

Exporting, Licensing, FDI and Productivity Choice: Theory and Evidence from Chilean Data*

Yiqing Xie [†]

Department of Economics
University of Colorado at Boulder

First Draft: May 2011
This draft: November 8, 2011

*I'd like to thank my advisor, James Markusen, for his support, help and guidance. I appreciate all the time and efforts of the members on my thesis committees: James Markusen, Yongmin Chen, Keith Maskus, Thibault Fally. I also want to thank Luis Castro for kindly offering me the Chilean data set. I am grateful to Cecilia Fieler, Loretta Fung, Wolfgang Keller, Sylvain Leduc, Ben Li and Ken Teshima for helpful discussions; and the participants at Canadian Economic Association and Western Economic Association for useful comments.

[†]Contact Info: yiqingxie@gmail.com, +1(720)2359107, <http://spot.colorado.edu/~xiey>.

Abstract

This paper develops a trade model in which two heterogeneous firms located in two different countries make their productivity choices by choosing their optimal R&D investment levels and then make a mode choice between exporting, licensing and FDI under Cournot competition in an open economy. 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. Besides the ex-ante productivity effect, the model also shows how the difference in market demand sizes of two countries causes different preference among mode choices. I test two sets of theoretical hypotheses developed in this paper by using Chilean firm-level panel data from 2001 to 2007. These are how different mode choices are associated with different productivity *levels* and market shares and how the productivity *difference* between more productive foreign plants and less productive domestic plants affects the optimal mode choice decision. The empirical results are consistent with the model predictions.

1 Introduction

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 investment¹. 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 paper 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 paper refers to "horizontal" FDI which means that a firm acquires a subsidiary in a foreign country to produce a final product purchased directly by consumers.

According to the theoretical model, two sets of interesting and testable theoretical hypotheses initiate the empirical study of the Chilean plant-level panel data. First, different mode choices of a foreign firm play a different role in the productivity and intra-industry allocation in the host country. Second, what ends up being an optimal mode choice is actually a result from the interactions between the more productive foreign firms and the less productive domestic firms in the host country.

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

¹FDI in this paper indicates horizontal foreign direct investment.

(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 paper, 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 θ and base marginal cost η) 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 iceberg trade cost when exporting. If firm H prefers licensing, firm F gets firm H 's technology and competes against firm H in both markets². 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 iceberg trade cost. Then in the second stage, two firms determine their corresponding 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 paper is more realistic in considering the effect on the whole international market (both host country and source country). This paper illustrates a model that combines

²I assume no exclusive licensing in either country. It is trivial that both firms will get the highest profits and prefer licensing if I allow exclusive licensing since both firms can have monopoly power within its own country. In addition, exclusive licensing 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.

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 paper 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 paper offers a more complete analysis of this relationship than most of the monopolistic competition literature.

This paper 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 productivity 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 paper 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 case, 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.

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 set, licensing choice hasn't been well studied in the existing empirical literature.

In the empirical section of this paper, I use the Chilean plant-level panel data from 2001 to 2007 to study two sets of theoretical hypotheses.³ 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

³There 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 the paper.

choice can be studied.

As to the first set of theoretical 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 with 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 theoretical 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 observed in the data. If the productivity advantage of more productive foreign firms is smaller in an industry, more licensing transactions are observed.

The following section (section 2) studies the interaction between productivity choice and mode choice by holding the market demand sizes of two countries 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 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 productivity effect by holding market sizes the same (section 2) from the market size effect by fixing the cost functions (section 3) on the productivity choice and mode choice. Given the Chilean data, I treat Chile as a host country and test two sets of hypotheses generated from the theoretical model in section 4. The last section (section 5) gives a brief conclusion of this paper.

2 (Ex-ante) Productivity Effect

2.1 Model Set-up

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

$$P = \alpha - \beta X, \quad (1)$$

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

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

which captures the relationship between firm H 's marginal cost c_H and its R&D investment level I_H with both η_H and θ_H positive. η_H is the base marginal cost (productivity) of firm H and θ_H indicates the R&D investment to productivity transformability. The cost function is more efficient if it has a smaller η_H and a larger θ_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

$$c_F = \eta_F - \theta_F I_F^{\frac{1}{2}}. \quad (3)$$

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 η and larger θ) compared with firm F without loss of generality. There is a symmetric iceberg trade cost which equals t if either firm chooses to export to the other country⁴. Firm F can pay a licensing fee (L) to firm H to get the same marginal cost function as firm H and thus choose the same level of marginal cost (productivity) as firm H . 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 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.

⁴The total marginal cost for firm H to export one unit of its goods to country f is $c_H + t$.

There are three possible cases that might end up as equilibrium.⁵ 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 iceberg 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 paper is non-exclusive 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 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 welfares 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.

2.1.1 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 an iceberg 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 cost levels 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

⁵In 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.

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:

$$X_{Hh}^E = \frac{1}{3\beta} (\alpha - 2c_H^E + c_F^E + t), \quad (4a)$$

$$X_{Hf}^E = \frac{1}{3\beta} (\alpha - 2c_H^E + c_F^E - 2t), \quad (4b)$$

$$X_{Fh}^E = \frac{1}{3\beta} (\alpha - 2c_F^E + c_H^E - 2t), \quad (4c)$$

$$X_{Ff}^E = \frac{1}{3\beta} (\alpha - 2c_F^E + c_H^E + t). \quad (4d)$$

Prices: (same in both countries)

$$P_h^E = P_f^E = \frac{1}{3} (\alpha + c_H^E + c_F^E + t). \quad (5)$$

Profits:

$$\pi_H^E = \frac{1}{9\beta} (\alpha - 2c_H^E + c_F^E + t)^2 + \frac{1}{9\beta} (\alpha - 2c_H^E + c_F^E - 2t)^2 - I_H^E, \quad (6a)$$

$$\pi_F^E = \frac{1}{9\beta} (\alpha - 2c_F^E + c_H^E + t)^2 + \frac{1}{9\beta} (\alpha - 2c_F^E + c_H^E - 2t)^2 - I_F^E. \quad (6b)$$

Welfares:

$$w_h^E = \frac{1}{18\beta} (2\alpha - c_H^E - c_F^E - t)^2 + \frac{1}{9\beta} (\alpha - 2c_H^E + c_F^E + t)^2 + \frac{1}{9\beta} (\alpha - 2c_H^E + c_F^E - 2t)^2 - I_H^E, \quad (7a)$$

$$w_f^E = \frac{1}{18\beta} (2\alpha - c_H^E - c_F^E - t)^2 + \frac{1}{9\beta} (\alpha - 2c_F^E + c_H^E + t)^2 + \frac{1}{9\beta} (\alpha - 2c_F^E + c_H^E - 2t)^2 - I_F^E. \quad (7b)$$

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.

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

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

And marginal cost levels are

$$c_H^E = \eta_H - \theta_H \sqrt{I_H^E}, \quad (9a)$$

$$c_F^E = \eta_F - \theta_F \sqrt{I_F^E}. \quad (9b)$$

2.1.2 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 iceberg 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:

$$X_{Hh}^M = \frac{1}{3\beta} (\alpha - 2c_H^M + c_F^M + t), \quad (10a)$$

$$X_{Hf}^M = \frac{1}{3\beta} (\alpha - 2c_H^M + c_F^M), \quad (10b)$$

$$X_{Fh}^M = \frac{1}{3\beta} (\alpha - 2c_F^M + c_H^M - 2t), \quad (10c)$$

$$X_{Ff}^M = \frac{1}{3\beta} (\alpha - 2c_F^M + c_H^M). \quad (10d)$$

Prices:

$$P_h^M = \frac{1}{3} (\alpha + c_H^M + c_F^M + t), \quad (11a)$$

$$P_f^M = \frac{1}{3} (\alpha + c_H^M + c_F^M). \quad (11b)$$

Profits:

$$\pi_H^M = \frac{1}{9\beta} (\alpha - 2c_H^M + c_F^M + t)^2 + \frac{1}{9\beta} (\alpha - 2c_H^M + c_F^M)^2 - I_H^M - D, \quad (12a)$$

$$\pi_F^M = \frac{1}{9\beta} (\alpha - 2c_F^M + c_H^M)^2 + \frac{1}{9\beta} (\alpha - 2c_F^M + c_H^M - 2t)^2 - I_F^M. \quad (12b)$$

Welfares:

$$w_h^M = \frac{1}{18\beta} (2\alpha - c_H^M - c_F^M - t)^2 + \frac{1}{9\beta} (\alpha - 2c_H^M + c_F^M + t)^2 + \frac{1}{9\beta} (\alpha - 2c_H^M + c_F^M)^2 - I_H^M - D, \quad (13a)$$

$$w_f^M = \frac{1}{18\beta} (2\alpha - c_H^M - c_F^M)^2 + \frac{1}{9\beta} (\alpha - 2c_F^M + c_H^M)^2 + \frac{1}{9\beta} (\alpha - 2c_F^M + c_H^M - 2t)^2 - I_F^M. \quad (13b)$$

The optimal R&D investment levels will be

$$I_H^M = \left\{ \frac{4\theta_H [(9\beta - 12\theta_F^2)\alpha - (18\beta - 12\theta_F^2)\eta_H + 9\beta\eta_F + 4.5\beta t]}{(9\beta - 8\theta_F^2)(9\beta - 8\theta_H^2) - 16\theta_H^2\theta_F^2} \right\}^2, \quad (14a)$$

$$I_F^M = \left\{ \frac{4\theta_F [(9\beta - 12\theta_H^2)\alpha - (18\beta - 12\theta_H^2)\eta_F + 9\beta\eta_H - (9\beta - 6\theta_H^2)t]}{(9\beta - 8\theta_F^2)(9\beta - 8\theta_H^2) - 16\theta_H^2\theta_F^2} \right\}^2. \quad (14b)$$

And marginal cost levels are

$$c_H^M = \eta_H - \theta_H \sqrt{I_H^M}, \quad (15a)$$

$$c_F^M = \eta_F - \theta_F \sqrt{I_F^M}. \quad (15b)$$

2.1.3 Case 3 (Licensing):

There are four assumptions in this model related with this licensing case 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 η and a larger θ . 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 ($I_H^O = I_F^O$)⁶ so that the marginal cost (productivity level) of these two firms under the licensing case is the same which is $c_H^O = \eta_H - \theta_H \sqrt{I_H^O} = c_F^O$. 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.⁷ 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 $L = \pi_F^{BO} - \pi_F^E$. 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 ($L = \pi_F^{BO} - \pi_F^M$). 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.

The fourth assumption is that the licensing is non-exclusive, 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 non-exclusive licensing assumption is realistic and to some extent can capture to fact that the parent firm usually has the least control of the technology spillovers under the licensing case among all three mode choices.

⁶Letter O stands for the licensing (international outsourcing) case in this paper.

⁷If 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.

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:

$$X_{Hh}^O = \frac{1}{3\beta} (\alpha - c_H^O + t), \quad (16a)$$

$$X_{Hf}^O = \frac{1}{3\beta} (\alpha - c_H^O - 2t), \quad (16b)$$

$$X_{Fh}^O = \frac{1}{3\beta} (\alpha - c_H^O - 2t), \quad (16c)$$

$$X_{Ff}^O = \frac{1}{3\beta} (\alpha - c_H^O + t). \quad (16d)$$

Prices: (same in both countries)

$$P_h^O = P_f^O = \frac{1}{3} (\alpha + 2c_H^O + t). \quad (17)$$

Profits: (before licensing fee paid)

$$\pi_H^{BO} = \frac{1}{9\beta} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta} (\alpha - c_H^O - 2t)^2 - I_H^O, \quad (18a)$$

$$\pi_F^{BO} = \frac{1}{9\beta} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta} (\alpha - c_H^O - 2t)^2 - I_H^O. \quad (18b)$$

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

$$L = \pi_F^{BO} - \pi_F^E, \text{ if } \pi_F^E \geq \pi_F^M; \quad (19a)$$

$$L = \pi_F^{BO} - \pi_F^M, \text{ if } \pi_F^E < \pi_F^M. \quad (19b)$$

After the licensing fee is determined, the profits of two firms after licensing fee paid and welfares of two countries can be expressed as following.

Profits: (after licensing fee paid)

$$\pi_H^O = \frac{1}{9\beta} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta} (\alpha - c_H^O - 2t)^2 - I_H^O + L, \quad (20a)$$

$$\pi_F^O = \frac{1}{9\beta} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta} (\alpha - c_H^O - 2t)^2 - I_H^O - L. \quad (20b)$$

Welfares:

$$w_h^O = \frac{1}{18\beta} (2\alpha - 2c_H^O - t)^2 + \frac{1}{9\beta} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta} (\alpha - c_H^O - 2t)^2 - I_H^O + L, \quad (21a)$$

$$w_f^O = \frac{1}{18\beta} (2\alpha - 2c_H^O - t)^2 + \frac{1}{9\beta} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta} (\alpha - c_H^O - 2t)^2 - I_H^O - L. \quad (21b)$$

The optimal R&D investment is

$$I_H^O = I_F^O = \left\{ \frac{\theta_H (\alpha - \eta_H - 0.5t)}{\frac{9}{4}\beta - \theta_H^2} \right\}^2, \quad (22)$$

with the marginal cost level

$$c_H^O = \eta_H - \theta_H \sqrt{I_H^O} = c_F^O. \quad (23)$$

2.2 The 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:

$$\begin{aligned}\pi_H^E &= \frac{1}{9\beta} \left(\alpha - 2\eta_H + \eta_F + t + 2\theta_H \sqrt{I_H^E} - \theta_F \sqrt{I_F^E} \right)^2 \\ &\quad + \frac{1}{9\beta} \left(\alpha - 2\eta_H + \eta_F - 2t + 2\theta_H \sqrt{I_H^E} - \theta_F \sqrt{I_F^E} \right)^2 - I_H^E,\end{aligned}\quad (24a)$$

$$I_H^E = \left\{ \frac{4\theta_H [(9\beta - 12\theta_F^2)\alpha - (18\beta - 12\theta_F^2)\eta_H + 9\beta\eta_F - (4.5\beta - 6\theta_F^2)t]}{(9\beta - 8\theta_F^2)(9\beta - 8\theta_H^2) - 16\theta_H^2\theta_F^2} \right\}^2, \quad (24b)$$

$$I_F^E = \left\{ \frac{4\theta_F [(9\beta - 12\theta_H^2)\alpha - (18\beta - 12\theta_H^2)\eta_F + 9\beta\eta_H - (4.5\beta - 6\theta_H^2)t]}{(9\beta - 8\theta_F^2)(9\beta - 8\theta_H^2) - 16\theta_H^2\theta_F^2} \right\}^2. \quad (24c)$$

FDI case:

$$\begin{aligned}\pi_H^M &= \frac{1}{9\beta} \left(\alpha - 2\eta_H + \eta_F + t + 2\theta_H \sqrt{I_H^M} - \theta_F \sqrt{I_F^M} \right)^2 \\ &\quad + \frac{1}{9\beta} \left(\alpha - 2\eta_H + \eta_F + 2\theta_H \sqrt{I_H^M} - \theta_F \sqrt{I_F^M} \right)^2 - I_H^M - D,\end{aligned}\quad (25a)$$

$$I_H^M = \left\{ \frac{4\theta_H [(9\beta - 12\theta_F^2)\alpha - (18\beta - 12\theta_F^2)\eta_H + 9\beta\eta_F + 4.5\beta t]}{(9\beta - 8\theta_F^2)(9\beta - 8\theta_H^2) - 16\theta_H^2\theta_F^2} \right\}^2, \quad (25b)$$

$$I_F^M = \left\{ \frac{4\theta_F [(9\beta - 12\theta_H^2)\alpha - (18\beta - 12\theta_H^2)\eta_F + 9\beta\eta_H - (9\beta - 6\theta_H^2)t]}{(9\beta - 8\theta_F^2)(9\beta - 8\theta_H^2) - 16\theta_H^2\theta_F^2} \right\}^2. \quad (25c)$$

Licensing case:

$$\pi_H^O = \frac{1}{9\beta} \left(\alpha - \eta_H + t + \theta_H \sqrt{I_H^O} \right)^2 + \frac{1}{9\beta} \left(\alpha - \eta_H - 2t + \theta_H \sqrt{I_H^O} \right)^2 - I_H^O + L, \quad (26a)$$

$$I_H^O = I_F^O = \left\{ \frac{\theta_H (\alpha - \eta_H - 0.5t)}{\frac{9}{4}\beta - \theta_H^2} \right\}^2. \quad (26b)$$

Proposition 1 *Given firm F 's cost function efficiency parameters η_F and θ_F , the mode choice of firm H can be expressed as following.*

1. *Given firm H 's base marginal cost η_H , with the change of firm H 's R&D investment*

to productivity transformability θ_H ,

$\theta_F < \theta_H \leq \underline{\theta} \Rightarrow$ the optimal mode choice: *Licensing*

$\underline{\theta} < \theta_H \leq \bar{\theta} \Rightarrow$ the optimal mode choice: *Exporting*

$\theta_H > \bar{\theta} \Rightarrow$ the optimal mode choice: *FDI*

2. Given firm H 's R&D investment to productivity transformability θ_H , with the change of firm H 's base marginal cost η_F ,

$\bar{\eta} < \eta_H \leq \eta_F \Rightarrow$ the optimal mode choice: *Licensing*

$\underline{\eta} \leq \eta_H < \bar{\eta} \Rightarrow$ the optimal mode choice: *Exporting*

$\eta_H < \underline{\eta} \Rightarrow$ the optimal mode choice: *FDI*

Licensing will turn out to have the largest profit when difference between two firms' ex-ante cost function efficiency parameters is small and 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 trade cost can encourage firm H to choose licensing instead of exporting.

Exporting will be the dominant strategy for firm H when trade cost is low and cost function difference between two firms is in the middle 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 iceberg 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 trade cost is high, FDI cost is low and 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 trade cost to outweigh the FDI cost.

Although firm H can successfully grab the entire extra profit that firm F can earn from the licensing case, 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 (low-productivity firm) lower, but it reduces the incentive of firm H 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 the FDI cases. 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 case, 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 marginal cost 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 other choices - either exporting or FDI as its optimal mode choice.

2.3 Welfare analysis

The incentive for firm H to conduct R&D investment is largest under the FDI case because it needs to compete against firm F to win a larger market share and zero trade cost with FDI facilities 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 cost 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 lowest 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 lowest under the FDI case and highest under 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 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.⁸

2.4 A Numerical Example

Considering that the R&D investment level and profit are affected by many parameters in the open economy such as market demand (α, β) , cost function of firm H (η_H, θ_H) and cost function of firm F (η_F, θ_F) , a numerical example is helpful for us to see how these parameters will affect the equilibrium decision and the welfares 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 (η_H) . This example can check how different θ_H (transformability from R&D investment to productivity of firm H) will affect the exporting, licensing and FDI decision in the open economy. θ_H increases from 0.1 to 0.45. 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 .

In all the figures attached at the end of this paper, 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.

Figure 1 shows the exporting, licensing and FDI decision (the mode choice) made by firm H . Given the 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 difference between θ_H and θ_F), it will choose to license its 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 θ_H , licensing choice will be dominated by either exporting or FDI because the licensing fee can no longer cover

⁸The model in this paper 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 current period welfare and long-run productivity.

the profit decrease 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 total trade cost. Firm H will just choose to export to country F when R&D investment to productivity transformability is in the middle range, 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 trade cost to outweigh the fixed FDI cost.

The following two figures (figure 2 and figure 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 choice for firm H while the licensing case relates with 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 other two mode choices. Figure 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 figure 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. Licensing actually discourages firm H to reduce its marginal cost compared with 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 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.

Figure 4 and figure 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 of the elimination of iceberg trade cost when firm H sells its product in country f . The market price is highest for the exporting case and 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 by 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 6 and 7 show the welfares under the optimal mode choice determined by firm H . Similar to the previous figures, there are also two jumps of welfares 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 figure 4 and 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 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 trade cost in country f .

3 Market Size Effect

3.1 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

$$P_i = \alpha - \beta_i X_i, i = h, f, \quad (27)$$

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 α . At the same price, the price elasticities of demand for both demand curves are also the same. Different β indicates different market demand size (no. of consumers). A smaller β 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 welfares under different mode choices will have the following results. The notations have the same meanings as those in section 2.

3.1.1 Case 1 (Exporting):

R&D investments:

$$I_H^E = \left\{ \frac{4\theta_H [(4.5B - 3\theta_F^2)\alpha - (9B - 3\theta_F^2)\eta_H + 4.5B\eta_F - (4.5B(2\beta_h - \beta_f) - 3\theta_F^2 2\beta_h)t / (\beta_f + \beta_h)]}{(9B - 4\theta_F^2)(9B - 4\theta_H^2) - 4\theta_H^2\theta_F^2} \right\}^2, \quad (28a)$$

$$I_H^E = \left\{ \frac{4\theta_F [(4.5B - 3\theta_H^2)\alpha - (9B - 3\theta_H^2)\eta_F + 4.5B\eta_H - (4.5B(2\beta_f - \beta_h) - 3\theta_H^2 2\beta_f)t / (\beta_f + \beta_h)]}{(9B - 4\theta_F^2)(9B - 4\theta_H^2) - 4\theta_H^2\theta_F^2} \right\}^2, \quad (28b)$$

where:

$$B = \frac{\beta_h\beta_f}{\beta_h + \beta_f}. \quad (29)$$

Marginal costs:

$$c_H^E = \eta_H - \theta_H \sqrt{I_H^E}, \quad (30a)$$

$$c_F^E = \eta_F - \theta_F \sqrt{I_F^E}. \quad (30b)$$

Quantities:

$$X_{Hh}^E = \frac{1}{3\beta_h} (\alpha - 2c_H^E + c_F^E + t), \quad (31a)$$

$$X_{Hf}^E = \frac{1}{3\beta_f} (\alpha - 2c_H^E + c_F^E - 2t), \quad (31b)$$

$$X_{Fh}^E = \frac{1}{3\beta_h} (\alpha - 2c_F^E + c_H^E - 2t), \quad (31c)$$

$$X_{Ff}^E = \frac{1}{3\beta_f} (\alpha - 2c_F^E + c_H^E + t). \quad (31d)$$

Prices: (same in both countries)

$$P_h^E = P_f^E = \frac{1}{3} (\alpha + c_H^E + c_F^E + t). \quad (32)$$

Profits:

$$\pi_H^E = \frac{1}{9\beta_h} (\alpha - 2c_H^E + c_F^E + t)^2 + \frac{1}{9\beta_f} (\alpha - 2c_H^E + c_F^E - 2t)^2 - I_H^E, \quad (33a)$$

$$\pi_F^E = \frac{1}{9\beta_f} (\alpha - 2c_F^E + c_H^E + t)^2 + \frac{1}{9\beta_h} (\alpha - 2c_F^E + c_H^E - 2t)^2 - I_F^E. \quad (33b)$$

Welfares:

$$w_h^E = \frac{1}{18\beta_h} (2\alpha - c_H^E - c_F^E - t)^2 + \frac{1}{9\beta_h} (\alpha - 2c_H^E + c_F^E + t)^2 + \frac{1}{9\beta_f} (\alpha - 2c_H^E + c_F^E - 2t)^2 - I_H^E, \quad (34a)$$

$$w_f^E = \frac{1}{18\beta_f} (2\alpha - c_H^E - c_F^E - t)^2 + \frac{1}{9\beta_f} (\alpha - 2c_F^E + c_H^E + t)^2 + \frac{1}{9\beta_h} (\alpha - 2c_F^E + c_H^E - 2t)^2 - I_F^E. \quad (34b)$$

3.1.2 Case 2 (FDI):

R&D investments:

$$I_H^M = \left\{ \frac{4\theta_H [(4.5B - 3\theta_F^2)\alpha - (9B - 3\theta_F^2)\eta_H + 4.5B\eta_F + (4.5B/\beta_h - 2\theta_F^2/\beta_h + 2\theta_F^2/\beta_f)Bt]}{(9B - 4\theta_F^2)(9B - 4\theta_H^2) - 4\theta_H^2\theta_F^2} \right\}^2, \quad (35a)$$

$$I_F^M = \left\{ \frac{4\theta_F [(4.5B - 3\theta_H^2)\alpha - (9B - 3\theta_H^2)\eta_F + 4.5B\eta_H - (9B/\beta_f - 4\theta_H^2/\beta_f + \theta_H^2/\beta_h)Bt]}{(9B - 4\theta_F^2)(9B - 4\theta_H^2) - 4\theta_H^2\theta_F^2} \right\}^2, \quad (35b)$$

where:

$$B = \frac{\beta_h\beta_f}{\beta_h + \beta_f}. \quad (36)$$

Marginal costs:

$$c_H^M = \eta_H - \theta_H \sqrt{I_H^M}, \quad (37a)$$

$$c_F^M = \eta_F - \theta_F \sqrt{I_F^M}. \quad (37b)$$

Quantities:

$$X_{Hh}^M = \frac{1}{3\beta_h} (\alpha - 2c_H^M + c_F^M + t), \quad (38a)$$

$$X_{Hf}^M = \frac{1}{3\beta_f} (\alpha - 2c_H^M + c_F^M), \quad (38b)$$

$$X_{Fh}^M = \frac{1}{3\beta_h} (\alpha - 2c_F^M + c_H^M - 2t), \quad (38c)$$

$$X_{Ff}^M = \frac{1}{3\beta_f} (\alpha - 2c_F^M + c_H^M). \quad (38d)$$

Prices:

$$P_h^M = \frac{1}{3} (\alpha + c_H^M + c_F^M + t), \quad (39a)$$

$$P_f^M = \frac{1}{3} (\alpha + c_H^M + c_F^M). \quad (39b)$$

Profits:

$$\pi_H^M = \frac{1}{9\beta_h} (\alpha - 2c_H^M + c_F^M + t)^2 + \frac{1}{9\beta_f} (\alpha - 2c_H^M + c_F^M)^2 - I_H^M - D, \quad (40a)$$

$$\pi_F^M = \frac{1}{9\beta_f} (\alpha - 2c_F^M + c_H^M)^2 + \frac{1}{9\beta_h} (\alpha - 2c_F^M + c_H^M - 2t)^2 - I_F^M. \quad (40b)$$

Welfares:

$$w_h^M = \frac{1}{18\beta_h} (2\alpha - c_H^M - c_F^M - t)^2 + \frac{1}{9\beta_h} (\alpha - 2c_H^M + c_F^M + t)^2 + \frac{1}{9\beta_f} (\alpha - 2c_H^M + c_F^M)^2 - I_H^M - D, \quad (41a)$$

$$w_f^M = \frac{1}{18\beta_f} (2\alpha - c_H^M - c_F^M)^2 + \frac{1}{9\beta_f} (\alpha - 2c_F^M + c_H^M)^2 + \frac{1}{9\beta_h} (\alpha - 2c_F^M + c_H^M - 2t)^2 - I_F^M. \quad (41b)$$

3.1.3 Case 3 (Licensing):

R&D investments:

$$I_H^O = I_F^O = \left\{ \frac{\theta_H (\alpha - \eta_H - (2/\beta_f - 1/\beta_h)Bt)}{\frac{9}{2}B - \theta_H^2} \right\}^2, \quad (42)$$

where:

$$B = \frac{\beta_h \beta_f}{\beta_h + \beta_f}. \quad (43)$$

Marginal costs:

$$c_H^O = \eta_H - \theta_H \sqrt{I_H^O} = c_F^O. \quad (44)$$

Quantities:

$$X_{Hh}^O = \frac{1}{3\beta_h} (\alpha - c_H^O + t), \quad (45a)$$

$$X_{Hf}^O = \frac{1}{3\beta_f} (\alpha - c_H^O - 2t), \quad (45b)$$

$$X_{Fh}^O = \frac{1}{3\beta_h} (\alpha - c_H^O - 2t), \quad (45c)$$

$$X_{Ff}^O = \frac{1}{3\beta_f} (\alpha - c_H^O + t). \quad (45d)$$

Prices: (same in both countries)

$$P_h^O = P_f^O = \frac{1}{3} (\alpha + 2c_H^O + t). \quad (46)$$

Profits: (before licensing fee paid)

$$\pi_H^{BO} = \frac{1}{9\beta_h} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta_f} (\alpha - c_H^O - 2t)^2 - I_H^O, \quad (47a)$$

$$\pi_F^{BO} = \frac{1}{9\beta_f} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta_h} (\alpha - c_H^O - 2t)^2 - I_H^O. \quad (47b)$$

Licensing fee:

$$L = \pi_F^{BO} - \pi_F^E, \text{ if } \pi_F^E \geq \pi_F^M; \quad (48a)$$

$$L = \pi_F^{BO} - \pi_F^M, \text{ if } \pi_F^E < \pi_F^M. \quad (48b)$$

Profits: (after licensing fee paid)

$$\pi_H^O = \frac{1}{9\beta_h} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta_f} (\alpha - c_H^O - 2t)^2 - I_H^O + L, \quad (49a)$$

$$\pi_F^O = \frac{1}{9\beta_f} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta_h} (\alpha - c_H^O - 2t)^2 - I_H^O - L. \quad (49b)$$

Welfares:

$$w_h^O = \frac{1}{18\beta_h} (2\alpha - 2c_H^O - t)^2 + \frac{1}{9\beta_h} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta_f} (\alpha - c_H^O - 2t)^2 - I_H^O + L, \quad (50a)$$

$$w_f^O = \frac{1}{18\beta_f} (2\alpha - 2c_H^O - t)^2 + \frac{1}{9\beta_f} (\alpha - c_H^O + t)^2 + \frac{1}{9\beta_h} (\alpha - c_H^O - 2t)^2 - I_H^O - L. \quad (50b)$$

3.2 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 $P_i = \alpha - \beta_i X_i$, $i = h, f$, 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 $c_H = 1 - 0.35I_H^{\frac{1}{2}}$ and the marginal cost function of firm F to be $c_F = 6 - 0.1I_F^{\frac{1}{2}}$. 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 productivity 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 (θ_H) is chosen to be too large or too small, the optimal mode choice will be dominated by the (ex-ante) productivity effect analyzed in section 2 so that market size effect cannot change firm H 's decision.

Same as the previous productivity 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 (figure 8). Whenever the mode choice is determined by firm H , the following figures (from figure 9 to figure 16) will show the R&D

investment levels, market prices and welfares of the two firms and two countries.

According to figure 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) productivity effect example if θ_H is set to be 0.35 shown by figure 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 trade cost is 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 iceberg 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 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 market size continues growing. Firm H will not choose licensing because country f 's market size is too small for trade cost saving so that firm F cannot pay enough amount of licensing fee; and it will not choose FDI because the FDI cost is larger than the 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 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 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 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 figure 8.

Figure 9 presents the optimal R&D investment levels of firm H . As to firm H who is 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 figure 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 FDI choice but not 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 (country f) under the exporting choice due to trade cost for firm H compared with the FDI case.

Figure 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 figure 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.

Figure 11 and figure 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, price is lower in country f than that in country h because FDI can only happen in country f and save the trade cost for consumers in that country. Similar to the (ex-ante) productivity 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

countries 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 with the productivity increase of firm F . This jump is more obvious for country f due to the trade cost saving effect of FDI in country f . Market price has an inverse relationship with market output. By looking at figure 11 and 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 13 and 14 are the total welfares 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 market demand size for country h ; and for country f this decrease is enhanced by market demand size decrease.

In order to see how 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 (figure 15 and 16) describe the market size effect on welfare per capita for both countries in this example.

In figure 15 and 16, the downward jump at each shifting point caused by mode choice change can still be observed as in figure 13 and 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 figure 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 $1/\beta_h$.

4 Empirical Estimations

I use the Chilean plant-level panel data to test two sets of theoretical predictions derived from the previous sections. First, 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, between these two foreign linkages, foreign subsidiaries have an even higher productivity level compared with domestic licensees. Together with the basic productivity advantage associated with foreign linkages, plants with access to foreign linkages on average are also larger in size and have a larger market share. Similarly, the intra-industry allocation effect of FDI is also larger than that of licensing.

Second, what determines the mode choice is 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 observed in the data. If the productivity advantage of more productive foreign firms is smaller in an industry, more licensing transactions are observed.

In this empirical section, I first calculate the total factor productivity by using Levinsohn-Petrin method ⁹ in 4.1. Then the first set of theoretical predictions are tested separately in 4.2 (foreign linkages and productivity) and 4.3 (foreign linkages and market share). The last sub-section 4.4 shows the results of the empirical estimation of the second set of theoretical hypotheses.

⁹Greenaway, Guariglia and Kneller (2007), Goldberg, Khandelwal, Pavcnik and Topalova (2010), Javorcik (2004), Javorcik and Spatareanu (2008) (2009) (2011), Kasahara and Rodrigue (2008), Park, Yang, Shi and Jiang (2008), and Topalova and Khandelwal (2011) have all used Levinsohn and Petrin methodology to calculate total factor productivity. As to the critiques on Levinsohn-Petrin method, please see Akerberg et al and De Loecker.

4.1 Total Factor Productivity Estimation

There are 111 4-digit level manufacturing industries. I cluster the data to 2-digit industry level to calculate total factor productivity by using Levinsohn-Petrin method. Except manufacture of office, accounting and computing machinery which only has 15 observations in seven years, the rest 19 2-digit industries all have enough observations. Table 1 shows the descriptive data of 20 clustering 2-digit industries.

Using Levinsohn-Petrin method to estimate total factor productivity corrects the problem that arises from the correlation between 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 2 reports the coefficients from 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 firms in Chile, I categorize the data into 4 different groups. The first group includes domestic no-licensing no-exporting plants. Plants in this group do not have any access to foreign linkages to affect their productivity and do not export either. This group usually indicates the low-end domestic productivity level in one country. The second group includes all domestic licensees (both exporters and non exporters). Plants in this group get access to foreign firms with higher productivity through licensing, which would increase their productivity. The third group 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 levels 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.¹⁰ 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 3 shows the mean and median productivity level of each group by two

¹⁰50% 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 paper, I will test all the hypotheses associated with foreign subsidiaries with both definitions.

different foreign subsidiary definitions. As the theory predicts, 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 aggregate data, there is no big difference between the two foreign subsidiary capital share definitions.

Figure 17 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 (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. Figure 17 is consistent with the results shown in table 3.

4.2 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 4 presents the results for the following regression equation. In the following equation, i stands for plant index i , j stands for industry j , r stands for region r and t stands for time t :

$$\begin{aligned} \ln(TFP_{it}) = & \alpha + \beta_1 * FDI_{it} + \beta_2 * Licensee_{it} + \Upsilon_1 * Industrydummies_j \\ & + \Upsilon_2 * Regiondummies_r + \Upsilon_3 * Timedummies_t + \mu_i + \omega_{it}. \end{aligned} \quad (51)$$

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 is one if a plant belongs to the foreign subsidiary group (group 2) and zero otherwise. *Licensee* dummy here only considers the domestic licensees that it equals one if a plant is domestic

and pays a positive licensing fee. These two dummy variables are mutually exclusive.

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. Column 1, 2, 5, 6 are using 4-digit industry dummies, while column 3, 4, 7, 8 are using the 2-digit industry dummies. Column 2, 4, 6, 8 also include some other controls: time-region control (population), time-industry control (average tariff rate) and firm-level control (capital labor ratio). The coefficients of *FDI* and *licensee* are both positive and significant and quite robust in significance and magnitude among different foreign subsidiary definitions and control variables. Compared to pure domestic plant with no foreign linkages, being a foreign subsidiary on average increases the 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. 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 licensee.

4.3 Foreign Linkages and Market Share

Question 2: Do foreign firms or domestic licensees have larger size compared with domestic firms without any foreign linkages?

According to the theoretical model, 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 reflecting market share are tested in the following: first is the logarithm of real total sales (table 5), second is the logarithm of real value added (table 6), and third is the logarithm of total employment (table 7). Taking the logarithm of any potential dependent variable and putting industry dummies 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:

$$\begin{aligned} \ln(y_{it}) = & \alpha + \beta_1 * FDI_{it} + \beta_2 * Licensee_{it} + \Upsilon_1 * Industrydummies_j \\ & + \Upsilon_2 * Regiondummies_r + \Upsilon_3 * Timedummies_t + \mu_i + \omega_{it}. \end{aligned} \quad (52)$$

I expect that both *FDI* and *licensee* dummy variables have positive and significant co-

efficients on any market share dependent variables, and the coefficient of FDI is larger than that of licensee. Table 5, 6 and 7 present the results of three random effect regressions. Similar to table 4, the first four columns of each table reports the regression results under the 50% capital share foreign subsidiary definition, and the last four columns are related to the 10% capital share foreign subsidiary definition. In each table, column 1, 2, 5, 6 are using 4-digit industry dummies, while column 3, 4, 7, 8 are using the 2-digit industry dummies. Column 2, 4, 6, 8 also include some other controls: time-region control (population), time-industry control (average tariff rate) and firm-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 have significantly larger market shares compared to 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 have significantly larger market share than domestic licensees.

Comparing table 5 to table 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 (table 5) than under the value added dependent variable (table 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.

4.4 Productivity Difference and Mode Choice

Question 3: Is FDI more likely to happen when the productivity difference between foreign firms and domestic firms is high? 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 foreign-domestic productivity difference affect the total numbers of FDI plants or domestic licensees and how it changes the total

industry-level foreign share or total licensing fee paid. The regression results are shown by table 8 (probit regressions at plant-level), table 9 (poisson MLE regressions of number of FDI plants or domestic licensees at 4-digit industry level) and table 10 (total foreign share or licensing fee at 4-digit industry level).

The key independent variable in both the plant-level probit regressions and the industry-level regressions 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 level ($TFP_{jt} = \frac{sales_{ijt}}{\sum_i sales_{ijt}} * TFP_{ijt}$). According to the previous literature ¹¹ and section 4.1 in the paper, domestic no-licensing exporters (group 4) indicate the highest level of domestic productivity, and foreign subsidiaries (group 3) show up 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.

The probit regression is expressed by the following equation:

$$y_{it} = \alpha + \beta * \ln(TFP3/TFP4)_{jt} + \Upsilon_1 * Industrydummies_j + \Upsilon_2 * Regiondummies_r + \Upsilon_3 * Timedummies_t + \Upsilon_4 * Othercontrols + \epsilon_{it}. \quad (53)$$

in which, y_{it} is either *FDI* dummy (shown by column 1, 3, 5, 7 in table 8) or *Licensee* dummy (shown by column 2, 4, 6, 8 in table 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 8) and 10% capital share foreign plants definition (last four columns in table 8) are tested separately. Moreover, I use both current period productivity difference $\ln(TFP3/TFP4)_t$ (column 1, 2, 5, 6) and lagged one period productivity difference $\ln(TFP3/TFP4)_{t-1}$ (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 mostly 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 defini-

¹¹Helpman, Melitz and Yeaple (2004), Javorcik (2004), and etc

tion 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 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 9. Second set of dependent variables is the total industry-level foreign share or licensing fee paid. Both these two variables are weighted by the real value of sales of each plant. The regression equation is:

$$y_{jt} = \alpha + \beta_1 * \ln(TFP3/TFP4)_{jt} + \beta_2 * 4digitIndustrySize + \Upsilon_1 * Industrydummies_{jt} + \Upsilon_3 * Timedummies_t + \epsilon_{jt}, \quad (54)$$

where y_{jt} can be 1. No. of FDI plants, 2. No. of domestic licensees, 3. weighted average foreign share ($\frac{sales_{ijt}}{\sum_i sales_{ijt}} * foreignshare_{ijt}$) and 4. logarithm of weighted average licensing fee ($\ln\left(\frac{sales_{ijt}}{\sum_i sales_{ijt}} * licensingfee_{ijt}\right)$). The industry controls are 2-digit industry dummies, 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 9 with dependent variable 1 and 2; and it is the logarithm of total sales in table 10 with dependent variable 3 and 4.

Table 9 to table 10 report the results consistent with the theoretical predictions and plant-level regressions (table 8). The coefficients of foreign-domestic productivity variable are all positive and significant under all FDI dependent variables (column 1 and 3 in both table 9 and table 10). And the coefficients are negative and significant under licensing dependent variables (column 2 and 4 in both table 9 and table 10). If the productivity advantage is larger for foreign plants, there are more foreign subsidiaries and fewer domestic licensees.

5 Conclusion 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 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 intermediate 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. If the difference between productivity choices 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 a more attractive choice. 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 welfares. The incentive of 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 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.

I find empirical supports from Chilean plant-level panel data with respect to two sets of testable theoretical hypotheses from the theoretical model developed in this paper. 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 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 pro-

ductivity difference will have the opposite effect on the mode choice.

References

- [1] Antràs, Pol. 2003. “Firms, Contracts, and Trade Structure.” *Quarterly Journal of Economics* 118: 1375-1418.
- [2] Antràs, Pol and Costinot, Arnaud 2010. “Intermediation and Economic Integration.” *American Economic Review* 100: 424-428.
- [3] Antràs, Pol and Helpman, Elhanan 2004. “Global Sourcing.” *Journal of Political Economy* 112: 552-580.
- [4] Antràs, Pol and Helpman, Elhanan 2008. “Contractual Frictions and Global Sourcing.” in Helpman, E., D. Marin, and T. Verdier. eds., *The Organization of Firms in a Global Economy* Harvard University Press.
- [5] Antràs, Pol and Rossi-Hansberg 2009. “Organizations and Trade.” *Annual Review of Economics* 1: 43-64.
- [6] Arnold, J. and Javorcik, B. 2009. “Gifted Kids or Pushy Parents? Foreign Direct Investment and Plant Productivity in Indonesia.” *Journal of International Economics* 79: 42-53.
- [7] Aw, B., Roberts, M. and Xu, D. 2008. “R&D Investments, Exporting, and the Evolution of Firm Productivity.” *American Economic Review* 98: 451-456.
- [8] Bernard, A., Eaton, J., Jensen, B. and Kortum, S. 2003. “Plants and Productivity in International Trade.” *American Economic Review* 93: 1268-1290.
- [9] Bustos, Paula 2011. “Trade Liberalization, Exports, and Technology Upgrading: Evidence on the Impact of MERCOSUR on Argentinian Firms.” *American Economic Review* 101: 304-340.

- [10] Carluccio, Juan and Fally, Thibault 2008. "Global Sourcing under Imperfect Capital markets." *working paper*
- [11] Chen, Y., Horstmann, I. and Markusen, J. 2008. "Physical Capital, Knowledge Capital and the Choice between FDI and Outsourcing." *working paper*
- [12] Chen, Y. and Riordan, M. 2007. "Price and Variety in the Spokes Model." *The Economic Journal* 117: 897-912.
- [13] Clerides, S. K., Lach, S. and Tybout, J 1998. "Is Learning by Exporting Important? Micro-Dynamic Evidence from Colombia, Mexico, and Morocco." *The Quarterly Journal of Economics* 113: 903-947.
- [14] Coe, D., Helpman, E. and Hoffmaister, A 1997. "North-South R&D Spillovers." *The Economic Journal* 107: 134-149.
- [15] Costantini, J. and Melitz, M. 2008. "The Dynamics of Firm-Level Adjustment to Trade Liberalization." in E. Helpman, D. Marin, and T. Verdier (eds.), *The Organization of Firms in a Global Economy* Harvard University Press.
- [16] De Loecker, J. 2007. "Do Exports Generate Higher Productivity? Evidence from Slovenia." *Journal of International Economics* 73: 69-98.
- [17] Ekholm, K. and Midelfart, K. H. 2005. "Relative Wages and Trade-induced Changes in Technology." *European Economic Review* 49: 1637-1663.
- [18] Ethier, W. and Markusen, J. 1996. "Multinational Firms, Technology diffusion and Trade." *Journal of International Economics* 41: 1-28.
- [19] Gallini, N. and Winter, R. 1985. "Licensing in the Theory of Innovation." *Rand Journal of Economics* 16: 237-252.
- [20] Ghosh, A. and Saha, S. 200. "Trade Policy in the Presence of Technology Licensing." *Review of International Economics* 16: 45-68.
- [21] Grossman, Gene M., Helpman, Elhanan and Szeidl, Adam 2005. "Complementarities between Outsourcing and Foreign Sourcing." *American Economic Review* 95: 19-24.

- [22] Grossman, Gene M., Helpman, Elhanan and Szeidl, Adam 2006. "Optimal integration strategies for the multinational firms." *Journal of International Economics* 70: 216-238.
- [23] Helpman, E., Melitz, M. and Yeaple, S. 2004. "Exports versus FDI with Heterogeneous Firms." *American Economic Review* 94: 300-316.
- [24] Helpman, E. 2006. "Trade, FDI, and the Organization of the Firm." *Journal of Economic Literature* 44: 589-630.
- [25] Horstmann, I. and Markusen, J. 1987. "Licensing versus Direct Investment: A Model of Internalization by the Multinational Enterprise." *The Canadian Journal of Economics* 20: 464-481.
- [26] Javorcik, B. 2004. "Does Foreign Direct Investment Increase the Productivity of Domestic Firms? In Search of Spillovers through Backward Linkages." *American Economic Review* 94: 605-627.
- [27] Keller, W. and Yeaple, S. 2009. "Multinational Enterprises, International Trade, and Productivity Growth: Firm-Level Evidence from the United States." *Review of Economics and Statistics* 91(4): 821-831.
- [28] Keller, W. and Yeaple, S. 2010. "Gravity in the Weightless Economy." *working paper*.
- [29] Levinsohn, James and Petrin, Amil 2003. "Estimating Production Functions Using Inputs to Control for Unobservables." *Review of Economic Studies* 70: 317-341.
- [30] Li, Ben 2010. "Multinational production and choice of technologies: New evidence on skill-biased technological change from China." *Economics Letters* 108(2): 181-183.
- [31] Li, Ben 2010. "Cross-Border Production, Technology Transfer, and the Choice of Partner." *working paper*.
- [32] Markusen, J. 1995. "The Boundaries of Multinational Enterprises and the Theory of International Trade." *The Journal of Economic Perspectives* 9: 169-189.
- [33] Markusen, J. 2002. *Multinationals and the Theory of International Trade* MIT Press.

- [34] Melitz, M. 2003. "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity." *Econometrica* 71: 1695-1725.
- [35] Melitz, M. and Ottaviano, G. 2008. "Market Size, Trade, and Productivity." *Review of Economic Studies* 75: 295-316.
- [36] Nunn, Nathan 2007. "Relationship-Specificity, Incomplete Contracts, and the Pattern of Trade." *Quarterly Journal of Economics* 122: 569-600.
- [37] Nunn, Nathan and Treffer, Daniel 2008. "The Boundaries of the Multinational Firm: An Empirical Analysis." in E. Helpman, D. Marin, and T. Verdier (eds.), *The Organization of Firms in a Global Economy* Harvard University Press, pp. 55-83.
- [38] Pavcnik, N. 2002. "Trade Liberalization, Exit, and Productivity Improvements: Evidence from Chilean Plants." *Review of Economic Studies* 69: 245-276.
- [39] Petrin, A., Poi, B. and Levinsohn, J. 2004. "Production Function Estimation in Stata Using Inputs to Control for Unobservables." *The Stata Journal* 4: 113-123.
- [40] Roberts, M. and Tybout, J. 1997. "The Decision to Export in Colombia: An Empirical Model of Entry with Sunk Costs." *American Economic Review* 87: 545-564.
- [41] Saggi, K. 1999. "Foreign Direct Investment, Licensing, and Incentives for Innovation." *Review of International Economics* 7: 699-714.
- [42] Yang, Lei and Maskus, Keith 2009. "Intellectual Property Rights, Technology Transfer and Exports in Developing Countries." *Journal of Development Economics* 90: 231-236.
- [43] Yeaple, S. 2005. "A Simple Model of Firm Heterogeneity, International Trade, and Wages." *Journal of International Economics* 65: 1-20.

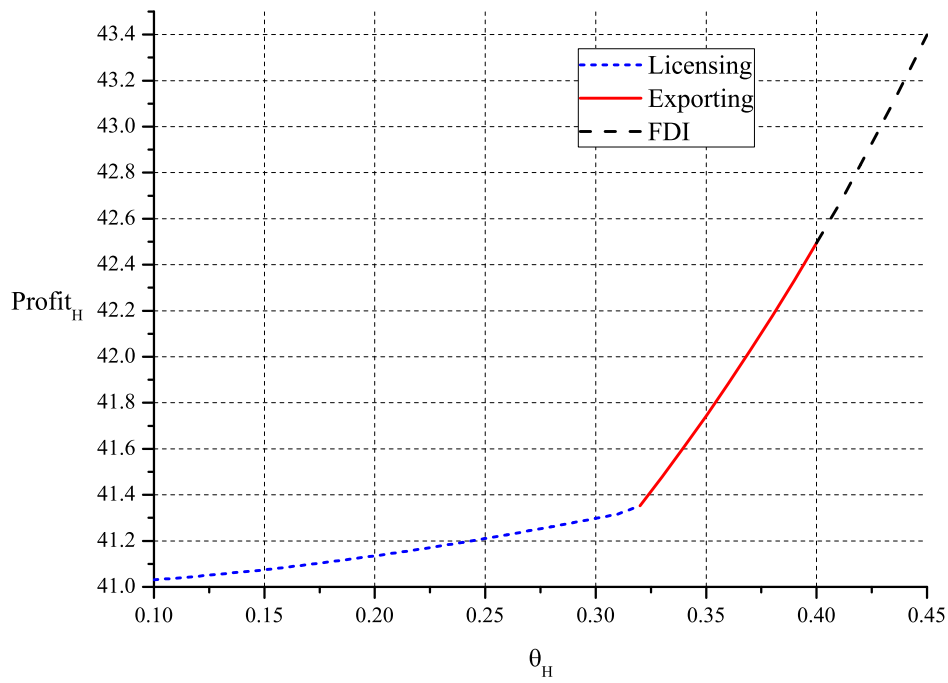


Figure 1: Exporting, Licensing and FDI choice - (Ex-ante) Productivity effect

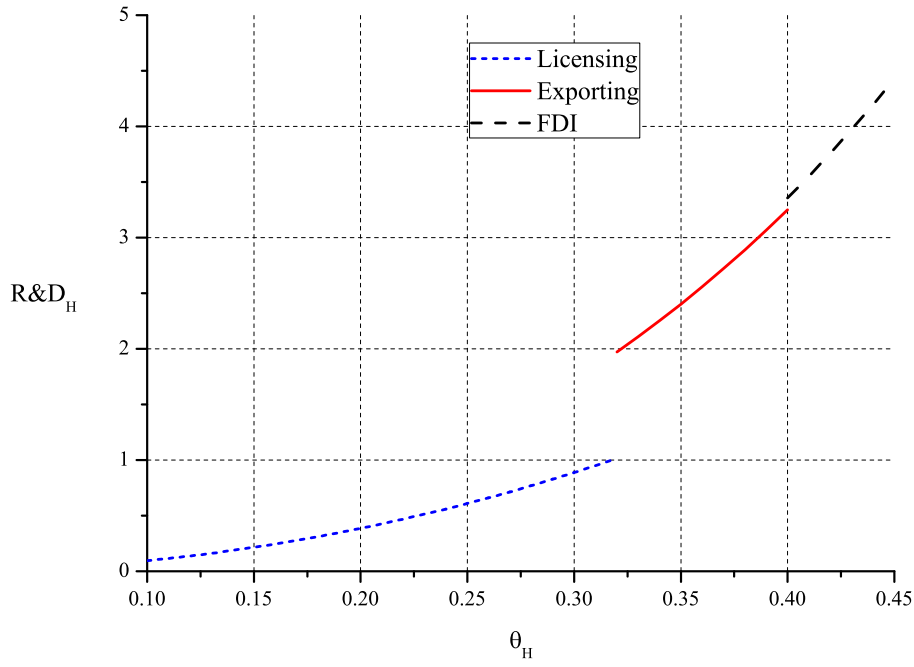


Figure 2: R&D investment of firm H

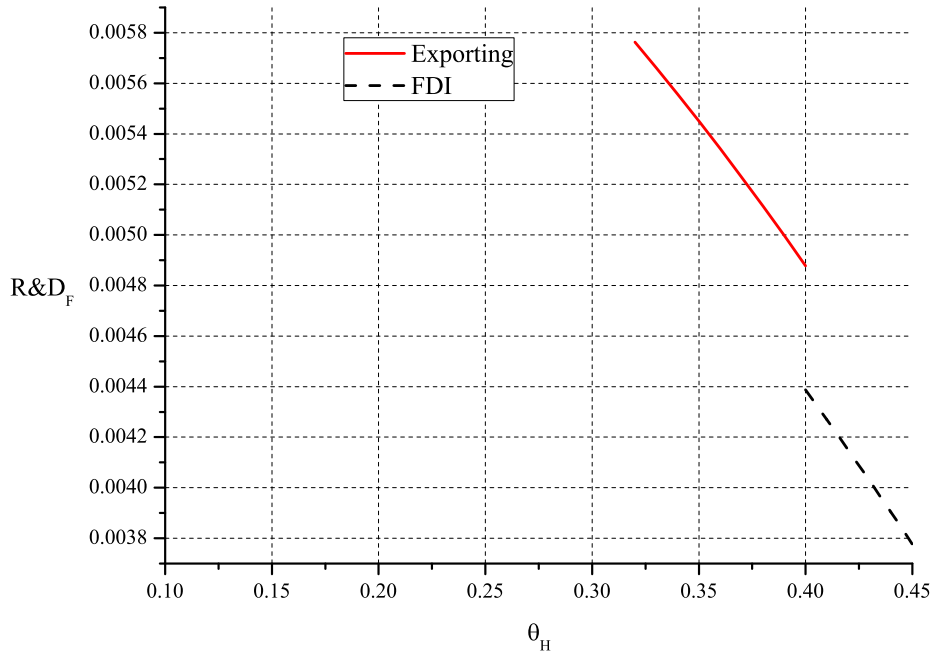


Figure 3: R&D investment of firm F

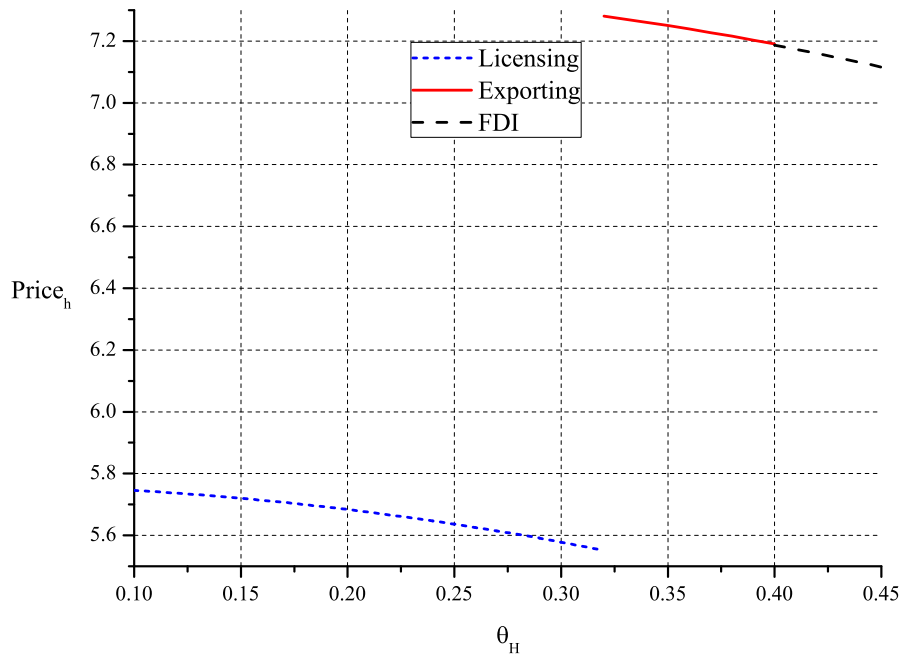


Figure 4: Market price in country h

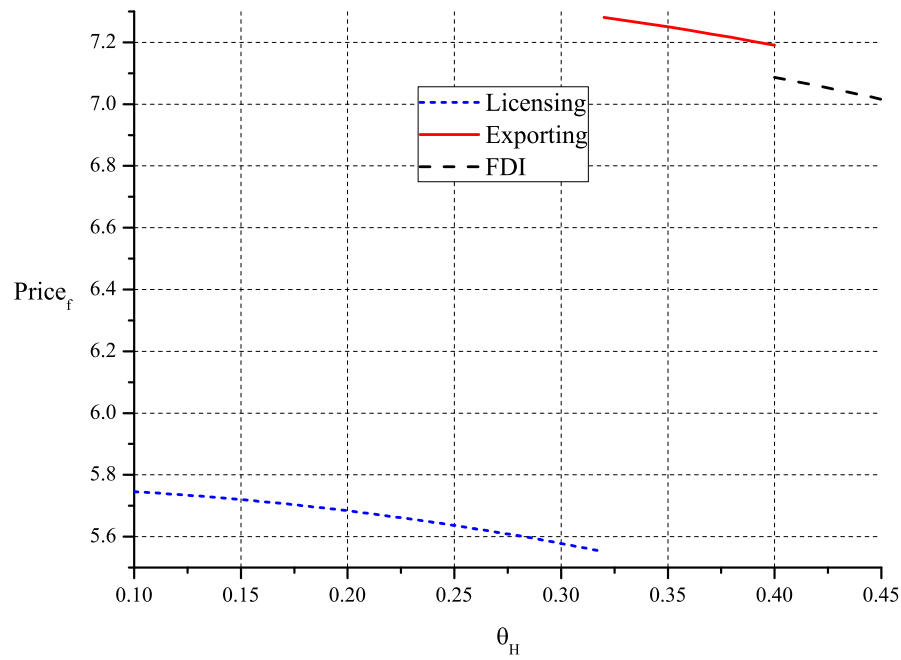


Figure 5: Market price in country f

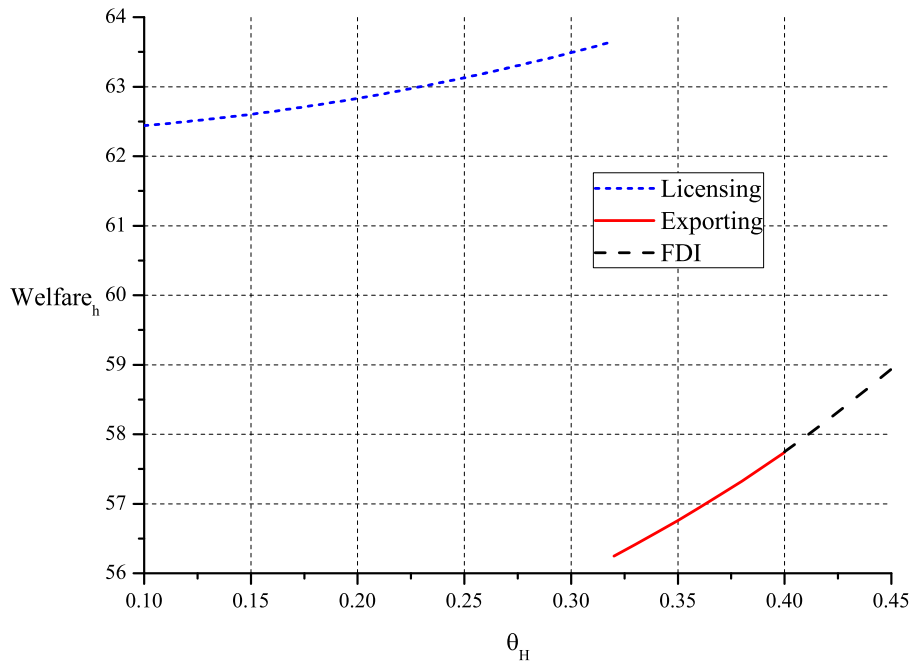


Figure 6: Welfare in country h

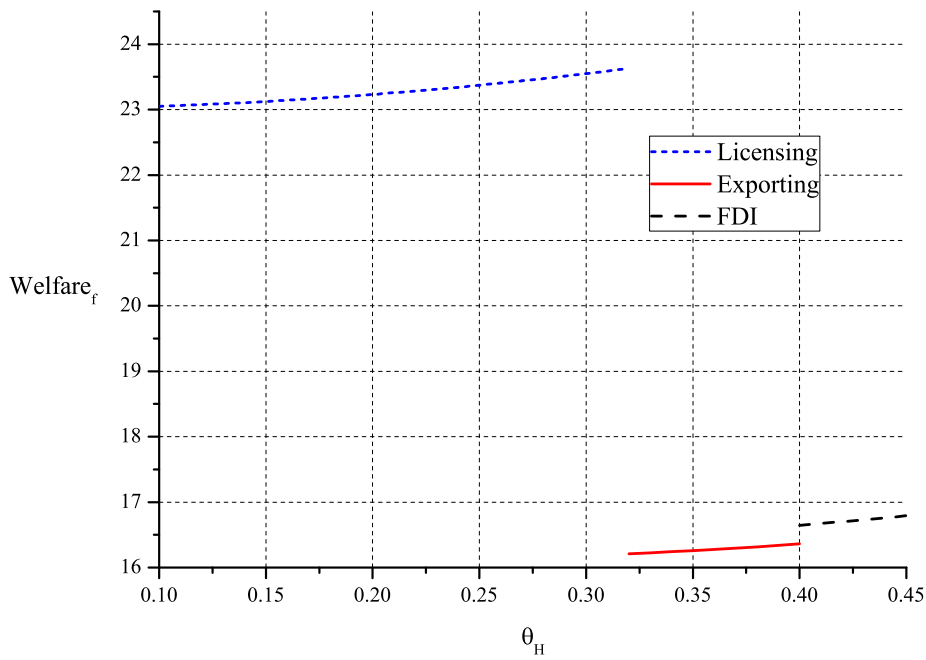


Figure 7: Welfare in country f

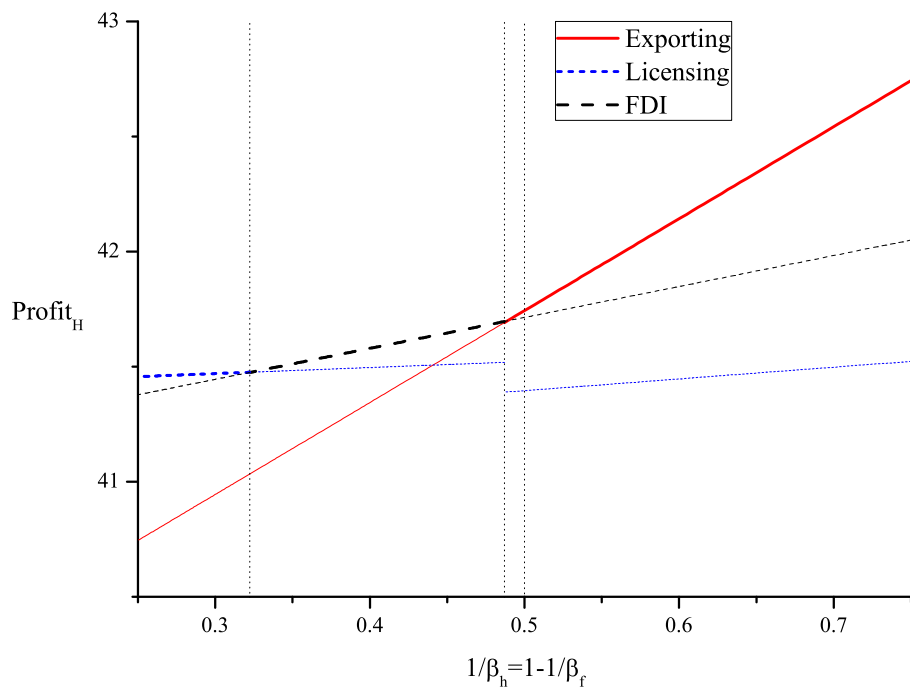


Figure 8: Exporting, Licensing and FDI choice - Market size effect

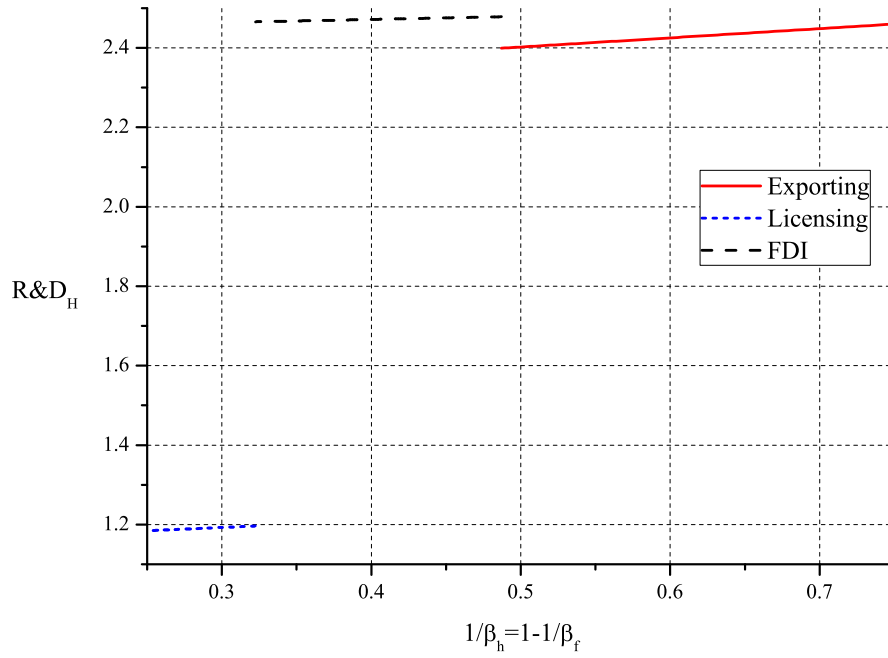


Figure 9: R&D investment choice of firm H

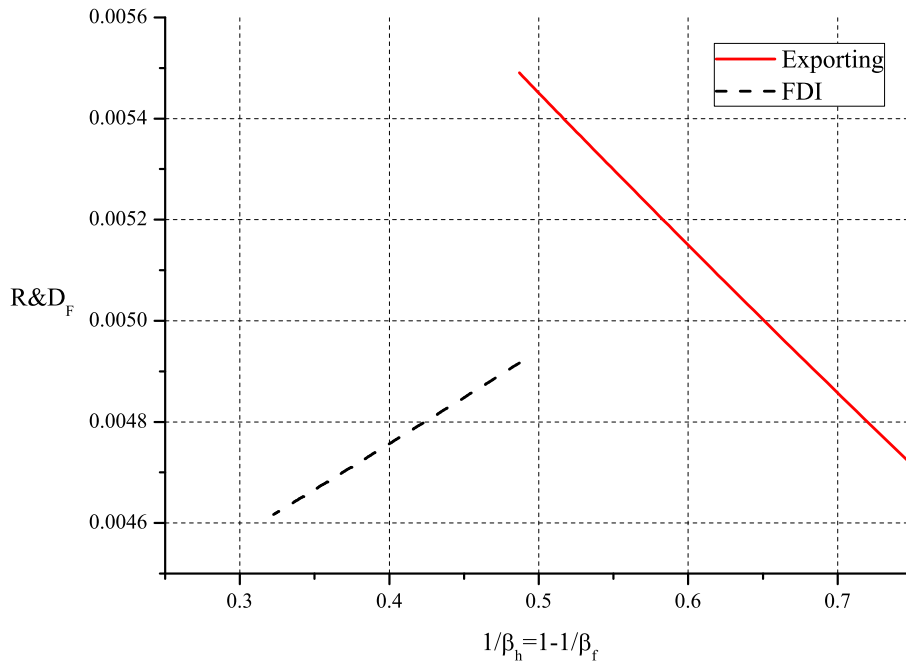


Figure 10: R&D investment choice of firm F

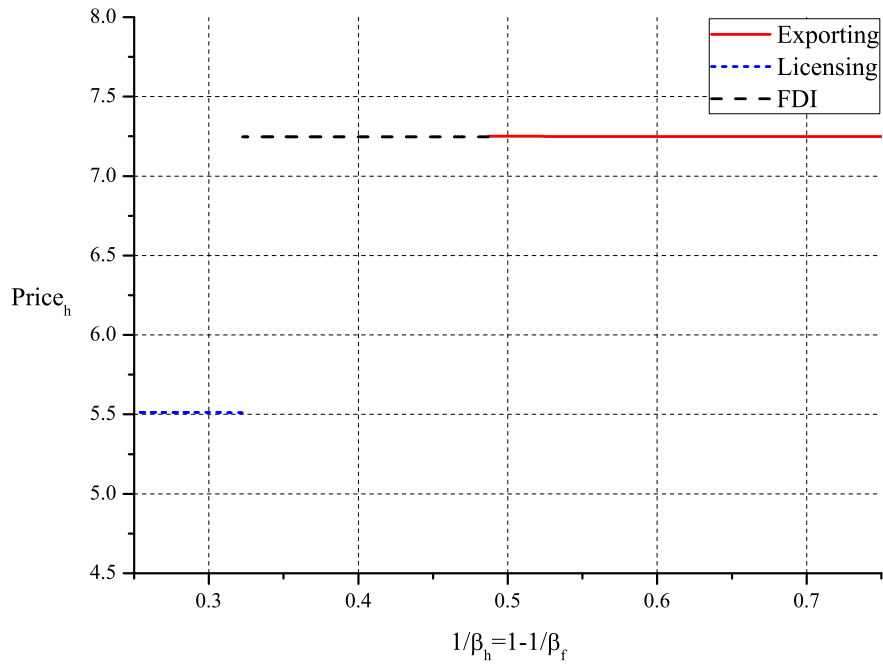


Figure 11: Market price in country h

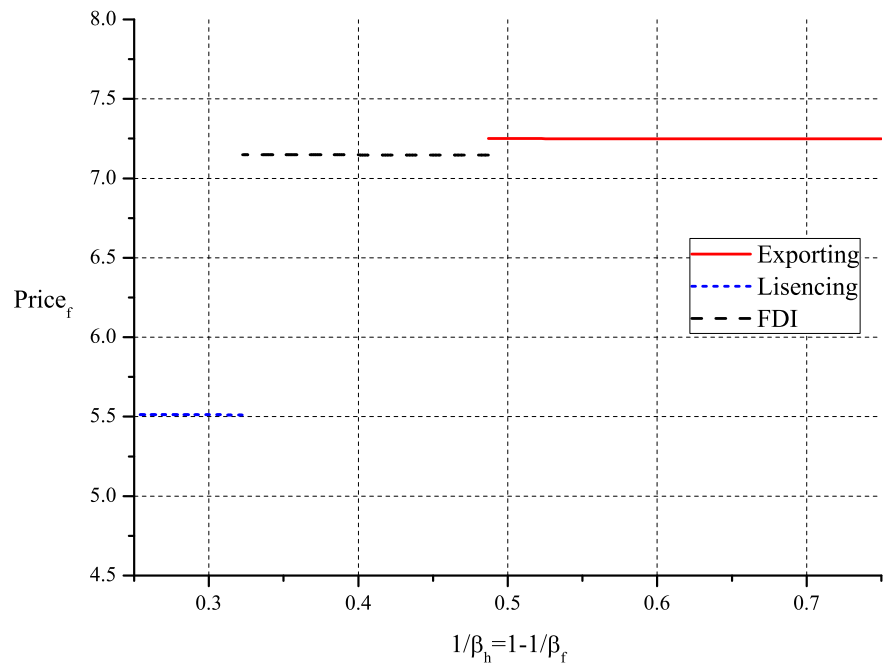


Figure 12: Market price in country f

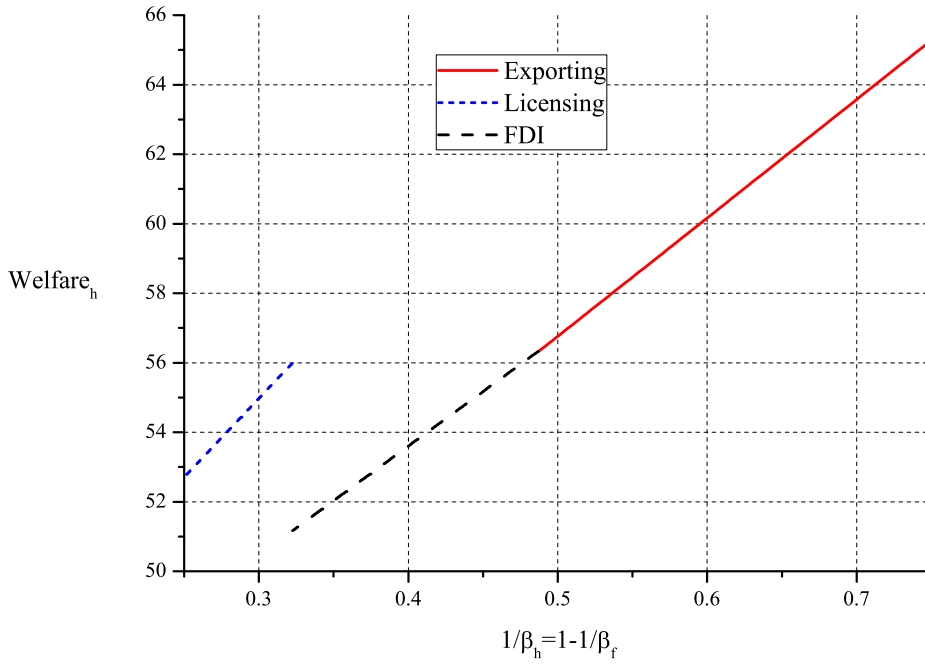


Figure 13: Total welfare in country h

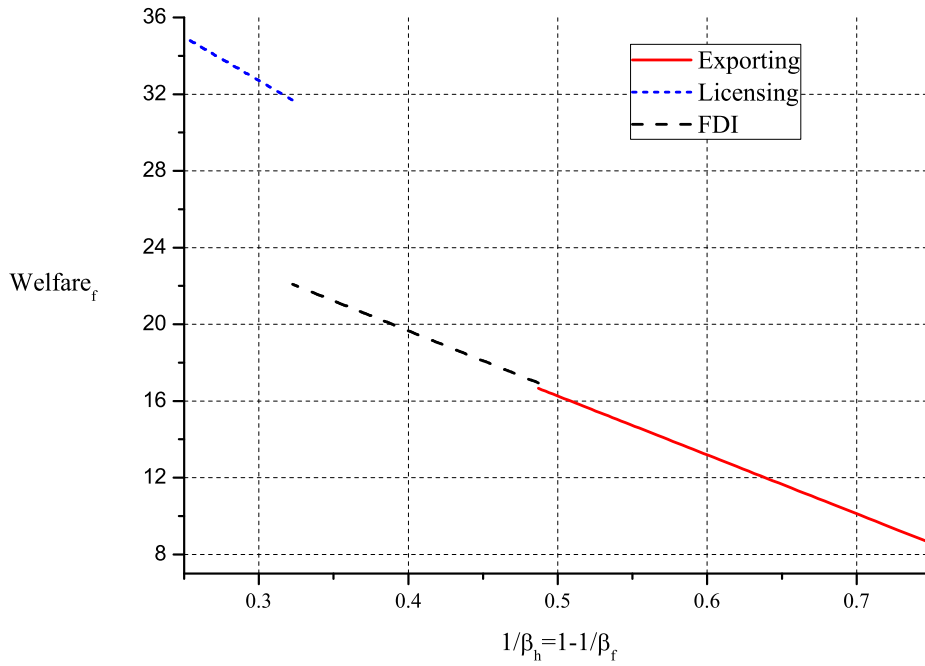


Figure 14: Total welfare in country f

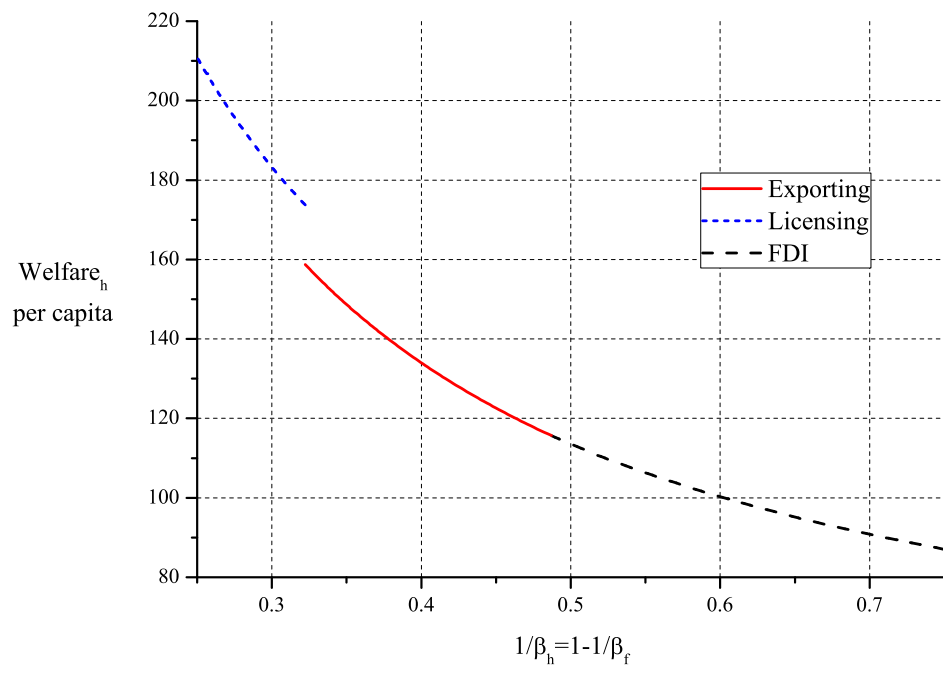


Figure 15: Welfare per capita in country h

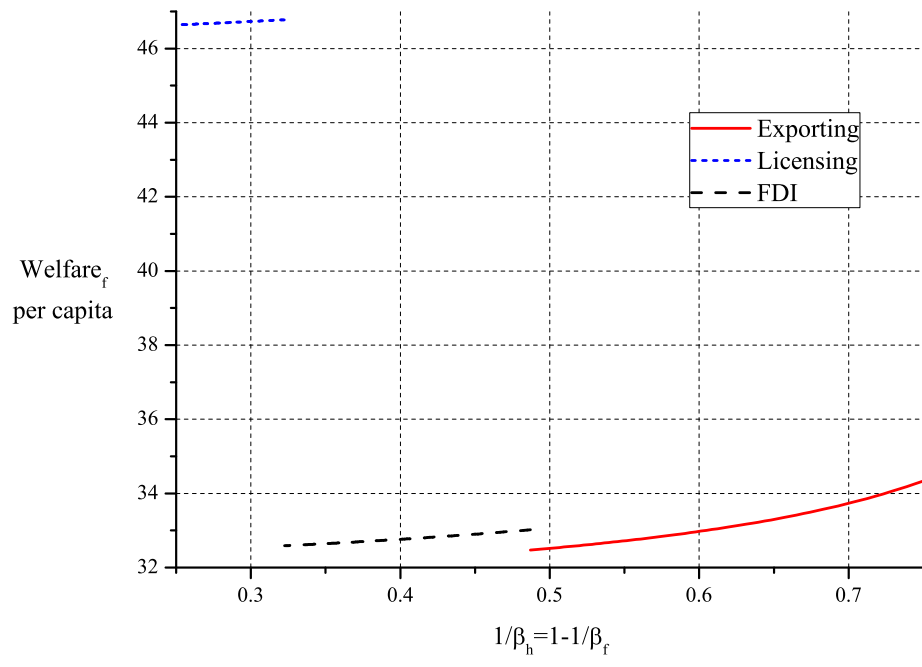


Figure 16: Welfare per capita in country f

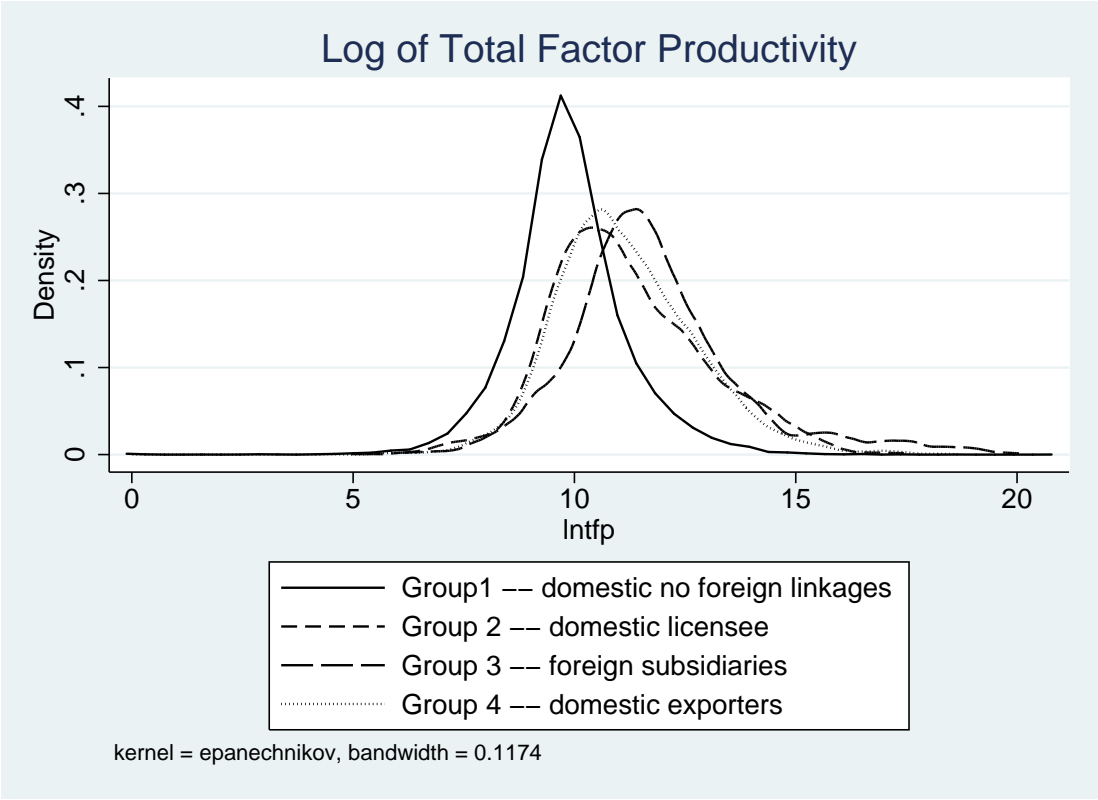


Figure 17: Total factor productivity by groups

Table 1. ISIC 2-digit industry codes and descriptions

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

Table 2. Coefficients from Levinsohn-Petrin regressions

ln (value added) Sector code	15	17	18	19	20	21	22	24	25	26
No. of observations	11080	1776	1862	940	2426	1080	1825	2165	2326	1908
ln(skilled labor)	0.38	0.68	0.57	0.65	0.46	0.43	0.56	0.65	0.53	0.42
ln(unskilled labor)	0.17	0.28	0.27	0.3	0.15	0.1	0.22	0.05	0.21	0.02
ln(capital)	0.04	0.05	0.05	0.05	0.02	0.01	0.05	0.05	0.07	0.02
Sum of coefficients	0.60	1.01	0.88	1.00	0.63	0.55	0.82	0.75	0.82	0.46

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

Table 3. Logarithm of total factor productivity by groups

Type of firm (50% capital share foreign plants)	no. of Obs	Mean	Median
Domestic no licensing no exporting (Group1)	27834	9.871	9.810
Domestic licensee (Group 2)	1398	11.171	10.956
Foreign subsidiary(Group 3)	1762	11.776	11.525
Domestic no licensing exporter (Group 4)	5508	11.154	10.981
Type of firm (10% capital share foreign plants)	no. of Obs	Mean	Median
Domestic no licensing no exporting (Group1)	27692	9.864	9.806
Domestic licensee (Group 2)	1360	11.124	10.885
Foreign subsidiary(Group 3)	2075	11.783	11.563
Domestic no licensing exporter (Group 4)	5375	11.132	10.957

Table 4. Effect of Foreign Linkage on TFP

VARIABLES	50% capital share -- foreign plant				10% capital share -- foreign plant			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ln tfp	ln tfp	ln tfp	ln tfp	ln tfp	ln tfp	ln tfp	ln tfp
FDI dummy	0.396*** (0.0475)	0.407*** (0.0476)	0.430*** (0.0478)	0.444*** (0.0478)	0.402*** (0.0426)	0.411*** (0.0427)	0.440*** (0.0429)	0.451*** (0.0430)
Licensee Dummy	0.156*** (0.0228)	0.161*** (0.0226)	0.158*** (0.0232)	0.163*** (0.0229)	0.152*** (0.0229)	0.157*** (0.0227)	0.153*** (0.0233)	0.158*** (0.0230)
Constant	9.351*** (0.113)	7.302*** (0.492)	9.141*** (0.0390)	7.250*** (0.480)	9.349*** (0.113)	7.307*** (0.492)	9.139*** (0.0390)	7.260*** (0.480)
Observations	36,502	36,486	36,502	36,486	36,502	36,486	36,502	36,486
Number of plantid	8,180	8,178	8,180	8,178	8,180	8,178	8,180	8,178
	4-digit industry dummies	4-digit industry dummies	2-digit industry dummies	2-digit industry dummies	4-digit industry dummies	4-digit industry dummies	2-digit industry dummies	2-digit industry dummies
	Year dummies	Year dummies	Year dummies	Year dummies	Year dummies	Year dummies	Year dummies	Year dummies
	Region dummies	Region dummies	Region dummies	Region dummies	Region dummies	Region dummies	Region dummies	Region dummies
	Other controls			Other controls		Other controls		Other controls

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

In all eight columns, the coefficients of FDI are tested to be significantly larger than the coefficients of Licensee.

Table 5. Effect of Foreign Linkage on Market Share – Total Sales

VARIABLES	50% capital share -- foreign plant				10% capital share -- foreign plant			
	(1) lnsales	(2) lnsales	(3) lnsales	(4) lnsales	(5) lnsales	(6) lnsales	(7) lnsales	(8) lnsales
FDI dummy	0.649*** (0.160)	0.654*** (0.160)	0.653*** (0.162)	0.661*** (0.162)	0.747*** (0.104)	0.750*** (0.104)	0.760*** (0.105)	0.764*** (0.105)
Licensee Dummy	0.212*** (0.0604)	0.214*** (0.0601)	0.211*** (0.0612)	0.214*** (0.0609)	0.217*** (0.0620)	0.219*** (0.0618)	0.215*** (0.0628)	0.217*** (0.0625)
Constant	13.33*** (0.898)	10.48*** (1.677)	12.28*** (0.116)	8.178*** (1.558)	13.31*** (0.892)	10.47*** (1.669)	12.27*** (0.115)	8.189*** (1.554)
Observations	36,845	36,828	36,845	36,828	36,845	36,828	36,845	36,828
Number of plantid	8,212	8,210	8,212	8,210	8,212	8,210	8,212	8,210
	4-digit industry dummies	4-digit industry dummies	2-digit industry dummies	2-digit industry dummies	4-digit industry dummies	4-digit industry dummies	2-digit industry dummies	2-digit industry dummies
	Year dummies	Year dummies	Year dummies	Year dummies	Year dummies	Year dummies	Year dummies	Year dummies
	Region dummies	Region dummies	Region dummies	Region dummies	Region dummies	Region dummies	Region dummies	Region dummies
		Other controls		Other controls		Other controls		Other controls

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

In all eight columns, the coefficients of FDI are tested to be significantly larger than the coefficients of Licensee.

Table 6. Effect of Foreign Linkage on Market Share – Value added

VARIABLES	50% capital share -- foreign plant				10% capital share -- foreign plant			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	lnvareal	lnvareal	lnvareal	lnvareal	lnvareal	lnvareal	lnvareal	lnvareal
FDI dummy	0.406*** (0.0531)	0.418*** (0.0534)	0.426*** (0.0534)	0.440*** (0.0537)	0.410*** (0.0467)	0.420*** (0.0469)	0.433*** (0.0469)	0.443*** (0.0471)
Licensee Dummy	0.201*** (0.0261)	0.206*** (0.0257)	0.201*** (0.0264)	0.206*** (0.0261)	0.199*** (0.0265)	0.203*** (0.0261)	0.197*** (0.0268)	0.202*** (0.0264)
Constant	12.77*** (0.232)	10.84*** (0.580)	12.20*** (0.0649)	10.48*** (0.532)	12.77*** (0.232)	10.84*** (0.580)	12.20*** (0.0648)	10.49*** (0.532)
Observations	36,502	36,486	36,502	36,486	36,502	36,486	36,502	36,486
Number of plantid	8,180	8,178	8,180	8,178	8,180	8,178	8,180	8,178
	4-digit industry dummies	4-digit industry dummies	2-digit industry dummies	2-digit industry dummies	4-digit industry dummies	4-digit industry dummies	2-digit industry dummies	2-digit industry dummies
	Year dummies	Year dummies	Year dummies	Year dummies	Year dummies	Year dummies	Year dummies	Year dummies
	Region dummies	Region dummies	Region dummies	Region dummies	Region dummies	Region dummies	Region dummies	Region dummies
		Other controls		Other controls		Other controls		Other controls

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

In all eight columns, the coefficients of FDI are tested to be significantly larger than the coefficients of Licensee.

Table 7. Effect of Foreign Linkage on Market Share – Total Employment

VARIABLES	50% capital share -- foreign plant				10% capital share -- foreign plant			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	lnemp	lnemp	lnemp	lnemp	lnemp	lnemp	lnemp	lnemp
FDI dummy	0.170*** (0.0280)	0.174*** (0.0279)	0.180*** (0.0289)	0.184*** (0.0288)	0.161*** (0.0258)	0.165*** (0.0257)	0.169*** (0.0263)	0.173*** (0.0262)
Licensee Dummy	0.080*** (0.0182)	0.079*** (0.0185)	0.080*** (0.0182)	0.080*** (0.0185)	0.078*** (0.0180)	0.077*** (0.0183)	0.078*** (0.0179)	0.077*** (0.0183)
Constant	3.623*** (0.314)	3.072*** (0.455)	3.414*** (0.0435)	3.026*** (0.328)	3.622*** (0.314)	3.076*** (0.456)	3.414*** (0.0435)	3.033*** (0.328)
Observations	36,845	36,828	36,845	36,828	36,845	36,828	36,845	36,828
Number of plantid	8,212	8,210	8,212	8,210	8,212	8,210	8,212	8,210
	4-digit industry dummies	4-digit industry dummies	2-digit industry dummies	2-digit industry dummies	4-digit industry dummies	4-digit industry dummies	2-digit industry dummies	2-digit industry dummies
	Year dummies	Year dummies	Year dummies	Year dummies	Year dummies	Year dummies	Year dummies	Year dummies
	Region dummies	Region dummies	Region dummies	Region dummies	Region dummies	Region dummies	Region dummies	Region dummies
	Other controls			Other controls		Other controls		Other controls

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

In all eight columns, the coefficients of FDI are tested to be significantly larger than the coefficients of Licensee.

Table 8. Effect of Productivity Difference on FDI or Licensing Decisions

VARIABLES	50% capital share -- foreign plant				10% capital share -- foreign plant			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	fdi50	licensee1	fdi50	licensee1	fdi10	licensee2	fdi10	licensee2
ln(TFP3/TFP4)	0.037*** (0.0115)	-0.040*** (0.0124)			-0.0054 (0.00899)	-0.061*** (0.0104)		
Lagged 1 period ln(TFP3/TFP4)			0.034*** (0.0129)	-0.034** (0.0137)			-0.013 (0.00998)	-0.056*** (0.0114)
Observations	28,510	28,432	22,194	22,194	29,361	29,309	22,869	22,869
	2-digit industry dummies	2-digit industry dummies	2-digit industry dummies	2-digit industry dummies	2-digit industry dummies	2-digit industry dummies	2-digit industry dummies	2-digit industry dummies
	Year dummies	Year dummies	Year dummies	Year dummies	Year dummies	Year dummies	Year dummies	Year dummies
	Region dummies	Region dummies	Region dummies	Region dummies	Region dummies	Region dummies	Region dummies	Region dummies
	Other controls	Other controls	Other controls	Other controls	Other controls	Other controls	Other controls	Other controls

Other controls include population (region-year), average tariff rate (industry-year) and capital labor ratio (plant)

Standard errors in parentheses

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

Table 9. Effect of Productivity Difference on the Number of FDIs or Licensees
(4-digit industry aggregate)

VARIABLES	50% capital share -- FDI		10% capital share -- FDI	
	(1) No.of FDIs	(2) No. of Licensees	(3) No.of FDIs	(4) No. of Licensees
ln(TFP3/TFP4)	0.0645** (0.0326)	-0.0772*** (0.0249)	0.0647* (0.0350)	-0.0998*** (0.0233)
No.of Plants	0.00147*** (0.000464)	0.00197*** (0.000285)	0.00146*** (0.000461)	0.00226*** (0.000292)
Observations	385	291	402	300
	2-digit industry dummies	2-digit industry dummies	2-digit industry dummies	2-digit industry dummies
	Year dummies	Year dummies	Year dummies	Year dummies

Robust standard errors in parentheses

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

Table 10. Effect of Productivity Difference on Foreign shares or Licensing Fee
(4 digit industry aggregate)

VARIABLES	50% capital share -- FDI		10% capital share -- FDI	
	(1) Foreign share	(2) Licensing fee	(3) Foreign share	(4) Licensing fee
ln(TFP3/TFP4)	7.452*** (1.347)	-0.170 (0.134)	7.175*** (1.027)	-0.317** (0.142)
ln(total sales)	-1.516 (1.904)	0.588** (0.277)	-1.452 (1.810)	0.557** (0.275)
Observations	385	291	402	300
R-squared	0.545	0.306	0.540	0.314
	2-digit industry dummies	2-digit industry dummies	2-digit industry dummies	2-digit industry dummies
	Year dummies	Year dummies	Year dummies	Year dummies

Robust standard errors in parentheses

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