - I^O_1, \\
\pi^O_2 &= \left[ \alpha - \frac{\beta}{2} (X^O_1 + X^O_2 + X^O_3 + X^O_4) \right] X^O_2 - c^O_2 X^O_2 - I^O_2, \\
\pi^O_3 &= \left[ \alpha - \frac{\beta}{2} (X^O_1 + X^O_2 + X^O_3 + X^O_4) \right] X^O_3 - c^O_3 X^O_3 - I^O_3, \\
\pi^O_4 &= \left[ \alpha - \frac{\beta}{2} (X^O_1 + X^O_2 + X^O_3 + X^O_4) \right] X^O_4 - c^O_4 X^O_4 - I^O_4.
\end{align*}
\]

(A.27)

The first order conditions of these profit functions (with respect to \( X^O_i \)) are

\[
\frac{\beta}{2} X^O_i = \alpha - \frac{\beta}{2} (X^O_1 + X^O_2 + X^O_3 + X^O_4) - c^O_i, \quad i = 1, 2, 3, 4.
\]

(A.28)

These firms’ profit-maximizing quantities, price and profits can be expressed as a function of their marginal costs as following.

Quantities:

\[
X^O_i = \frac{2}{5\beta} \left( \alpha + \sum_{j=1}^{4} c^O_j - 5c^O_i \right), \quad i = 1, 2, 3, 4.
\]

(A.29)

Prices: (same in both countries)

\[
P^O_h = P^O_f = \frac{1}{5} \left( \alpha + \sum_{j=1}^{4} c^O_j \right).
\]

(A.30)
Profits:
\[
\pi_i^O = \frac{2}{25\beta} \left( \alpha + \sum_{j=1}^{4} c_j^O - 5c_i^O \right)^2 - I_i^O, \ i = 1, 2, 3, 4. \tag{A.31}
\]

Step 2: By taking first order derivatives with respect to \(I_i^O\) of the four equations in (A.31), the following system of equations can be derived. The solution of (A.32) shows the optimal R&D investment levels \(I_i^O\) (\(i = 1, 2, 3, 4\)).

\[
\left( \frac{25\beta}{8\theta_1} - 4\theta_1 \right) (I_1^O)^{1/2} + \theta_2 (I_2^O)^{1/2} + \theta_3 (I_3^O)^{1/2} + \theta_4 (I_4^O)^{1/2} = \alpha - 4\eta_1 + \eta_2 + \eta_3 + \eta_4
\]

\[
\theta_1 (I_1^O)^{1/2} + \left( \frac{25\beta}{8\theta_2} - 4\theta_2 \right) (I_2^O)^{1/2} + \theta_3 (I_3^O)^{1/2} + \theta_4 (I_4^O)^{1/2} = \alpha + \eta_1 - 4\eta_2 + \eta_3 + \eta_4
\]

\[
\theta_1 (I_1^O)^{1/2} + \theta_2 (I_2^O)^{1/2} + \left( \frac{25\beta}{8\theta_3} - 4\theta_3 \right) (I_3^O)^{1/2} + \theta_4 (I_4^O)^{1/2} = \alpha + \eta_1 + \eta_2 - 4\eta_3 + \eta_4
\]

\[
\theta_1 (I_1^O)^{1/2} + \theta_2 (I_2^O)^{1/2} + \theta_3 (I_3^O)^{1/2} + \left( \frac{25\beta}{8\theta_4} - 4\theta_4 \right) (I_4^O)^{1/2} = \alpha + \eta_1 + \eta_2 + \eta_3 - 4\eta_4 \tag{A.32}
\]

After knowing the optimal R&D investment levels \(I_i^O\), the marginal costs of all four firms and their corresponding intra-industry allocations (market outputs, market price and profits) can be derived.
Appendix B

Derivations for Chapter 3

B.1 Ex-ante Efficiency Effect

B.1.1 Case 1 (Exporting):

In the open economy, there is a variable trade cost $t$. Both firm $H$ and firm $F$ will incur the same unit trade cost if they choose to export to the other country.

The inverse demand function of country $h$ and $f$ in the open economy are

$$ P = \alpha - \beta (X_{Hh} + X_{Fh}) $$

$$ P = \alpha - \beta (X_{Hf} + X_{Ff}) $$

respectively.

Step 1: Suppose that both firms have decided their R&D investments and marginal costs. The profit functions of firm $H$ and firm $F$ are

$$ \pi^E_H = \left[ \alpha - \beta \left( X^E_{Hh} + X^E_{Fh} \right) - c^E_H \right] X^E_{Hh} + \left[ \alpha - \beta \left( X^E_{Hf} + X^E_{Ff} \right) - c^E_H - t \right] X^E_{Hf} - I^E_H, $$

$$ \pi^E_F = \left[ \alpha - \beta \left( X^E_{Hh} + X^E_{Fh} \right) - c^E_F - t \right] X^E_{Fh} + \left[ \alpha - \beta \left( X^E_{Hf} + X^E_{Ff} \right) - c^E_F \right] X^E_{Ff} - I^E_F. $$

(B.2)

By deriving the first order conditions of the above two profit functions with respect to $X^E_{Hh}$, $X^E_{Hf}$, $X^E_{Fh}$ and $X^E_{Ff}$ respectively, in the equilibrium, Quantities:

$$ X^E_{Hh} = \frac{1}{3\beta} \left( \alpha - 2c^E_H + c^E_F + t \right), $$
\[ X^E_H = \frac{1}{3\beta} (\alpha - 2c^E_H + c^E_F - 2t), \]
\[ X^E_F = \frac{1}{3\beta} (\alpha - 2c^E_F + c^E_H - 2t), \]
\[ X^E_{Ff} = \frac{1}{3\beta} (\alpha - 2c^E_F + c^E_H + t). \]  
(B.3)

Price: (same in both country)
\[ P^E_h = P^E_f = \frac{1}{3} (\alpha + c^E_H + c^E_F + t). \]  
(B.4)

Profits:
\[ \pi^E_H = \frac{1}{9\beta} (\alpha - 2c^E_H + c^E_F + t)^2 + \frac{1}{9\beta} (\alpha - 2c^E_F + c^E_H - 2t)^2 - I^E_H, \]
\[ \pi^E_F = \frac{1}{9\beta} (\alpha - 2c^E_F + c^E_H + t)^2 + \frac{1}{9\beta} (\alpha - 2c^E_F + c^E_H - 2t)^2 - I^E_F. \]  
(B.5)

Welfare levels:
\[ w^E_h = \frac{1}{18\beta} (2\alpha - c^E_H - c^E_F - t)^2 + \frac{1}{9\beta} (\alpha - 2c^E_F + c^E_H + t)^2 + \frac{1}{9\beta} (\alpha - 2c^E_F + c^E_H - 2t)^2 - I^E_H, \]
\[ w^E_f = \frac{1}{18\beta} (2\alpha - c^E_H - c^E_F - t)^2 + \frac{1}{9\beta} (\alpha - 2c^E_F + c^E_H + t)^2 + \frac{1}{9\beta} (\alpha - 2c^E_F + c^E_H - 2t)^2 - I^E_F. \]  
(B.6)

Step 2: In order to maximize the profit, by deriving the first order conditions with respect to \( I^E_H \) and \( I^E_F \) of (B.5), the optimal R&D investment levels are determined:
\[ I^E_H = \left\{ \frac{4\theta_H [((9\beta - 12\theta^2_F) \alpha \beta - (18\beta - 12\theta^2_F) \eta_H + 9\beta \eta_F - (4.5\beta - 6\theta^2_F)t)]}{(9\beta - 8\theta^2_F) (9\beta - 8\theta^2_H) - 16\theta^2_H \theta^2_F} \right\}^2, \]
\[ I^E_F = \left\{ \frac{4\theta_F [((9\beta - 12\theta^2_H) \alpha \beta - (18\beta - 12\theta^2_H) \eta_F + 9\beta \eta_H - (4.5\beta - 6\theta^2_H)t)]}{(9\beta - 8\theta^2_H) (9\beta - 8\theta^2_H) - 16\theta^2_H \theta^2_F} \right\}^2. \]  
(B.7)

By plugging (B.7) into the marginal cost functions of firm \( H \) and firm \( F \) and (B.3) – (B.6), the intra-industry allocations between two firms in the open economy can be expressed as functions of the demand parameters (\( \alpha \) and \( \beta \)), the trade cost parameter (\( t \)) and the cost function parameters (\( \eta_H, \theta_H, \eta_F \) and \( \theta_F \)).

B.1.2 Case 2 (FDI):

Firm \( H \) chooses to do FDI by itself. It incurs a fixed exogenous FDI cost \( D \) and sets up a subsidiary in country \( f \). In this case, firm \( H \) does not have the variable trade cost when it sells
goods in country $f$. Since I assume that this fixed FDI cost is too large for less productive firm $F$ to afford, firm $F$ can only export to country $h$ by bearing a variable trade cost $t$.

Step 1: Suppose that both firms have decided their R&D investments and marginal costs. The profit functions of firm $H$ and firm $F$ are

$$
\pi_H^M = [\alpha - \beta (X_{hh}^M + X_{fh}^M) - c_H^M] X_{hh}^M + [\alpha - \beta (X_{hf}^M + X_{ff}^M) - c_H^M] X_{hf}^M - I_H^M - D,
$$

$$
\pi_F^M = [\alpha - \beta (X_{hh}^M + X_{fh}^M - c_F^M - t)] X_{fh}^M + [\alpha - \beta (X_{hf}^M + X_{ff}^M - c_F^M)] X_{ff}^M - I_F^M. \quad \text{(B.8)}
$$

By deriving the first order conditions of the above two profit functions with respect to $X_{hh}^M$, $X_{hf}^M$, $X_{fh}^M$ and $X_{ff}^M$ respectively, in the equilibrium,

Quantities:

$$
X_{hh}^M = \frac{1}{3\beta} \left( \alpha - 2c_H^M + c_F^M + t \right),
$$

$$
X_{hf}^M = \frac{1}{3\beta} \left( \alpha - 2c_H^M + c_F^M \right),
$$

$$
X_{fh}^M = \frac{1}{3\beta} \left( \alpha - 2c_F^M + c_H^M - 2t \right),
$$

$$
X_{ff}^M = \frac{1}{3\beta} \left( \alpha - 2c_F^M + c_H^M \right). \quad \text{(B.9)}
$$

Prices:

$$
P_{hh}^M = \frac{1}{3} \left( \alpha + c_H^M + c_F^M + t \right),
$$

$$
P_{hf}^M = \frac{1}{3} \left( \alpha + c_H^M + c_F^M \right). \quad \text{(B.10)}
$$

Profits:

$$
\pi_H^M = \frac{1}{9\beta} \left( \alpha - 2c_H^M + c_F^M + t \right)^2 + \frac{1}{9\beta} \left( \alpha - 2c_H^M + c_F^M \right)^2 - I_H^M - D,
$$

$$
\pi_F^M = \frac{1}{9\beta} \left( \alpha - 2c_F^M + c_H^M \right)^2 + \frac{1}{9\beta} \left( \alpha - 2c_F^M + c_H^M - 2t \right)^2 - I_F^M. \quad \text{(B.11)}
$$

Welfare levels:

$$
w_{hh}^M = \frac{1}{18\beta} \left( 2\alpha - c_H^M - c_F^M - t \right)^2 + \frac{1}{9\beta} \left( \alpha - 2c_H^M + c_F^M + t \right)^2 + \frac{1}{9\beta} \left( \alpha - 2c_H^M + c_F^M \right)^2 - I_H^M - D,
$$

$$
w_{hf}^M = \frac{1}{18\beta} \left( 2\alpha - c_H^M - c_F^M \right)^2 + \frac{1}{9\beta} \left( \alpha - 2c_F^M + c_H^M \right)^2 + \frac{1}{9\beta} \left( \alpha - 2c_F^M + c_H^M - 2t \right)^2 - I_F^M. \quad \text{(B.12)}
$$
Step 2: In order to maximize the profit, by deriving the first order conditions with respect to $I^M_H$ and $I^M_F$ of (B.11), the optimal R&D investment levels will be:

\[
I^M_H = \left\{ \frac{4\theta_H \left[ (9\beta - 12\theta^2_F) \alpha - (18\beta - 12\theta^2_H) \eta_H + 9\beta \eta_F + 4.5\beta t \right]}{(9\beta - 8\theta^2_F) (9\beta - 8\theta^2_H) - 16\theta^2_H \theta^2_F} \right\}^2,
\]

\[
I^M_F = \left\{ \frac{4\theta_F \left[ (9\beta - 12\theta^2_H) \alpha - (18\beta - 12\theta^2_H) \eta_F + 9\beta \eta_H - (9\beta - 6\theta^2_H) \right]}{(9\beta - 8\theta^2_F) (9\beta - 8\theta^2_H) - 16\theta^2_H \theta^2_F} \right\}^2. \quad (B.13)
\]

By plugging (B.13) into the marginal cost functions of firm $H$ and firm $F$ and (B.9) – (B.12), the intra-industry allocations between two firms in the open economy can be expressed as functions of the demand parameters ($\alpha$ and $\beta$), the trade cost parameter ($t$), the FDI fixed cost parameter ($D$) and the cost function parameters ($\eta_H$, $\theta_H$, $\eta_F$ and $\theta_F$).

**B.1.3 Case 3 (Licensing):**

When firm $H$ chooses to license its more efficient cost function to firm $F$, both firm $H$ and firm $F$ still have to incur the same variable trade cost when they export to the other country. The licensing case is a special situation of the export case with both firms enjoying the same ex-ante efficiency.

Step 1: Since the licensing case is a special situation of the export case with both firms enjoying the same ex-ante efficiency. According to (B.3) – (B.6),

Quantities:

\[
X^O_{Hh} = \frac{1}{3\beta} \left( \alpha - c^O_H + t \right),
\]

\[
X^O_{Hf} = \frac{1}{3\beta} \left( \alpha - c^O_H - 2t \right),
\]

\[
X^O_{Fh} = \frac{1}{3\beta} \left( \alpha - c^O_H - 2t \right),
\]

\[
X^O_{Ff} = \frac{1}{3\beta} \left( \alpha - c^O_H + t \right). \quad (B.14)
\]

Prices: (same in both countries)

\[
P^O_h = P^O_f = \frac{1}{3} \left( \alpha + 2c^O_H + t \right). \quad (B.15)
\]
Profits: (before licensing fee paid)

\[
\begin{align*}
\pi_{BO}^H &= \frac{1}{9\beta} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta} (\alpha - c_H^O - 2t)^2 - I_H^0, \\
\pi_{BO}^F &= \frac{1}{9\beta} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta} (\alpha - c_H^O - 2t)^2 - I_H^0. \\
\end{align*}
\] (B.16)

Profits: (after licensing fee paid)

\[
\begin{align*}
\pi_{BO}^H &= \frac{1}{9\beta} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta} (\alpha - c_H^O - 2t)^2 - I_H^0 + L, \\
\pi_{BO}^F &= \frac{1}{9\beta} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta} (\alpha - c_H^O - 2t)^2 - I_H^0 - L. \\
\end{align*}
\] (B.17)

Welfare levels:

\[
\begin{align*}
w_{OH}^O &= \frac{1}{18\beta} (2\alpha - 2c_H^O - t)^2 + \frac{1}{9\beta} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta} (\alpha - c_H^O - 2t)^2 - I_H^0 + L, \\
w_{OF}^O &= \frac{1}{18\beta} (2\alpha - 2c_H^O - t)^2 + \frac{1}{9\beta} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta} (\alpha - c_H^O - 2t)^2 - I_H^0 - L. \\
\end{align*}
\] (B.18)

Step 2: In order to maximize the profit, by deriving the first order conditions with respect to \(I_H^O\) and \(I_F^O\) of (B.17), the optimal R&D investment (same for both firms) is

\[
I_H^O = I_F^O = \left\{ \frac{\theta_H (\alpha - \eta_H - 0.5t)}{\frac{9}{4} \beta - \theta_H^2} \right\}^2.
\] (B.19)

By plugging (B.19) into the marginal cost functions of firm \(H\) and firm \(F\) and (B.14) – (B.18), the intra-industry allocations between two firms in the open economy can be expressed as functions of the demand parameters (\(\alpha\) and \(\beta\)), the trade cost parameter (\(t\)), the licensing fee parameter (\(L\)) and the cost function parameters (\(\eta_H, \theta_H, \eta_F\) and \(\theta_F\)).

Licensing fee actually equals all the extra profit that firm \(F\) can gain through this licensing transaction according to the model assumption, which is

\[
L = \pi_{BO}^F - \pi_{\pi_F}^E, \text{ if } \pi_{\pi_F}^E \geq \pi_{\pi_F}^M; \\
L = \pi_{BO}^F - \pi_{\pi_F}^M, \text{ if } \pi_{\pi_F}^E < \pi_{\pi_F}^M.
\] (B.20)
B.2 Market Size Effect

I release the symmetric demand assumption to allow two countries $h$ and $f$ to have different domestic inverse demand functions which are

$$P_i = \alpha - \beta_i X_i, \; i = h, f.$$  \hfill (B.21)

All the derivations are the same as in section B.1, except now different countries have different $\beta_i$.

B.2.1 Case 1 (Exporting):

R&D investments:

$$I^E_H = \left\{ \frac{4\theta_H \left[ (4.5B - 3\theta_F^2) \alpha - (9B - 3\theta_F^2) \eta_H + 4.5B\eta_F - (4.5B(2\beta_h - \beta_f) - 3\theta_F^2 2\beta_h)t / (\beta_f + \beta_h) \right]}{(9B - 4\theta_F^2) (9B - 4\theta_H^2) - 4\theta_H^2 \theta_F^2} \right\}^2,$$

$$I^E_F = \left\{ \frac{4\theta_F \left[ (4.5B - 3\theta_H^2) \alpha - (9B - 3\theta_H^2) \eta_F + 4.5B\eta_H - (4.5B(2\beta_f - \beta_h) - 3\theta_H^2 2\beta_f)t / (\beta_f + \beta_h) \right]}{(9B - 4\theta_H^2) (9B - 4\theta_F^2) - 4\theta_H^2 \theta_F^2} \right\}^2,$$

where:

$$B = \frac{\beta_h \beta_f}{\beta_h + \beta_f}.$$

Marginal costs:

$$c^E_H = \eta_H - \theta_H \sqrt{I^E_H},$$

$$c^E_F = \eta_F - \theta_F \sqrt{I^E_F}.$$  \hfill (B.23)

Quantities:

$$X^E_{Hh} = \frac{1}{3\beta_h} \left( \alpha - 2c^E_H + c^E_F + t \right),$$

$$X^E_{Hf} = \frac{1}{3\beta_f} \left( \alpha - 2c^E_H + c^E_F - 2t \right),$$

$$X^E_{Fh} = \frac{1}{3\beta_h} \left( \alpha - 2c^E_F + c^E_H - 2t \right),$$

$$X^E_{Ff} = \frac{1}{3\beta_f} \left( \alpha - 2c^E_F + c^E_H + t \right).$$  \hfill (B.24)
Prices: (same in both countries)

\[ P_H^E = P_F^E = \frac{1}{3} (\alpha + c_H^E + c_F^E + t). \] (B.25)

Profits:

\[ \pi_H^E = \frac{1}{9\beta_h} (\alpha - 2c_H^E + c_F^E + t)^2 + \frac{1}{9\beta_f} (\alpha - 2c_H^E + c_F^E - 2t)^2 - I_H^E, \]
\[ \pi_F^E = \frac{1}{9\beta_f} (\alpha - 2c_F^E + c_H^E + t)^2 + \frac{1}{9\beta_h} (\alpha - 2c_F^E + c_H^E - 2t)^2 - I_F^E. \] (B.26)

Welfare levels:

\[ w_H^E = \frac{1}{18\beta_h} (2\alpha - c_H^E - c_F^E - t)^2 + \frac{1}{9\beta_h} (\alpha - 2c_H^E + c_F^E + t)^2 + \frac{1}{9\beta_f} (\alpha - 2c_H^E + c_F^E - 2t)^2 - I_H^E, \]
\[ w_F^E = \frac{1}{18\beta_f} (2\alpha - c_F^E - c_H^E - t)^2 + \frac{1}{9\beta_f} (\alpha - 2c_F^E + c_H^E + t)^2 + \frac{1}{9\beta_h} (\alpha - 2c_F^E + c_H^E - 2t)^2 - I_F^E. \] (B.27)

B.2.2 Case 2 (FDI):

R&D investments:

\[ I_M^H = \left\{ \frac{4\theta_H \left[ (4.5B - 3\theta_F^2) \alpha - (9B - 3\theta_H^2) \eta_H + 4.5B\eta_F + (4.5B/\beta_h - 2\theta_F^2/\beta_h + 2\theta_F^2/\beta_f)Bt \right]}{\left(9B - 4\theta_H^2\right)(9B - 4\theta_F^2)} \right\}^2, \]
\[ I_M^F = \left\{ \frac{4\theta_F \left[ (4.5B - 3\theta_H^2) \alpha - (9B - 3\theta_H^2) \eta_F + 4.5B\eta_H - (9B/\beta_f - 4\theta_F^2/\beta_h + \theta_F^2/\beta_h)Bt \right]}{\left(9B - 4\theta_H^2\right)(9B - 4\theta_F^2)} \right\}^2, \] (B.28)

where:

\[ B = \frac{\beta_h \beta_f}{\beta_h + \beta_f}. \]

Marginal costs:

\[ c_M^H = \eta_H - \theta_H \sqrt{I_M^H}, \]
\[ c_M^F = \eta_F - \theta_F \sqrt{I_M^F}. \] (B.29)
Quantities:

\[ X_{Hh}^M = \frac{1}{3\beta_h} (\alpha - 2c_H^M + c_F^M + t), \]
\[ X_{Hf}^M = \frac{1}{3\beta_f} (\alpha - 2c_H^M + c_F^M), \]
\[ X_{Fh}^M = \frac{1}{3\beta_h} (\alpha - 2c_F^M + c_H^M - 2t), \]
\[ X_{Ff}^M = \frac{1}{3\beta_f} (\alpha - 2c_F^M + c_H^M). \]  

(B.30)

Prices:

\[ P_{\text{Hh}}^M = \frac{1}{3} (\alpha + c_H^M + c_F^M + t), \]
\[ P_{\text{Ff}}^M = \frac{1}{3} (\alpha + c_H^M + c_F^M). \]  

(B.31)

Profits:

\[ \pi_{Hh}^M = \frac{1}{9\beta_h} (\alpha - 2c_H^M + c_F^M + t)^2 + \frac{1}{9\beta_f} (\alpha - 2c_H^M + c_F^M)^2 - I_{Hh}^M - D, \]
\[ \pi_{Ff}^M = \frac{1}{9\beta_f} (\alpha - 2c_F^M + c_H^M)^2 + \frac{1}{9\beta_h} (\alpha - 2c_F^M + c_H^M - 2t)^2 - I_{Ff}^M. \]  

(B.32)

Welfare levels:

\[ w_{\text{Hh}}^M = \frac{1}{18\beta_h} (2\alpha - c_H^M - c_F^M - t)^2 + \frac{1}{9\beta_h} (\alpha - 2c_H^M + c_F^M + t)^2 + \frac{1}{9\beta_f} (\alpha - 2c_H^M + c_F^M)^2 - I_{Hh}^M - D, \]
\[ w_{\text{Ff}}^M = \frac{1}{18\beta_f} (2\alpha - c_F^M - c_H^M)^2 + \frac{1}{9\beta_f} (\alpha - 2c_F^M + c_H^M)^2 + \frac{1}{9\beta_h} (\alpha - 2c_F^M + c_H^M - 2t)^2 - I_{Ff}^M. \]  

(B.33)

B.2.3 Case 3 (Licensing):

R&D investments:

\[ I_{Hh}^O = I_{Ff}^O = \left( \frac{\theta_H (\alpha - \eta_H - (2/\beta_f - 1/\beta_h)Bt)}{\frac{9}{2}B - \theta_H^2} \right)^2, \]  

(B.34)

where:

\[ B = \frac{\beta_h \beta_f}{\beta_h + \beta_f}. \]

Marginal costs:

\[ c_H^O = \eta_H - \theta_H \sqrt{I_{Hh}^O} = c_F^O. \]  

(B.35)
Quantities:

\[ X_{Oh}^O = \frac{1}{3\beta_h} (\alpha - c_H^O + t) , \]
\[ X_{Oh}^O = \frac{1}{3\beta_f} (\alpha - c_H^O - 2t) , \]
\[ X_{Oh}^O = \frac{1}{3\beta_h} (\alpha - c_H^O - 2t) , \]
\[ X_{Oh}^O = \frac{1}{3\beta_f} (\alpha - c_H^O + t) . \] (B.36)

Prices: (same in both countries)

\[ P_h^O = P_f^O = \frac{1}{3} (\alpha + 2c_H^O + t) . \] (B.37)

Profits: (before licensing fee paid)

\[ \pi_{HO}^{BO} = \frac{1}{9\beta_h} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta_f} (\alpha - c_H^O - 2t)^2 - I_H^O, \]
\[ \pi_{FO}^{BO} = \frac{1}{9\beta_f} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta_h} (\alpha - c_H^O - 2t)^2 - I_H^O. \] (B.38)

Profits: (after licensing fee paid)

\[ \pi_{HO}^{O} = \frac{1}{9\beta_h} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta_f} (\alpha - c_H^O - 2t)^2 - I_H^O + L, \]
\[ \pi_{FO}^{O} = \frac{1}{9\beta_f} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta_h} (\alpha - c_H^O - 2t)^2 - I_H^O - L. \] (B.39)

Welfare levels:

\[ w_h^O = \frac{1}{18\beta_h} (2\alpha - 2c_H^O - t)^2 + \frac{1}{9\beta_h} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta_f} (\alpha - c_H^O - 2t)^2 - I_H^O + L, \]
\[ w_f^O = \frac{1}{18\beta_f} (2\alpha - 2c_H^O - t)^2 + \frac{1}{9\beta_f} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta_h} (\alpha - c_H^O - 2t)^2 - I_H^O - L. \] (B.40)

Licensing fee:

\[ L = \pi_{FO}^{BO} - \pi_{FO}^{M}, \text{ if } \pi_{FO}^{E} \geq \pi_{FO}^{M}; \]
\[ L = \pi_{FO}^{BO} - \pi_{FO}^{M}, \text{ if } \pi_{FO}^{E} < \pi_{FO}^{M} \] (B.41)
Appendix C

Derivations for Chapter 4

C.1 Choosing a Target Firm to Implement FDI

C.1.1 Greenfield Investment

Demand:

\[ P = \alpha - \beta X = \alpha - \beta (x_M + x_H + x_L) \quad (C.1) \]

Profit functions of the competing firms:

\[ \pi_M = [\alpha - \beta (x_M + x_H + x_L)] x_M - c_M x_M \]
\[ \pi_H = [\alpha - \beta (x_M + x_H + x_L)] x_H - c_H x_H \]
\[ \pi_L = [\alpha - \beta (x_M + x_H + x_L)] x_L - c_L x_L \quad (C.2) \]

In order to maximize the profits, first order conditions:

\[ \alpha - 2\beta x_M - \beta x_H - \beta x_L = c_M = 0 \]
\[ \alpha - \beta x_M - 2\beta x_H - \beta x_L = c_H = c \]
\[ \alpha - \beta x_M - \beta x_H - 2\beta x_L = c_L = \sigma c \quad (C.3) \]

By summing three equations in (C.3),

\[ 3\alpha - 4\beta x_M - 4\beta x_H - 4\beta x_L = (1 + \sigma) c \]
\[ 3\alpha - 4\beta (x_M + x_H + x_L) = (1 + \sigma) c \]
Equilibrium:

Total market output:

\[ X = \frac{3\alpha - (1 + \sigma)c}{4\beta} \]  
(C.4)

Market price:

\[ P = \alpha - \frac{3\alpha - (1 + \sigma)c}{4} = \frac{\alpha + (1 + \sigma)c}{4} \]  
(C.5)

Individual firms’ outputs (firm \( M \), firm \( H \) and firm \( L \)):

\[ x_M = \frac{\alpha + (1 + \sigma)c}{4\beta} \]
\[ x_H = \frac{\alpha + (\sigma - 3)c}{4\beta} \]
\[ x_L = \frac{\alpha + (1 - 3\sigma)c}{4\beta} \]  
(C.6)

The model assumes that all three competing firms can make a positive profit in the host country market, which implicitly assumes that the least productive firm (firm \( L \)) at least has a positive equilibrium output level under this most competitive FDI implementation target choice (greenfield investment). The condition for this implicit assumption is:

\[ \alpha > (3\sigma - 1)c \]

Individual firms’ (before FDI-cost) profits (firm \( M \), firm \( H \) and firm \( L \)):

\[ \pi_{Gb}^M = \frac{[\alpha + (1 + \sigma)c]^2}{16\beta} \]
\[ \pi_{Gb}^H = \frac{[\alpha + (\sigma - 3)c]^2}{16\beta} \]
\[ \pi_{Gb}^L = \frac{[\alpha + (1 - 3\sigma)c]^2}{16\beta} \]  
(C.7)

The latter two equations in (C.7) are also the potential FDI costs for acquiring a more productive firm and acquiring a less productive firm respectively. The FDI cost for greenfield investment is assumed to be zero.
C.1.2 Acquiring a More Productive Firm

Demand:

\[ P = \alpha - \beta X = \alpha - \beta x_M - \beta x_L \quad \text{(C.8)} \]

Profit functions of the competing firms:

\[ \pi_M = [\alpha - \beta (x_M + x_L)] x_M - c_M x_M \]
\[ \pi_L = [\alpha - \beta (x_M + x_L)] x_L - c_L x_L \quad \text{(C.9)} \]

In order to maximize the profits, first order conditions:

\[ \alpha - 2\beta x_M - \beta x_L = c_M = 0 \]
\[ \alpha - \beta x_M - 2\beta x_L = c_L = \sigma c \quad \text{(C.10)} \]

By summing two equations in (C.10),

\[ 2\alpha - 3\beta X = \sigma c \]

Equilibrium:
Total market output:
\[ X = \frac{2\alpha - \sigma c}{3\beta} \quad \text{(C.11)} \]

Market price:
\[ P = \frac{\alpha + \sigma c}{3} \quad \text{(C.12)} \]

Individual firms’ outputs (firm M and firm L):
\[ x_M = \frac{\alpha + \sigma c}{3\beta} \]
\[ x_L = \frac{\alpha - 2\sigma c}{3\beta} \quad \text{(C.13)} \]

Individual firms’ (before FDI-cost) profits (firm M and firm L):
\[ \pi^H_M = \frac{(\alpha + \sigma c)^2}{9\beta} \]
\[ \pi^H_L = \frac{(\alpha - 2\sigma c)^2}{9\beta} \quad \text{(C.14)} \]
C.1.3 Acquiring a Less Productive Firm

Demand:

\[ P = \alpha - \beta X = \alpha - \beta x_M - \beta x_H \]  
\[ (C.15) \]

Profit functions of the competing firms:

\[ \pi_M = [\alpha - \beta (x_M + x_H)] x_M - c_M x_M \]

\[ \pi_H = [\alpha - \beta (x_M + x_H)] x_H - c_H x_H \]  
\[ (C.16) \]

In order to maximize the profits, first order conditions:

\[ \alpha - 2\beta x_M - \beta x_H = c_M = 0 \]

\[ \alpha - \beta x_M - 2\beta x_H = c_H = c \]  
\[ (C.17) \]

By summing two equations in (C.17),

\[ 2\alpha - 3\beta X = c \]

Equilibrium:

Total market output:

\[ X = \frac{2\alpha - c}{3\beta} \]  
\[ (C.18) \]

Market price:

\[ P = \frac{\alpha + c}{3} \]  
\[ (C.19) \]

Individual firms’ outputs (firm M and firm H):

\[ x_M = \frac{\alpha + c}{3\beta} \]

\[ x_H = \frac{\alpha - 2c}{3\beta} \]  
\[ (C.20) \]

Individual firms’ (before FDI-cost) profits (firm M and firm H):

\[ \pi_{M}^{LB} = \frac{(\alpha + c)^2}{9\beta} \]

\[ \pi_{H}^{LB} = \frac{(\alpha - 2c)^2}{9\beta} \]  
\[ (C.21) \]
C.1.4 Comparing Three FDI Target Choices

By subtracting FDI costs from firm $M$’s (before FDI-cost) profits under different FDI target choices, the (after FDI-cost paid) profits for firm $M$ are:

$$\pi_G = \frac{(\alpha + (1 + \sigma)c)^2}{16\beta} - 0 = \frac{(3\alpha + 3\sigma c + 3c)(3\alpha + 3\sigma c + 3c)}{144\beta} \quad (C.22)$$

$$\pi_H = \frac{(\alpha + \sigma c)^2}{9\beta} - \frac{[\alpha + (\sigma - 3)c]^2}{16\beta} = \frac{(7\alpha + 7\sigma c - 9c)(\alpha + \sigma c + 9c)}{144\beta} \quad (C.23)$$

$$\pi_L = \frac{(\alpha + c)^2}{9\beta} - \frac{[\alpha + (1 - 3\sigma)c]^2}{16\beta} = \frac{(7\alpha + 7c - 9\sigma c)(\alpha + c + 9\sigma c)}{144\beta} \quad (C.24)$$

Comparing $\pi_H$ to $\pi_L$:

When $\pi_H \geq \pi_L$,

$$\frac{(7\alpha + 7\sigma c - 9c)(\alpha + \sigma c + 9c)}{(7\alpha + 7c - 9\sigma c)(\alpha + c + 9\sigma c)} \geq 1$$

$$\frac{(\alpha + \sigma c + 9c)}{(\alpha + c + 9\sigma c)} \geq \frac{(7\alpha + 7\sigma c - 9c)}{(7\alpha + 7\sigma c - 9c)}$$

$$\frac{1}{\alpha + c + 9\sigma c} \leq \frac{2}{7\alpha + 7\sigma c - 9c}$$

$$\alpha \leq \frac{11}{5} c (\sigma + 1),$$

in addition $\alpha > (3\sigma - 1)c$, so

$$(3\sigma - 1)c < \alpha \leq \frac{11}{5} c (\sigma + 1).$$

When $\pi_H < \pi_L$,

$$\alpha > \frac{11}{5} c (\sigma + 1).$$

Comparing $\pi_G$ to $\pi_H$:

When $\pi_G \geq \pi_H$,

$$\frac{(3\alpha + 3\sigma c + 3c)(3\alpha + 3\sigma c + 3c)}{(7\alpha + 7\sigma c - 9c)(\alpha + \sigma c + 9c)} \geq 1$$

$$\alpha^2 + 2(\sigma - 9)\alpha c + (\sigma - 3)(\sigma - 15)c^2 \geq 0$$

$$\alpha \geq (15 - \sigma)c.$$
When $\pi^G_M < \pi^H_M$,

$(\alpha > (3\sigma - 1)c)$

$(3\sigma - 1)c < \alpha < (15 - \sigma)c$.

Comparing $\pi^G_M$ to $\pi^L_M$:

When $\pi^G_M \geq \pi^L_M$,

$\alpha > (15\sigma - 1)c$.

When $\pi^G_M < \pi^L_M$,

$(\alpha > (3\sigma - 1)c)$

$(3\sigma - 1)c < \alpha < (15\sigma - 1)c$.

Summarizing all the conditions above,

When $\sigma \leq 4$ (small heterogeneity among firms),

$\pi^H_M$ is max when

$3\sigma - 2 < \frac{\alpha - c}{c} \leq \frac{11}{5}\sigma + \frac{6}{5};$

$\pi^L_M$ is max when

$\frac{11}{5}\sigma + \frac{6}{5} < \frac{\alpha - c}{c} < 15\sigma - 2;$

$\pi^G_M$ is max when

$\frac{\alpha - c}{c} \geq 15\sigma - 2.$

When $\sigma > 4$ (large heterogeneity among firms),

$\pi^L_M$ is max when

$3\sigma - 2 < \frac{\alpha - c}{c} < 15\sigma - 2;$

$\pi^G_M$ is max when

$\frac{\alpha - c}{c} \geq 15\sigma - 2.$
C.2 Choosing a Target Firm to Implement Licensing

According to the assumption that variable trade cost $t$ is zero in Chapter 4, the profits that these competing firms can earn in the host country under the exporting case are the same as the profits under the greenfield investment case. Please refer to the equations in (C.6):

\[
\begin{align*}
\pi^E_M &= \frac{[\alpha + (1 + \sigma) c]^2}{16\beta}, \\
\pi^E_H &= \frac{[\alpha + (\sigma - 3) c]^2}{16\beta}, \\
\pi^E_L &= \frac{[\alpha + (1 - 3\sigma) c]^2}{16\beta}.
\end{align*}
\] (C.25)

C.2.1 Licensing to a More Productive Firm

Demand:

\[ P = \alpha - \beta X = \alpha - \beta (x_M + x_H + x_L) \] (C.26)

Profit functions of the competing firms:

\[
\begin{align*}
\pi_M &= [\alpha - \beta (x_M + x_H + x_L)] x_M - c_M x_M \\
\pi_H &= [\alpha - \beta (x_M + x_H + x_L)] x_H - c_H x_H \\
\pi_L &= [\alpha - \beta (x_M + x_H + x_L)] x_L - c_L x_L
\end{align*}
\] (C.27)

In order to maximize the profits, first order conditions:

\[
\begin{align*}
\alpha - 2\beta x_M - \beta x_H - \beta x_L &= c_M = 0 \\
\alpha - \beta x_M - 2\beta x_H - \beta x_L &= c_H = c_M = 0 \\
\alpha - \beta x_M - \beta x_H - 2\beta x_L &= c_L = \sigma c
\end{align*}
\] (C.28)

Individual firms’ (before licensing fee paid) equilibrium profits (firm $M$, firm $H$ and firm $L$):

\[
\begin{align*}
\pi^Hb_{Ml} &= \frac{[\alpha + \sigma c]^2}{16\beta} \\
\pi^Hb_{Hl} &= \frac{[\alpha + \sigma c]^2}{16\beta} \\
\pi^Hb_{Ll} &= \frac{[\alpha - 3\sigma c]^2}{16\beta}
\end{align*}
\] (C.29)
In order to meet the assumption that the least productive firm (firm $L$) can still survive under the most competitive case, the licensing target choice model implicitly assumes that $\alpha > 3\sigma c$.

According to the second equation in (C.25), the maximum licensing fee that firm $H$ can afford is:

$$L^H = \frac{(\alpha + \sigma c)^2}{16\beta} - \frac{(\alpha - 3c + \sigma c)^2}{16\beta} = \frac{3c}{16\beta} (2\alpha + 2\sigma c - 3c).$$ (C.30)

So the after licensing fee paid profit for firm $M$ is

$$\pi^H_{Ml} = \pi^H_{Mi} + L^H = \frac{(\alpha + \sigma c)^2}{16\beta} + \frac{3c}{16\beta} (2\alpha + 2\sigma c - 3c).$$ (C.31)

### C.2.2 Licensing to a Less Productive Firm

#### Demand:

$$P = \alpha - \beta X = \alpha - \beta (x_M + x_H + x_L)$$ (C.32)

#### Profit functions of the competing firms:

$$\pi_M = [\alpha - \beta (x_M + x_H + x_L)] x_M - c_M x_M$$

$$\pi_H = [\alpha - \beta (x_M + x_H + x_L)] x_H - c_H x_H$$

$$\pi_L = [\alpha - \beta (x_M + x_H + x_L)] x_L - c_L x_L$$ (C.33)

In order to maximize the profits, first order conditions:

$$\alpha - 2\beta x_M - \beta x_H - \beta x_L = c_M = 0$$

$$\alpha - \beta x_M - 2\beta x_H - \beta x_L = c_H = c$$

$$\alpha - \beta x_M - \beta x_H - 2\beta x_L = c_L = c_M = 0$$ (C.34)

Individual firms’ (before licensing fee paid) equilibrium profits (firm $M$, firm $H$ and firm $L$):

$$\pi^L_{Ml} = \frac{[\alpha + c]^2}{16\beta}$$

$$\pi^L_{Hi} = \frac{[\alpha - 3c]^2}{16\beta}$$

$$\pi^L_{Li} = \frac{[\alpha + c]^2}{16\beta}$$ (C.35)
According to the third equation in (C.25), the maximum licensing fee that firm $L$ is willing to pay is:

$$\begin{align*}
L^L &= \frac{(\alpha + c)^2}{16\beta} - \frac{(\alpha - 3\sigma c + c)^2}{16\beta} = \frac{3\sigma c}{16\beta} (2\alpha + 2c - 3\sigma c).
\end{align*}$$  \hspace{1cm} (C.36)

So the after licensing fee paid profit for firm $M$ is

$$\begin{align*}
\pi^L_{ML} = \pi^L_{MB} + L^L &= \frac{(\alpha + c)^2}{16\beta} + \frac{3\sigma c}{16\beta} (2\alpha + 2c - 3\sigma c).
\end{align*}$$  \hspace{1cm} (C.37)

### C.2.3 Comparing Two Licensing Target Choices

Comparing $\pi^H_{ML}$ (C.31) to $\pi^L_{ML}$ (C.37):

- When $\pi^H_{ML} \geq \pi^L_{ML}$, ($\alpha > 3\sigma c$)
  
  $$3\sigma c < \alpha \leq \frac{5(\sigma + 1)c}{2}.$$

- When $\pi^H_{ML} < \pi^L_{ML}$,
  
  $$\alpha > \frac{5(\sigma + 1)c}{2}.$$

So, if $\sigma \leq 5$ (small heterogeneity among firms), $\pi^H_{ML}$ is max when

$$3\sigma - 1 < \frac{\alpha - c}{c} \leq \frac{5(\sigma - 1)}{2};$$

$\pi^L_{ML}$ is max when

$$\frac{\alpha - c}{c} > \frac{5(\sigma - 1)}{2}.$$

If $\sigma > 5$ (large heterogeneity among firms), $\pi^L_{ML}$ is always max.

Note: The licensing choices are better than pure exporting choices for firm $M$. $\pi^H_{ML} > \pi^E_{ML}$ requires that $\alpha > \frac{5 - 2\sigma}{2}c$, and $\pi^L_{ML} > \pi^E_{ML}$ needs that $\alpha > \frac{5\sigma - 2}{2}c$. These conditions are always satisfied as $a > 3\sigma c$. 