Productivity Differences among Unaffiliated Domestic Firms, Licensees and Foreign Subsidiaries*

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Abstract

Many papers consider the entry mode choice of multinational firms into host-country markets, generally focusing on the multinationals themselves. Here we change the focus to the domestic firms competing with the multinationals or linked to them as licensees or foreign affiliates. We begin with an empirical exercise using Chilean plant-level data which motivates and informs the theory to follow. We show that plants which are foreign owned have higher productivity, sales and value added than those that are linked to a foreign firm through licensing, and that the latter in turn have higher productivity and larger size than domestic unaffiliated firms. Across industries, those with a larger difference between the productivity of domestic firms and foreign subsidiaries are industries with a larger share of foreign affiliates.

The theory section models a domestic (host) and foreign (multinational) firm which differ in exogenous (ex-ante) efficiency parameters, the foreign firm being more efficient. Endogenous variables are (a) investment decisions by both firms which can increase (ex-post) productivity and (b) the multinationals entry mode choice: licensing, exporting or FDI.

Small, medium, and large ex-ante efficiency differences lead the foreign multinational to choose licensing, exporting and FDI respectively. Briefly, this pattern of mode choice implies that a larger ex-ante efficiency difference is magnified ex-post by the endogenous investment choices of the firms. Using licensing as a reference point, the host firm reduces its investment and productivity under foreign entry by exporting and even more so under FDI. These latter two modes of foreign entry thus imply negative productivity effects on unaffiliated local firms, which is broadly consistent with empirical evidence.

Again using licensing as a reference point, the switch to exporting and then to FDI as the foreign multinational becomes more (ex-ante) efficient leads to a higher domestic price and lower domestic welfare. The adverse effects of these mode switches are due to a technological inefficiency effect and an anti-competitive effect. With due caution about recommendations based on any specific theoretical model, the policy implication here suggests a role for policies that encourage licensing.

1 Introduction

Multinational firms play an 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. Foreign firms in turn face the problem that how they should sell their products in a more liberalized world market, referred to as mode choice. The mode choices we consider here are exporting to the host country, licensing a host-country firm, or foreign direct investment which creates a local competitor to the host-country firm. The foreign 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 the productivity of domestic firms in the host country.

Our focus here is on the productivity levels of firms in the host country rather than the multinationals themselves. More specifically, we are interested in the comparisons among domestically owned firms with no foreign affiliations, domestic firms having licensing agreements with a foreign firm, and subsidiaries of foreign multinational corporations. We begin with an empirical exercise using Chilean plant-level data 2001-2007 which motivates and informs the theory to follow. 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 us to look for a relationship between firm type (unaffiliated domestic, licensee, or subsidiary) and productivity.

We show that firms which are foreign owned have higher productivity, sales and value added than those that are linked to a foreign firm through licensing. The licensees in turn have higher productivity and larger size than domestic unaffiliated firms. Across industries, those with larger differences between the productivity of domestic firms and foreign subsidiaries are industries with a larger share of foreign affiliates.

The theoretical model has two heterogeneous firms (firm F and firm H) located in different countries (country f (foreign) and country h (host)). The firms differ in exogenous (ex-ante) cost parameters, and compete in both the host and foreign market. Endogenous variables are (a) cost-reducing investment decisions by both firms and (b) the foreign multinationals entry mode choice: exporting, licensing, or FDI. Investment by a firm reduces its marginal cost (increases productivity), with marginal cost given by an exogenous base-cost parameter minus an investment effect multiplicative in a second exogenous parameter. We assume that the foreign multinational has a lower value of the base-cost parameter and thus will have a bigger market share for a given level of investment than the host firm. And/or the multinational has a larger value of the second parameter, indicating that cost-reducing investment will have a higher marginal product for the foreign firm. For both reasons, the multinational has the larger incentive to engage in investment, but this interacts with the mode choice decision, and the mode choice decision in turn affects the investment decision of the host-country firm.

The model is a three-stage game. In the first stage, firm F which has a more efficient cost function makes its mode choice (exporting, licensing or FDI). Firm H with a less efficient marginal cost function accepts firm F's mode choice according to the assumptions in the model. Under the exporting choice, both firms choose to serve both markets (country f and country h) and bear a symmetric variable trade cost when exporting. If firm F prefers licensing, firm H gets firm F's technology and competes against firm F in both markets. We assume that firm F extracts all the rents from granting the license. Under the FDI choice, firm F pays a fixed cost and sets up a (horizontal) subsidiary in country h to avoid any variable trade cost, while firm H exports to country f and still bears the variable trade cost.

In the second stage, two firms determine their corresponding ex-post marginal costs (productivity) by choosing their optimal cost-reducing investment levels endogenously. In the last stage (third stage) the two firms compete against each other by choosing their optimal output levels (Cournot duopoly competition) in both foreign and host country markets in the open economy. Thus while the foreign firm extracts the rents from the license, it cannot block competition in the output decision stage.

The central experiment with the model is to increase the ex-ante efficiency advantage of firm F holding the ex-ante technology of firm H constant. A small ex-ante efficiency advantage for the multinational leads to licensing its technology to the host firm, and to a zero ex-post productivity difference. An intermediate productivity difference leads to a choice of exporting, a larger ex-post productivity difference and a lower productivity for the host firm than under licensing. A large ex-ante efficiency difference leads to the choice of FDI and an even larger ex-post productivity difference relative to either licensing or exporting.

The switch from licensing to exporting as firm F becomes more efficient is due to the third-stage output competition effect. Under licensing, firm F is making firm H more competitive and reducing firm F's profits in both markets. At a certain point, these lost profits outweigh the licensing fee that firm F can extract and so it switches to exporting to cut off this competitive effect. The switch leaves firm H with its inferior technology, leading firm H to reduce the investment and become even less productive ex post. The switch from exporting to FDI at a higher level of ex-ante efficiency for firm F is more intuitive. As firm F gets more efficient, firm F increases investment and firm H reduces investment, shifting total sales and market share to firm F. At some point, this makes it optimal for firm F to switch from exporting, a high variable cost option, to FDI, a high fixed-cost option. The switch makes firm F more competitive in country h, which causes firm H to reduce investment, leading to an even lower ex-post productivity.

Using the licensing outcome as a reference point, the results have implications for the host economy as a whole. First, the switches to exporting and then FDI as the foreign firm becomes more efficient not only have an adverse affect on the domestic firm, but they raise the price of the good and lower the welfare in the host country. This is due to a simultaneously determined adverse productivity effect and an anti-competitive effect. As the foreign firm becomes more efficient, licensing its technology has an increasingly negative effect on its profits in the output decision stage which eventually dominates the licensing fee it extracts as just noted. The switch to exporting or FDI not only leaves the domestic firm with a worse base technology, but further worsens its productivity by reducing investment. This in turn gives the foreign firm a much more dominant position in Cournot competition which leads to a higher equilibrium price and lower welfare in the host country. While we are cautious about making policy recommendations from any specific theoretical model, our results do suggest a possible role for encourage licensing by foreign firms, conditional of course of licensing not blocking output-stage competition.

The existing theoretical work on the mode choice and productivity choice favors two types of models. Monopolistic competition models usually assume that different productivity levels are given exogenously (Helpman, Melitz and Yeaple, 2004). Oligopolistic-competition models which apply Cournot competition use knowledge capital or human capital to differentiate firms (Horstmann and Markusen, 1987; Ethier and Markusen, 1996) or allow firms to change R&D investment levels to determine their productivity (Saggi, 1999; Ghosh and Saha, 2007). But the focus is generally on the multinationals themselves and not the effect of the mode choice on host-country domestic firms. While the number of domestic firms responds endogenously to multinational entry in all free-entry models (Markusen, 2002), there is no effect on the host-country firm's productivity other than through a firm scale effect in the oligopoly models, and even that is absent in monopolistic-competition models.

As in the case of the theoretical literature, many empirical papers' focus tends to be on the multinationals themselves or on the mode choice of a domestic firm and not on the consequences of those mode decisions on other host-country firms. There are quite a few empirical papers focusing on the interactions between export 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 export decision and mode choice (FDI or exporting) and the impact of export decision and mode choice (FDI) on firms' ex-post productivity levels in different ways. Due to the lack of licensing information in most datasets, licensing hasn't been well studied in the existing empirical literature.

Other empirical papers consider foreign entry as exogenous, and analyze its effects on local independent firms. The literature on this is large and a review is beyond the scope of this paper.[1] Aitken and Harrison (1999), Javorcik (2004), and Görg and Greenaway (2004) created a lot of further interest. Important subsequent work includes Keller and Yeaple (2009). A relevant recent paper is Haller (2013) which also provides a up-to-date review of existing knowledge. Most papers do not look at specific channels for spillovers from FDI, just evidence whether or not they exist. Haller (2013) is an exception, and finds negative effects of foreign entry on domestic firms in some sectors. To clarify our contribution, we are not looking at the effect of foreign entry on independent, unaffiliated domestic firms. Our task is to analyze how the foreign firms mode choice determines the affiliation status of the domestic firm and its investment and productivity, and how this in turn affects domestic prices and welfare.

2 Motivation Evidence

The Encuesta Nacional Industrial Anual (ENIA, translated as "Annual National Industrial Survey") of Chile is plant-level data and includes both licensee and foreign subsidiary information so that we can take a glance at how different types of host-country firms behave and perform differently in their productivities and market shares. We refer to the unit as firms because nearly ninety percent of the plants are single-plant firms. The version of ENIA that we access covers the years 2001-2007, includes 111 4-digit level manufacturing industries (ISIC, Rev.3), and reports firm-level statistics such as location (administrative region), ownership, total sales, value added, total employment and etc.

While this dataset has great advantages, particularly with respect to ownership and licensing, it has limitations that do not allow explicit testing or estimation of hypotheses derived from the theoretical model to follow. Specifically, there are few switches of firms

[1] A search in the Social Science Citation Index under "FDI Spillovers" yields 53 pages of results.

between independent, licensees, and foreign owned and new entry of multinationals in our short time series. Thus we cannot observe ex ante productivity differences in the way they are modeled in the theory. What we are observing is essentially ex post productivity in terms of the model. All we can say is that these ex post observations are consistent with the theory, and will avoid the temptation to assume or infer causality. As noted in the introduction, we can also say that the theory is consistent with a body of evidence showing that multinational entry does have negative effects on independent host-county firms.

We treat Chile as a host country (country h in our theory) and find three sets of empirical results. First, within industries, firms that are foreign subsidiaries have higher productivities, larger sizes, and larger market shares than licensees, which in turn have higher values of these variables than independent (unaffiliated) domestic firms. Second, across industries, those that have higher productivity differences between unaffiliated domestic firms and foreign affiliates are industries in which foreign affiliates have a larger share of total sales. If the productivity advantage of foreign firms is smaller in an industry, there are more licensing transactions. At the firm level, a larger average productivity advantage of foreign subsidiaries increases the probability of an individual firm to become a foreign subsidiary and decreases its probability to be a domestic licensee. While this across-industry finding does not directly relate to our model, we think it is consistent with an extended version of the model in which there is free entry and exit of domestic firms and foreign subsidiaries. Third, the literature has shown that the existence of foreign subsidiaries and its host-country domestic competitors' productivity are either negatively related or not correlated at all. Similar evidence is found with our Chilean firms. The existence of foreign subsidiaries and the extent of foreign ownership in one industry is associated with less productive Chilean domestic firms.

There are two groups of control variables used in our regressions. First, we have the firm-level activity measure (firm-time), which is capital/labor ratio (KL). The figures are computed using data reported by the ENIA. Second, we employ population (region-time) and foreign tariff rate (industry-time)[2] to control for the changes in the local demand and foreign market.

2.1 Foreign Linkages, Productivity and Market Share

In order to take a look at the productivity and market share between different types of firms in Chile, we categorize the data into three different groups. The first group (Group 1) includes unaffiliated domestic firms without any license. The second group (Group 2) includes all domestic licensees. The third group (Group 3) is the foreign subsidiary group. The cut-off for domestic and foreign firms in our empirical part is 100% capital share.[3]

The productivity measure, the logarithm of total factor productivity (TFP), is estimated using the Ackerberg-Caves-Frazer (ACF; 2006) method, which builds on the earlier approaches of Olley-Pakes (1996) and Levinsohn-Petrin (2003)[4]. Figure 1 shows the Kernel density of the natural log of total factor productivity by different groups. Graphically firms in group 1(unaffiliated domestic firms) have a larger proportion in low-productivity firms and a smaller proportion in high-productivity firms indicated by the solid line, while group 3 (foreign subsidiaries) has a smaller proportion in low-productivity firms and a larger proportion in high-productivity firms (dotted line). Group 2 (long dashed line) which includes all domestic licensees has a distribution in the middle.

The first question we raise here tries to reveal the relationship between different foreign linkages and firm-level productivity. Do foreign subsidiaries or domestic licensees exhibit higher productivity compared to unaffiliated domestic firms?

Foreign subsidiaries and domestic licensees in Chile can reflect the corresponding productivity levels of their parent firms or licensors. The first column in table 1 presents the

[2]The foreign tariff rate is calculated at the industry-year level and is defined as the weighted tariff-equivalent trade barrier for Chiles five largest export destinations.

[3]10% capital share is a widely accepted definition for foreign subsidiaries in the multinational literature. All our empirical results still hold if we apply the 10% capital share definition for foreign subsidiaries.

[4]Calculations of TFP using such methods are widely used in the trade literature. See, for example, Amiti and Konings (2007), Goldberg, Khandelwal, Pavcnik, and Topalova (2010), and Greenaway, Guariglia and Kneller (2007). In particular, for uses of the ACF method, see Arnold, Javorcik, Lipscomb and Mattoo (2008), Javorcik and Li (2008), and Petrin and Sivadasan (2011).

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

$$\begin{aligned} ln(TFP_{ijrt}) &= \alpha + \beta_1 * FDI_{ijrt} + \beta_2 * Licensee_{ijrt} + \Upsilon_1 * Industrydummies_j \\ &\quad + \Upsilon_2 * Regiondummies_r + \Upsilon_3 * Timedummies_t + \epsilon_{ijrt}. \end{aligned} \tag{1}$$

The dependent variable is the natural log of the total factor productivity of each firm, and the key independent variables are two mutually exclusive dummy variables: FDI and *Licensee*. FDI equals one if a firm belongs to the foreign subsidiary group (group 3) and zero otherwise. *Licensee* only considers the domestic licensees that it equals one if a firm is domestic and pays a positive licensing fee to foreign firms. The coefficients of FDI and *Licensee* are both positive and significant. Compared to unaffiliated domestic firms (the reference group in these regressions), being a foreign subsidiary on average has a higher natural log of total factor productivity (by about 0.77), and getting access to foreign licenses increases the natural log of total factor productivity by around 0.43. This means that foreign subsidiaries are about 8.3% more productive and domestic licensees are about 4.6% more productive than unaffiliated domestic firms. Moreover, the coefficient of FDI is significantly larger in magnitude than the coefficient of *Licensee* (almost double). Foreign subsidiaries on average exhibit higher productivity than domestic licensees.

Besides the firm-level productivity, we are also interested in whether foreign subsidiaries or domestic licensees have larger sizes (larger market shares) than unaffiliated domestic firms.

Three dependent variables (y_{ijrt}) reflecting firm size are tested in the following: first is the logarithm of real total sales (2nd column in table 1, second is the logarithm of real value added (3rd column in table 1), and third is the logarithm of total employment (4th column in table 1). These dependent variables are also market share indicators by adding the industry control variables in the regressions. The following regression equation is as followed:

$$
\begin{aligned}
ln(y_{ijrt}) \quad = \quad & \alpha + \beta_1 * FDI_{ijrt} + \beta_2 * Licensee_{ijrt} + \Upsilon_1 * Industrydummies_j \\
& + \Upsilon_2 * Regiondummies_r + \Upsilon_3 * Timedummies_t + \epsilon_{ijrt}. \qquad (2)
\end{aligned}
$$

Column 2, 3 and 4 in table 1 present the results of these three regressions. Both the coefficients of FDI and $Licensee$ are positive and significant at 1% level which indicates that firms with foreign linkages on average are significantly larger (have significantly larger market shares) than unaffiliated domestic firms belonging to group 1. In addition, the magnitude of the coefficient of FDI is significantly greater than that of $Licensee$ for both total sales and value added variables, which means that foreign subsidiaries are larger (have larger market shares) than domestic licensees.

2.2 Productivity Difference and Mode Choice

Besides the clear ranking of the productivity and market share of these three types of firms, we also observe more foreign subsidiaries and fewer licensing transactions when the productivity difference between foreign subsidiaries and unaffiliated domestic firms is large. We aggregate the plant-level data into 4-digit industry level to construct the key variable: foreign-domestic productivity difference. We calculate the weighted average total factor productivity by groups by weighting their real total sales at each 4-digit industry level ($ln(TFP_{jt}) = \frac{sales_{ijt}}{\sum_i sales_{ijt}} * ln(TFP_{ijt})$). According to the previous literature[5] and section 2.1 in this paper, unaffiliated domestic firms (group 1) represent the domestic low productivity, while foreign subsidiaries (group 3) represent the foreign high productivity. And therefore this independent variable can be calculated by the difference between the weighted average industry-level productivity of group 3 and that of group 1. This productivity difference can be expressed by "$ln(TFP^3_{jt}) - ln(TFP^1_{jt})$" where superscripts 3 and 1 indicate the group

[5] See Helpman, Melitz and Yeaple (2004), Javorcik (2004), and etc.

number (3 for foreign subsidiary and 1 for unaffiliated domestic firm). We further simplify this domestic-foreign productivity difference with notation "$lnTFP3 - lnTFP1$".

At the 4-dight industry level, we test how the foreign-domestic productivity difference is associated with the total numbers of foreign subsidiaries or domestic licensees and how it relates to the average industry-level foreign share or average licensing fee paid. The regression results are shown by table 2a (poisson MLE regressions for numbers of foreign subsidiaries or domestic licensees and pooled OLS for average foreign share or licensing fee at 4-digit industry level).

The dependent variables can be divided into two sets. First set includes the total number of foreign subsidiaries and the total number of domestic licensees at 4-digit industry level. Since these two dependent variables are both count data, we use Poisson MLE (column 1 and 2 in table 2a). Second set of dependent variables includes the average industry-level foreign share and average industry-level licensing fee. Both these two variables are weighted by the sales share of each firm. The pooled OLS regression results are reported by column 3 and 4 in table 2a. The regression equation is:

$$\begin{aligned} y_{jt} &= \alpha + \beta_1 * (lnTFP3 - lnTFP1)_{jt} + \beta_2 * 4digitIndustrySize \\ &\quad + \Upsilon_1 * Industrydummies_{j'} + \Upsilon_3 * Timedummies_t + \epsilon_{jt}, \end{aligned} \tag{3}$$

where y_{jt} is

1. No. of FDI firms (Poisson MLE regression),
2. No. of domestic licensees (Poisson MLE regression),
3. weighted average foreign share $(\frac{sales_{ijt}}{\sum_i sales_{ijt}} * foreignshare_{ijt})$ (Pooled OLS regression),
4. logarithm of weighted average licensing fee $(\ln\left(\frac{sales_{ijt}}{\sum_i sales_{ijt}} * licensingfee_{ijt}\right))$ (Pooled OLS regression).

The industry controls are dummy variables at 2-digit, so we also include one 4-digit industry size control variable (industry-time) in these regressions. The 4-digit industry size control variable is the total number of firms for the first set with dependent variable 1 and 2; and it is the logarithm of industry total sales with dependent variable 3 and 4. We find that when there is a larger difference between foreign and domestic productivities, more inward FDI in a 4-digit industry are received by the host country, while fewer licensing behaviors are observed.

We apply firm-level tests by using Probit regressions to see how productivity difference between foreign firms and domestic firms affects the mode choice of FDI decision or licensing decision. The independent variable is still the 4-digit industry average productivity difference between foreign and domestic firms. The probit regression is expressed by the following equation:

$$\begin{aligned} y_{it} &= \alpha + \beta * (lnTFP3 - lnTFP1)_{jt} + \Upsilon_1 * Industrydummies_j \\ &\quad + \Upsilon_2 * Regiondummies_r + \Upsilon_3 * Timedummies_t + \epsilon_{it}. \end{aligned} \tag{4}$$

in which, the dependent dummy variable y_{it} is either FDI (shown by column 1 in table 2b) or *Licensee* (shown by column 3 in table 2b). 2-digit industry controls, time controls and region controls are included in the regressions. In the regression of FDI choice, there is an endogeneity problem since the industry-level productivity difference variable is generated from the foreign subsidiaries' productivity. The effect of productivity difference on FDI decision may be underestimated since more foreign subsidiaries in one industry could reduce the foreign-domestic productivity difference by increasing the toughness of competition in this market and thus driving the least productive domestic firms out of the market. And therefore, we apply an IV test to solve this endogeneity problem. The instrument variable we use is the weighted average skilled labor ratio difference between foreign subsidiaries and domestic firms at 4-digit industry level. The IV adjusted coefficient of the productivity difference between foreign and domestic firms on FDI is significant and positive (column 2 in table 2b).[6]

In addition, we use both current period productivity difference $(lnTFP3 - lnTFP1)_{jt}$ (column 1, 2, 3 in table 2b) and lagged one period productivity difference $ln((lnTFP3 - lnTFP1)_{jt-1}$ (column 4, 5, 6 in table 2b) as the independent variable, and the results are very similar. With a larger productivity difference between these two types of firms, FDI is more likely to take place and licensing is less likely to happen. The coefficients of $lnTFP3 - lnTFP1$ for the IV adjusted FDI regressions are positive and significant (column 2 and 4 in table 2b); and the coefficients of $lnTFP3 - lnTFP1$ are all negative and significant for the *Licensee* regressions (column 3 and 6 in table 2b).

2.3 Foreign Subsidiaries and Domestic Firms' Productivity

It has been a long debating question on the technology spillovers through the existence of foreign subsidiaries and the extent of foreign ownership to the domestic competitors in the same industry[7]. We use the number for FDI firms in one 4-digit industry to measure the the existence of foreign subsidiaries and the weighted average foreign share to measure the extent of foreign ownership. We apply firm-level fixed effects regressions to check on the relationship between the foreign ownership in one industry and the productivity of domestic Chilean firms:

$$ln(TFP_{ijrt}) = \alpha + \beta * Ex_{jt}^{FDI} + \Upsilon * Timedummies_t + \omega_i + \epsilon_{ijrt}. \tag{5}$$

The dependent variable is the natural log of the total factor productivity of each domestic Chilean firm. We test the unaffiliated domestic firms (Group 1) and domestic licensees (Group 2) separately. Table 3 reports the regression results. We can see that the existence of foreign subsidiaries and the extent of foreign ownership are both negatively related to

[6] The Wald test of exogeneity suggests there is an endogeneity problem with the firm-level FDI regression, but no such problem with the firm-level *Licensee* regression. The instrument variables are tested to be positive and significant in the first stage regressions.

[7] It was defined as horizontal spillover in Javorcik (2004).

unaffiliated domestic firms' productivity (column 1 and 3 in table 3); and nether of them is correlated with the productivity of domestic licensees (column 2 and 4 in table 3). Those findings align well with the horizontal spillover of FDI literature for many other countries, eg. Indonesia, China and etc.

3 Theoretical Framework

Driven by these interesting empirical findings, we develop a theoretical model with a three-stage game to explain the mode choice decision of multinational firms and productivity differences among unaffiliated domestic firms, licensees and foreign subsidiaries.

3.1 Model Set-up

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

$$P = \alpha - \beta X, \tag{6}$$

where P stands for the price of the good and X for the quantity. In each country there is a monopoly firm. Firm F is the domestic firm for Country f (foreign country) and firm H is the domestic firm for Country h (host country). In order to maximize its profit, each firm chooses its cost-reducing investment level first and then determines its marginal cost level by its given cost function. Firm F's marginal cost function is

$$c_F = \eta_F - \theta_F I_F^{\frac{1}{2}}, \tag{7}$$

which captures the relationship between firm F's marginal cost c_F and its cost-reducing investment level I_F with both η_F and θ_F positive. η_F is the base marginal cost (the inverse of the productivity) of firm F and θ_F indicates the investment to productivity transformability.

The cost function is more efficient if it has a smaller η_F and a larger θ_F. With a higher investment level, firm F's ex-post marginal cost level is lower, which means the productivity level of the firm is higher. In addition, the investment has a diminishing reduction effect on the marginal cost. Similarly, firm H's marginal cost function is

$$c_H = \eta_H - \theta_H I_H^{\frac{1}{2}}. \tag{8}$$

In the open economy, firm F and H which sell homogeneous goods compete by choosing their optimal quantities (Cournot competition) in both country f and country h. we assume firm F has a more efficient cost function (smaller η and larger θ) compared to firm H without loss of generality. There is a symmetric variable trade cost which equals t if either firm chooses to export to the other country[8]. Firm H can pay a licensing fee (L) to firm F to get the same marginal cost function as firm F and thus choose the same level of marginal cost (productivity) as firm F. Firm F can choose to incur a fixed investment D (horizontal FDI) in country h so that it can sell goods to country h directly without trade cost. Suppose this fixed investment is large enough so that firm H cannot afford the FDI cost due to its less efficient cost function.

There are three possible cases that might end up as an equilibrium.[9] First, both firms choose to export to the other country with no licensing or FDI. In this case, both firms choose their optimal investment levels interdependently and have different marginal cost levels. Second, firm F chooses to do FDI to get rid of the variable trade cost while firm H chooses to export. The two firms also have different cost levels due to their different choices of investment under this case. Third, firm F accepts the offer from firm H and licenses its production technology (more efficient marginal cost function) to firm H. The licensing in this paper cannot block any output competition so that the two firms will compete in

[8]The total marginal cost for firm F to export one unit of its goods to country h is $c_F + t$.

[9]In the theoretical model, it is possible that more productive firm F acquires less productive firm H and becomes a monopolist in the world market (both country f and country h). 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.

both markets (country f and country h). After paying the licensing fee, firm H gets the same marginal cost function as firm F. Hence both firms will choose the same cost-reducing investment level and enjoy the same ex-post marginal cost.

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

3.1.1 Case 1: Exporting

Both firms compete against each other by choosing their optimal cost-reducing investment in country f and h separately. Firm F incurs a variable trade cost t if it exports to country h, while firm H incurs the same amount of trade cost t if it sells in country f. The model reduces to a two-stage game given that the mode choice has been determined to be exporting. Both firms need to choose their 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, market prices and maximized profits.

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

Quantities:

$$X_{Ff}^{E} = \frac{1}{3\beta}\left(\alpha - 2c_F^E + c_H^E + t\right), \tag{9a}$$

$$X_{Fh}^{E} = \frac{1}{3\beta}\left(\alpha - 2c_F^E + c_H^E - 2t\right), \tag{9b}$$

$$X_{Hf}^{E} = \frac{1}{3\beta}\left(\alpha - 2c_H^E + c_F^E - 2t\right), \tag{9c}$$

$$X_{Hh}^{E} = \frac{1}{3\beta}\left(\alpha - 2c_H^E + c_F^E + t\right). \tag{9d}$$

Prices: (same in both countries)

$$P_f^E = P_h^E = \frac{1}{3}\left(\alpha + c_F^E + c_H^E + t\right). \tag{10}$$

Profits:

$$\pi_F^E = \frac{1}{9\beta}\left(\alpha - 2c_F^E + c_H^E + t\right)^2 + \frac{1}{9\beta}\left(\alpha - 2c_F^E + c_H^E - 2t\right)^2 - I_F^E, \tag{11a}$$

$$\pi_H^E = \frac{1}{9\beta}\left(\alpha - 2c_H^E + c_F^E + t\right)^2 + \frac{1}{9\beta}\left(\alpha - 2c_H^E + c_F^E - 2t\right)^2 - I_H^E. \tag{11b}$$

Welfare levels:

$$w_f^E = \frac{1}{18\beta}\left(2\alpha - c_F^E - c_H^E - t\right)^2 + \frac{1}{9\beta}\left(\alpha - 2c_F^E + c_H^E + t\right)^2 + \frac{1}{9\beta}\left(\alpha - 2c_F^E + c_H^E - 2t\right)^2 - I_F^E, \tag{12a}$$

$$w_h^E = \frac{1}{18\beta}\left(2\alpha - c_F^E - c_H^E - t\right)^2 + \frac{1}{9\beta}\left(\alpha - 2c_F^E + c_A^E + t\right)^2 + \frac{1}{9\beta}\left(\alpha - 2c_H^E + c_F^E - 2t\right)^2 - I_H^E. \tag{12b}$$

In order to maximize the profit, we determine the optimal cost-reducing investment levels and also calculate the marginal costs according to the cost functions.

$$I_F^E = \left\{ \frac{4\theta_F \left[\left(9\beta - 12\theta_H^2\right)\alpha - \left(18\beta - 12\theta_H^2\right)\eta_F + 9\beta\eta_H - (4.5\beta - 6\theta_H^2)t \right]}{\left(9\beta - 8\theta_H^2\right)\left(9\beta - 8\theta_F^2\right) - 16\theta_F^2\theta_H^2} \right\}^2, \tag{13a}$$

$$I_H^E = \left\{ \frac{4\theta_H \left[\left(9\beta - 12\theta_F^2\right)\alpha - \left(18\beta - 12\theta_F^2\right)\eta_H + 9\beta\eta_F - (4.5\beta - 6\theta_F^2)t \right]}{\left(9\beta - 8\theta_H^2\right)\left(9\beta - 8\theta_F^2\right) - 16\theta_F^2\theta_H^2} \right\}^2. \tag{13b}$$

And marginal costs are

$$c_F^E = \eta_F - \theta_F \sqrt{I_F^E}, \tag{14a}$$

$$c_H^E = \eta_H - \theta_H \sqrt{I_H^E}. \tag{14b}$$

3.1.2 Case 2: FDI

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

Quantities:

$$X_{Ff}^M = \frac{1}{3\beta}\left(\alpha - 2c_F^M + c_H^M + t\right), \tag{15a}$$

$$X_{Fh}^M = \frac{1}{3\beta}\left(\alpha - 2c_F^M + c_H^M\right), \tag{15b}$$

$$X_{Hf}^M = \frac{1}{3\beta}\left(\alpha - 2c_H^M + c_F^M - 2t\right), \tag{15c}$$

$$X_{Hh}^M = \frac{1}{3\beta}\left(\alpha - 2c_H^M + c_F^M\right). \tag{15d}$$

Prices:

$$P_f^M = \frac{1}{3}\left(\alpha + c_F^M + c_H^M + t\right), \tag{16a}$$

$$P_h^M = \frac{1}{3}\left(\alpha + c_F^M + c_H^M\right). \tag{16b}$$

Profits:

$$\pi_F^M = \frac{1}{9\beta}\left(\alpha - 2c_F^M + c_H^M + t\right)^2 + \frac{1}{9\beta}\left(\alpha - 2c_F^M + c_H^M\right)^2 - I_F^M - D, \tag{17a}$$

$$\pi_H^M = \frac{1}{9\beta}\left(\alpha - 2c_H^M + c_F^M\right)^2 + \frac{1}{9\beta}\left(\alpha - 2c_H^M + c_F^M - 2t\right)^2 - I_H^M. \tag{17b}$$

Welfare levels:

$$w_f^M = \frac{1}{18\beta}\left(2\alpha - c_F^M - c_H^M - t\right)^2 + \frac{1}{9\beta}\left(\alpha - 2c_F^M + c_H^M + t\right)^2 + \frac{1}{9\beta}\left(\alpha - 2c_F^M + c_H^M\right)^2 - I_F^M - D, \tag{18a}$$

$$w_h^M = \frac{1}{18\beta}\left(2\alpha - c_F^M - c_H^M\right)^2 + \frac{1}{9\beta}\left(\alpha - 2c_H^M + c_F^M\right)^2 + \frac{1}{9\beta}\left(\alpha - 2c_H^M + c_F^M - 2t\right)^2 - I_H^M. \tag{18b}$$

The optimal investment levels will be

$$I_F^M = \left\{\frac{4\theta_F\left[\left(9\beta - 12\theta_H^2\right)\alpha - \left(18\beta - 12\theta_H^2\right)\eta_F + 9\beta\eta_H + 4.5\beta t\right]}{\left(9\beta - 8\theta_H^2\right)\left(9\beta - 8\theta_F^2\right) - 16\theta_F^2\theta_H^2}\right\}^2, \tag{19a}$$

$$I_H^M = \left\{\frac{4\theta_H\left[\left(9\beta - 12\theta_F^2\right)\alpha - \left(18\beta - 12\theta_F^2\right)\eta_H + 9\beta\eta_F - \left(9\beta - 6\theta_F^2\right)t\right]}{\left(9\beta - 8\theta_H^2\right)\left(9\beta - 8\theta_F^2\right) - 16\theta_F^2\theta_H^2}\right\}^2. \tag{19b}$$

And marginal costs are

$$c_F^M = \eta_A - \theta_F\sqrt{I_F^M}, \tag{20a}$$

$$c_H^M = \eta_H - \theta_H\sqrt{I_H^M}. \tag{20b}$$

3.1.3 Case 3: Licensing

There are four assumptions in this model related to the licensing case. Superscript O stands for the licensing (international outsourcing) case. The first assumption is that firm F is the firm with a more efficient cost function, that is, firm F has a smaller η and a larger θ . If the optimal mode choice is licensing, firm F should be the licenser that licenses its production technology (more efficient cost function) to firm H which is the licensee.

The second assumption of the licensing case is that firm F licenses its more efficient cost function to firm H and firm H can determine how to make use of this new production technology by choosing its optimal cost-reducing investment level. With this assumption and the same demand function in both countries, in equilibrium firm H chooses the same investment as firm F ($I_F^O = I_H^O$) so that the marginal costs (productivity levels) of these two firms under the licensing case are the same: $c_F^O = \eta_F - \theta_F \sqrt{I_F^O} = c_H^O$. This second assumption tries to capture the fact that less efficient firm can learn a better production technology by paying, 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 H) is to decide its own cost-reducing investment level according to the more efficient cost function.

The third assumption lets firm F have all the bargaining power to determine the licensing fee.[10] With the simplification of the bargaining process, firm F gains such a licensing fee L that firm H will enjoy 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 F, the licensing fee is the entire extra profit firm H can earn under the licensing case compared with the profit in the exporting case which can be expressed by $L = \pi_H^{BO} - \pi_H^E$. However, if the FDI profit

[10]If we relax the licensing fee bargaining power assumption which can allow firm H does not completely give away its extra profit, this will not change the mode choice decision qualitatively as long as the licensing fee is not zero.

is greater than the exporting profit for firm F, then the second best choice for firm H is the FDI case and the licensing fee can be expressed by $L = \pi_H^{BO} - \pi_H^M$. Superscript B indicates the before-licensing-fee-paid situation.

The fourth assumption is that the licensing cannot block any output competition, which means that firm F cannot set up a pre-licensing contract with firm H to exclude the possibility of firm H using the better production technology to compete against it in either country f or country h. This assumption is realistic and to some extent can capture to fact that the parent firm usually has the least control of the technology spillover under the licensing case among all three mode choices.

If the licensing case turns out to be the equilibrium in the open economy, both firms will enjoy the same marginal cost (productivity) by choosing the same cost-reducing investment according to the second assumption. The equilibrium happens to be the same as the symmetric cost function situation under the exporting case. We can derive the prices, the outputs, and the profits before the licensing fee is paid as following.

Quantities:

$$X_{Ff}^O = \frac{1}{3\beta}\left(\alpha - c_F^O + t\right), \tag{21a}$$

$$X_{Fh}^O = \frac{1}{3\beta}\left(\alpha - c_F^O - 2t\right), \tag{21b}$$

$$X_{Hf}^O = \frac{1}{3\beta}\left(\alpha - c_F^O - 2t\right), \tag{21c}$$

$$X_{Hh}^O = \frac{1}{3\beta}\left(\alpha - c_F^O + t\right). \tag{21d}$$

Prices: (same in both countries)

$$P_f^O = P_h^O = \frac{1}{3}\left(\alpha + 2c_F^O + t\right). \tag{22}$$

Profits: (before licensing fee paid)

$$\pi_F^{BO} = \frac{1}{9\beta}\left(\alpha - c_F^O + t\right)^2 + \frac{1}{9\beta}\left(\alpha - c_F^O - 2t\right)^2 - I_F^O, \tag{23a}$$

$$\pi_H^{BO} = \frac{1}{9\beta}\left(\alpha - c_F^O + t\right)^2 + \frac{1}{9\beta}\left(\alpha - c_F^O - 2t\right)^2 - I_F^O. \tag{23b}$$

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

$$L = \pi_H^{BO} - \pi_H^E, \text{ if } \pi_H^E \geq \pi_H^M; \tag{24a}$$

$$L = \pi_H^{BO} - \pi_H^M, \text{ if } \pi_H^E < \pi_H^M. \tag{24b}$$

After the licensing fee is determined, the profits of two firms after licensing fee paid can be expressed as:

Profits: (after licensing fee paid)

$$\pi_F^O = \frac{1}{9\beta}\left(\alpha - c_F^O + t\right)^2 + \frac{1}{9\beta}\left(\alpha - c_F^O - 2t\right)^2 - I_F^O + L, \tag{25a}$$

$$\pi_H^O = \frac{1}{9\beta}\left(\alpha - c_F^O + t\right)^2 + \frac{1}{9\beta}\left(\alpha - c_F^O - 2t\right)^2 - I_F^O - L. \tag{25b}$$

Welfare levels:

$$w_f^O = \frac{1}{18\beta}\left(2\alpha - 2c_F^O - t\right)^2 + \frac{1}{9\beta}\left(\alpha - c_F^O + t\right)^2 + \frac{1}{9\beta}\left(\alpha - c_F^O - 2t\right)^2 - I_F^O + L, \tag{26a}$$

$$w_h^O = \frac{1}{18\beta}\left(2\alpha - 2c_F^O - t\right)^2 + \frac{1}{9\beta}\left(\alpha - c_F^O + t\right)^2 + \frac{1}{9\beta}\left(\alpha - c_F^O - 2t\right)^2 - I_F^O - L. \tag{26b}$$

The optimal cost-reducing investment is

$$I_F^O = I_H^O = \left\{ \frac{\theta_F \left(\alpha - \eta_F - 0.5t\right)}{\frac{9}{4}\beta - \theta_F^2} \right\}^2, \tag{27}$$

with the marginal cost level

$$c_F^O = \eta_F - \theta_F \sqrt{I_F^O} = c_H^O. \tag{28}$$

3.2 Mode Choice Decision

The FDI fixed cost (D) is high enough relative to its productivity to exclude firm H from choosing FDI, so firm H exports to country f under all circumstances. The mode choice is simplified to comparing firm F's maximum profits listed below among the three cases.

Exporting case:

$$\begin{aligned} \pi_F^E &= \frac{1}{9\beta} \left(\alpha - 2\eta_F + \eta_H + t + 2\theta_F \sqrt{I_F^E} - \theta_H \sqrt{I_H^E} \right)^2 \\ &+ \frac{1}{9\beta} \left(\alpha - 2\eta_F + \eta_H - 2t + 2\theta_F \sqrt{I_F^E} - \theta_H \sqrt{I_H^E} \right)^2 - I_F^E, \end{aligned} \tag{29}$$

where I_F^E and I_H^E are given by (13).

FDI case:

$$\begin{aligned} \pi_F^M &= \frac{1}{9\beta} \left(\alpha - 2\eta_F + \eta_H + t + 2\theta_F \sqrt{I_F^M} - \theta_H \sqrt{I_H^M} \right)^2 \\ &+ \frac{1}{9\beta} \left(\alpha - 2\eta_F + \eta_H + 2\theta_F \sqrt{I_F^M} - \theta_H \sqrt{I_H^M} \right)^2 - I_F^M - D, \end{aligned} \tag{30}$$

where I_F^M and I_H^M are given by (19).

Licensing case:

$$\pi_F^O = \frac{1}{9\beta}\left(\alpha - \eta_F + t + \theta_F\sqrt{I_F^O}\right)^2 + \frac{1}{9\beta}\left(\alpha - \eta_F - 2t + \theta_F\sqrt{I_F^O}\right)^2 - I_F^O + L, \qquad (31)$$

where $I_F^O = I_H^M$ is given by (27).

These expressions for investment levels and therefore profits under the three modes are complex equations of many parameter values and not very transparent. We have spent considerable time on these, and are confident that they yield the same ordering of mode choices as the multinational firm F becomes more advantaged in its two cost parameters (lower η or higher θ). Beginning with a low advantage, lowering η or raising θ moves firm F from licensing to exporting to FDI. However, for some parameter values (e.g., α, β, D and t), one or possibly two modes may not be chosen for any cost and productivity advantage. For example, as the trade cost t goes to zero, FDI will never be chosen. A very low value of fixed FDI cost D and high trade cost t implies that exporting will never be chosen: firm F jumps from licensing to FDI as its advantage rises.

In a short appendix to the paper, we present a set of parameter restrictions such that all three modes are chosen for different values of firm F's cost parameters. These involve, for example, an intermediate level of t and a level of D that is not "too small". Again, we do not believe that these restrictions affect the ordering of mode choices, only whether or not all three exist. Subject to these restrictions, it is always the case that firm F's best "outside option" or "threat point" to determine the licensing fee is the exporting option. That is, in the region of productivity parameters where firm F chooses licensing, its next best alternative is always exporting, not FDI. Thus the licensing fee L in (31) is determined on this basis. Our parameter restrictions then lead to the following result.

Proposition: Given firm H's cost function efficiency parameters η_H and θ_H, and firm F's base marginal cost η_F ($\eta_F < \eta_H$), with the change of firm F's cost-reducing investment to productivity transformability θ_F which is larger than θ_H, there exists $\underline{\theta}$ and $\overline{\theta}$ that the mode choice of firm F can be expressed as following:

when $\theta_H < \theta_F \leq \underline{\theta}$, the optimal mode choice is Licensing;

when $\underline{\theta} < \theta_F \leq \overline{\theta}$, the optimal mode choice is Exporting;

when $\theta_F > \overline{\theta}$, the optimal mode choice is FDI.

Licensing yields the largest profit for firm F when the ex-ante difference between the two firms' cost function efficiency parameters is small. The extra market share and extra mark-up that firm F can gain from output competition against a weaker rival under the case of exporting or FDI yields a smaller increase in profit than the licensing fee.

The key to understanding why firm F switches from licensing to exporting as its cost advantage rises, in spite of capturing all rents created under licensing, lies in our assumption that licensing cannot prevent duopoly output competition in the final stage of the game. Licensing makes firm H more competitive in the output decision stage and this effect increases in the size of the cost advantage that firm H gets from using firm F's technology. Furthermore, getting more efficient cost function increases firm H's ex-post cost-reducing investment and competitiveness. Licensing is analogous to firm F creating a negative externality for itself. As firm F's advantage increases, the total two-firm (industry) profit from licensing increases slower than under the exporting case, with exporting yielding higher industry profit at some point: exporting is "anti-competitive" and thus good for the joint profit. So even though firm F captures all additional profits under licensing, it still switches to exporting.

The switch from exporting to FDI is more intuitive. Briefly, as firm F gets even more efficient, it captures an increased market share and increases its output. At some point, it is optimal to switch from exporting, a high variable cost option, to FDI, a high fixed-cost option.

3.3 A Numerical Example

Considering that the cost-reducing investment and profit are affected by many parameters in the open economy such as market demand (α, β), cost function of firm F (η_F, θ_F) and cost function of firm H (η_H, θ_H), we give a numerical example to see how these parameters affect the equilibrium decision and the welfare levels of the two countries.

In the example, the market inverse demand function for both countries is $P = 15 - 2X_i$, $i = f, h$. we set the cost function of firm H to be $c_H = 6 - 0.1I_H^{\frac{1}{2}}$ $(\eta_H = 6, \theta_H = 0.1)$ and also fix the base productivity level of firm F to be 1 (η_F). This example can check how different θ_F's (cost-reducing investment to productivity transformability of firm F) affect the exporting, licensing or FDI decision in the open economy. θ_F increases from 0.1 to 0.45. The variable trade cost t is 0.3, and the FDI cost D is 1.35. The FDI cost is set to be high enough so that firm H will never choose to conduct FDI in country f.

In rest of the figures in 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 F. After the optimal mode choice is determined, the rest of the graphs show the optimal cost-reducing investment levels, market prices and welfare levels.

Figure 2 shows the mode choice (exporting, licensing, or FDI) made by firm F with its profit on the vertical axis. The results give the pattern that **Proposition** states: as the cost function advantage of firm F increases from a relatively low level, firm F first chooses licensing, then exporting, and then FDI. The (maximal or envelop) profit curve is continuous but kinked at the mode switches where two curves for different mode choices cross (there is a small kink at the switch from exporting to FDI that is not very apparent).

The following two figures (figure 3 and figure 4) present the investment choices for two firms under different optimal mode choices. FDI case is associated with the highest investment while the licensing case relates to the lowest investment for firm F, which is just the opposite to the investment of firm H. Firm H's cost-reducing investment, which is the same as firm F's under the licensing case, is much larger than the investment under the other two mode choices. Figure 4 only shows two segments of investment for firm H in order to graph a more clear trend of the exporting and FDI modes. In figure 3, there are two jumps - both happen when there is a mode choice switch. The first jump happens when firm F shifts from licensing to exporting. When firm F switches to exporting, firm H makes its investment decision based on its lower θ_H rather than having access to the higher θ_F. Firm H reduces its investment, and firm F increases its investment to gain a larger market share. The second jump shows up when firm F 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 variable trade cost for firm F due to FDI enhances the potential for firm F to win a larger market share in country h and therefore induces this upward investment jump.

Figure 5 and figure 6 show the market price in each country. The prices are the same for both countries under the licensing and exporting cases due to the symmetry of two market demands and variable trade costs. And consumers in country h enjoy a lower market price than those in country f under the FDI mode because the elimination of the variable trade cost only happens when firm F sells its products in country h. The market price is the highest under the exporting case and the lowest under the licensing case for both countries. The price jump caused by the switch from licensing mode to exporting mode is large in magnitude due to both a negative effect on the investment and productivity of firm H, and an anti-competitive effect in the output decision stage. The jump between exporting and FDI modes is relatively smaller with an even less obvious change in country f. The price decrease under FDI mode is mainly caused by the higher ex-post productivity choice by firm F. And FDI can only happen in country h by firm F so that consumers in country h benefit more with a larger price decrease and a larger market output increase.

The effects of firm F's increasing advantage show on investment levels (figures 3 and 4) and prices (figures 5 and 6) provide the intuition for the welfare results in Figures 7 and 8.

As we have noted, the mode switch from licensing to exporting is anti-competitive: firm F captures much larger market shares in both markets facing a weaker rival, which decreases the total two-firm (industry) outputs in both markets and raises the prices. It is interesting to note that the welfare also decreases in firm F's home market country f. At the point of the jump from licensing to exporting, firm F gets the same profit as noted in figure 2 which is a part of country f's welfare, but consumer surplus in country f falls because of the price increase from the anti-competitive effect.

The mode switch from exporting to FDI has a negligible effect on country f's welfare as shown (not really visible) in figure 7. There is only a very small price change in country f at the switching point as firm F increases and firm H decreases investments by a tiny amount, these changes offset each other in the output decision stage for country f. However, country h enjoys a small welfare gain as figure 8 shows. Since firm F no longer pays any variable trade cost, the equilibrium price in country h falls (figure 6), and the gain in consumer surplus outweighs the loss of profit for firm H.

4 Conclusion

By holding the market size same for both countries to analyze the interaction between productivity choice and mode choice, we get the following conclusions. As to mode choice, licensing is the mode choice for firm F when ex-ante difference between cost functions of two firms is small while FDI is chosen when this ex-ante difference is large. Although firm F with a more efficient cost function can successfully extract the entire extra profit that firm H with a less efficient cost function can earn under the licensing case, still licensing is not always the optimal mode choice. Licensing makes firm H more competitive in the output decision stage, and this adversely dissipates the joint profit and leads to a switch to exporting or FDI at some point.

The mode choice interacts with the ex-post productivity and competitiveness outcomes and thus affects the welfare levels. Specifically, the switch from licensing to exporting leads to a significantly lower productivity and output for firm H, with the further anti-competitive effect in the output decision stage. This latter effect can be sufficiently strong that the welfare of country f decreases as well as that of country h at the point that firm F switches. The loss of consumer surplus due to the higher price in country f reduces welfare whereas there is locally no change in the profit of firm F at the switching point. Country h experiences both a loss of consumer surplus and a loss of profit for firm H at the switching point. The welfare in h improves under the FDI mode relative to exporting, with consumer surplus gain outweighing a small loss in the profit of firm H.

The model offers some theoretical explanations for three sets of the empirical findings that we discover in the Chilean plant-level data. First, foreign linkages (licensing and FDI) are associated with higher firm-level productivity compared to unaffiliated domestic firms. Foreign subsidiaries are even more productive than domestic licensees. The foreign linkage effect also carries to firm size (market share) that both foreign subsidiaries and domestic licensees are larger in size than unaffiliated domestic firms. Second, a larger productivity difference between more productive foreign subsidiaries and less productive unaffiliated domestic firms encourages FDI and discourages licensing. Third, the entry of foreign subsidiaries is negatively related to unaffiliated domestic firms' productivity.

Thinking back on the era of strategic trade policy, when we eventually learned that almost any policy prescription can be generated by some combinations of assumptions, we are duly cautious about making recommendations here. With the narrow confines of this model, policies that encourage licensing deserve a look. The exporting outcome is the worst for country h due to both a negative productivity effect and an anti-competitive effect. FDI is preferred to exporting, but we are not confident that this last result is very robust.

Table 1: Effects of Foreign Linkages on TFP and Market Shares

	Productivity	Market Shares		
Dependent Variable:	$\ln(TFP)$	$\ln(Sales)$	$\ln(VA)$	$\ln(Emp)$
	(1)	(2)	(3)	(4)
FDI	0.712***	2.595***	1.942***	0.973***
	(0.065)	(0.184)	(0.115)	(0.078)
$Licensee$	0.409***	2.079***	1.751***	1.113***
	(0.039)	(0.112)	(0.078)	(0.054)
4-digit Industry Controls	Yes	Yes	Yes	Yes
Time Controls	Yes	Yes	Yes	Yes
Region Controls	Yes	Yes	Yes	Yes
Other Controls	Yes	Yes	Yes	Yes
R^2	0.376	0.225	0.293	0.207
No. of Obs.	$36,486$	$36,828$	$36,486$	$36,828$

Note: 1. The standard errors are clustered at the firm-level for the pooled OLS regression. Standard errors are presented in parentheses. ***, **, and * denote significance at 1%, 5%, and 10% respectively.
2. The coefficients of FDI are tested to be significantly larger than the coefficients of $Licensee$ for column (1), (2) and (3).

Table 2: Effect of Foreign-Domestic Productivity Difference on FDI and Licensing

a. 4-digit Industry-level Aggregate FDI and Licensing Behaviors

	Poisson MLE		Pooled OLS	
Dependent Variable	No. of FDI Firms (1)	No. of Licensees (2)	Foreign Share (3)	ln(Licensing Fee) (4)
$lnTFP3 - lnTFP1$	0.051^{**}	-0.018	3.468^{***}	0.048
	(0.025)	(0.023)	(0.775)	(0.096)
No. of Plants	0.001^{***}	0.002^{***}		
	(0.0004)	(0.0002)		
Industry Total Sales			-4.367^{**}	0.576^{**}
			(1.953)	(0.255)
2-digit Industry Controls	Yes	Yes	Yes	Yes
Time Controls	Yes	Yes	Yes	Yes
(Pseudo) R^2	0.197	0.244	0.470	0.323
No. of Obs.	355	258	355	258

b. Firm-level FDI and Licensing Probability (Probit Model)

Dependent Variable	FDI (1)	FDI (IV) (2)	Licensee (3)	FDI (4)	FDI(IV) (5)	Licensee (6)
$lnTFP3 - lnTFP1$	-0.011	0.533^{***}	-0.025^{***}			
	(0.009)	(0.050)	(0.010)			
Lagged ($lnTFP3 - lnTFP1$)				0.002	0.500^{***}	-0.020^{**}
				(0.011)	(0.064)	(0.010)
2-digit Industry Controls	Yes	Yes	Yes	Yes	Yes	Yes
Time Controls	Yes	Yes	Yes	Yes	Yes	Yes
Region Controls	Yes	Yes	Yes	Yes	Yes	Yes
Pseudo R^2	0.112		0.038	0.122		0.035
No. of Obs.	26,252	26,252	26,252	20,503	20,503	20,503

Note: 1. Robust standard errors are presented in parentheses. ***, **, and * denote significance at 1%, 5%, and 10% respectively.

2. We use the 4-digit industry average productivity difference between foreign subsidiaries and unaffiliated domestic firms. The IV is the 4-digit industry average skilled labor ratio difference between foreign subsidiaries and unaffiliated domestic firms.

3. The IV's (skilled labor ratio difference and its lagged term) are tested to be positive and significant in the first stage regressions, which are not reported due to the space limit.

Table 3: Existence and Extent of FDI v.s. Domestic firm Productivity

Firm-level Fixed Effects Regressions

Dependent Variable: $\ln(TFP)$	Group 1 Unaffiliated Domestic Firms (1)	Group 2 Domestic Licensees (2)	Group 1 Unaffiliated Domestic Firms (3)	Group 2 Domestic Licensees (4)
No. of FDI firms	-0.007^{***}	0.016		
	(0.003)	(0.012)	(0.115)	
4-digit Industry Foreign Share			-0.001^{*}	0.001
			(0.0006)	(0.003)
Time Controls	Yes	Yes	Yes	Yes
R^2	0.007	0.005	0.004	0.004
No. of firms	6,246	557	6,246	557
No. of Obs.	23,755	1,108	23,755	1,108

Note: Standard errors are presented in parentheses. ***, **, and * denote significance at 1%, 5%, and 10% respectively.

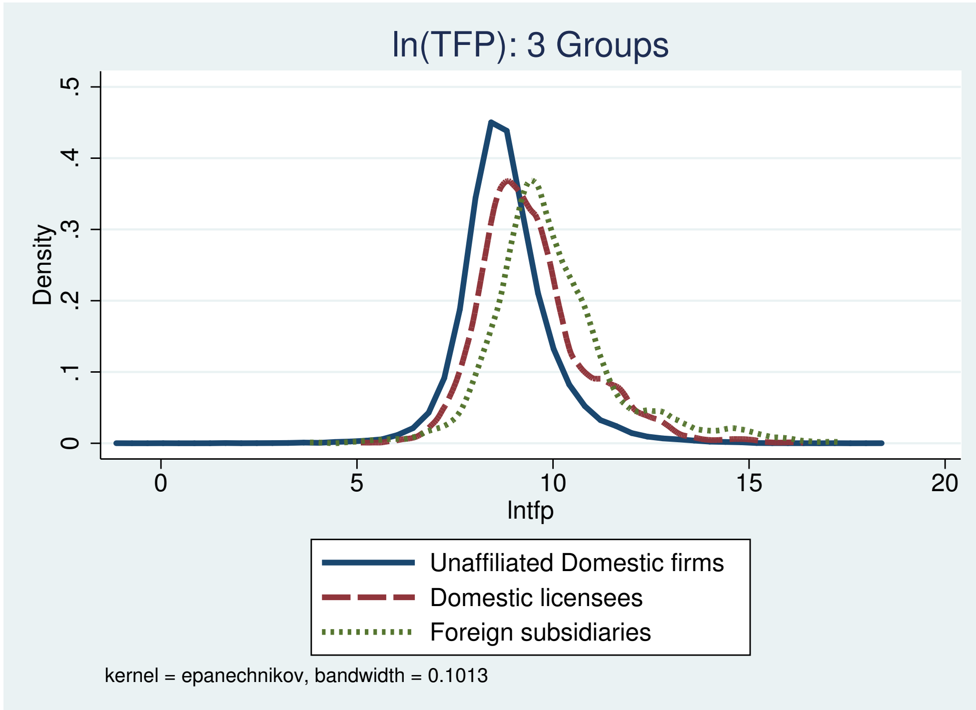

Figure 1: Total factor productivity by groups

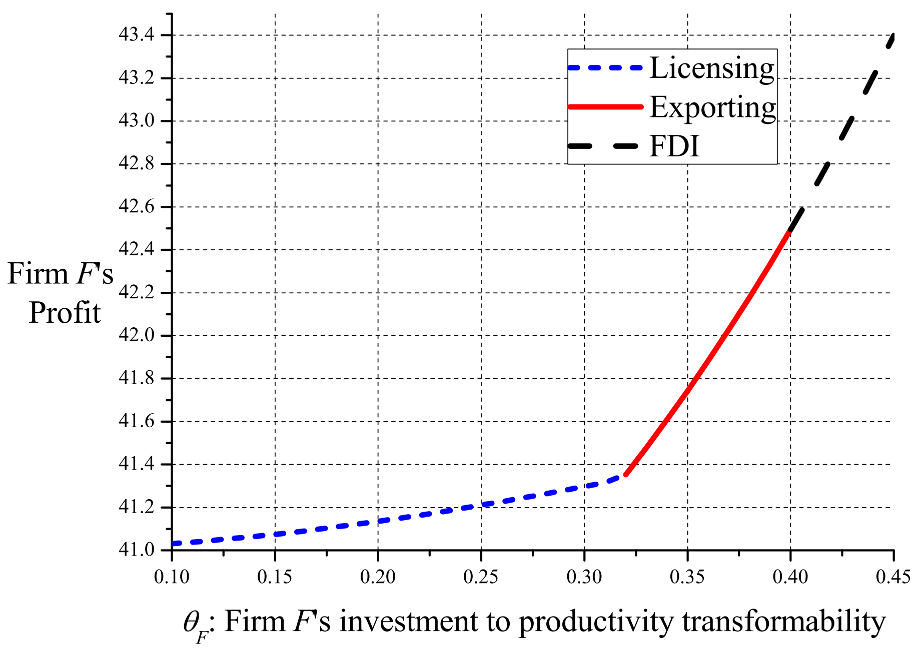

Figure 2: Exporting, Licensing and FDI choice - (Ex-ante) efficiency effect

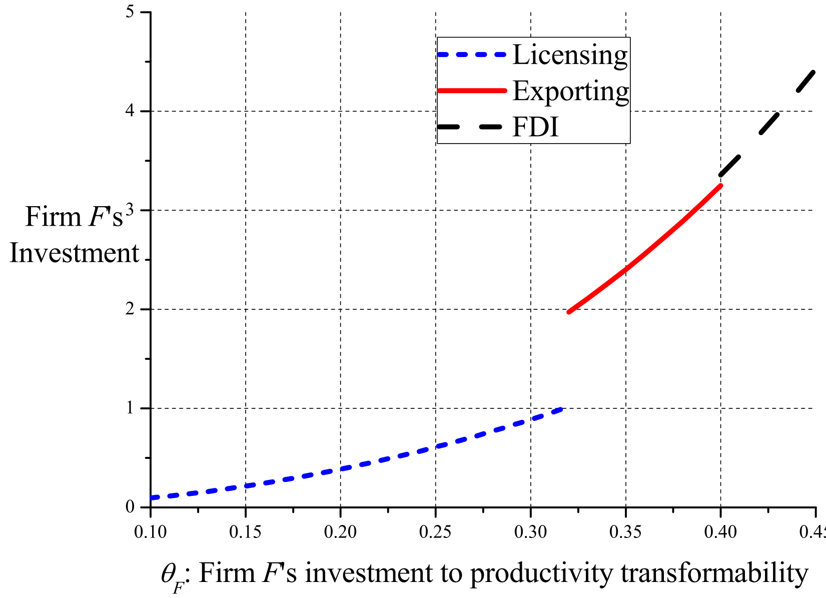

Figure 3: Cost-reducing investment of firm F

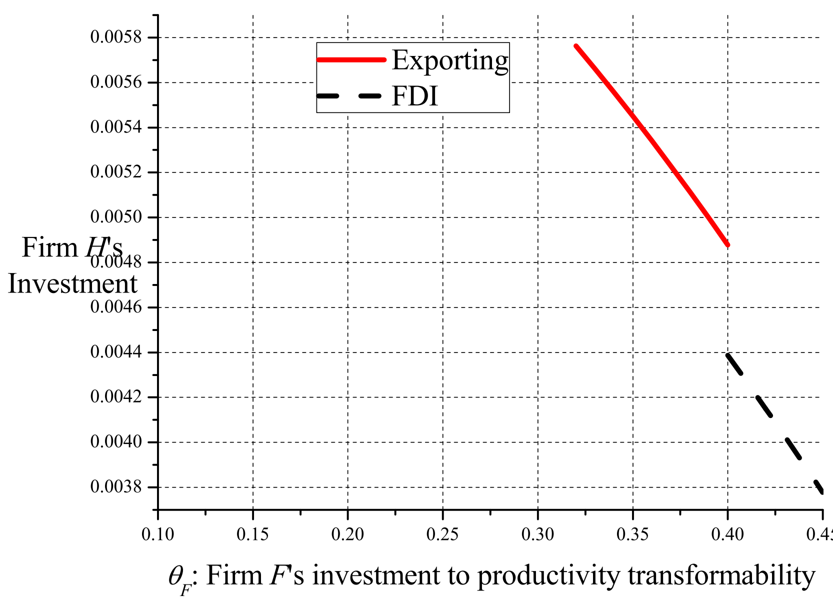

Figure 4: Cost-reducing investment of firm H

Note: Firm H's cost-reducing investment is the same as firm F's under the licensing choice shown by Fig.3 and is much larger in magnitude than the investments under the other two mode choices shown by Fig.4.

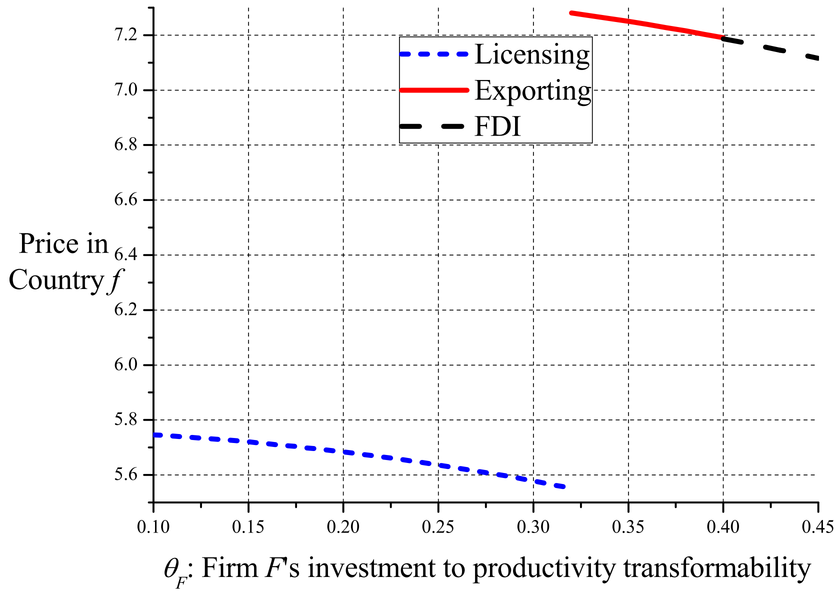

Figure 5: Market price in country f

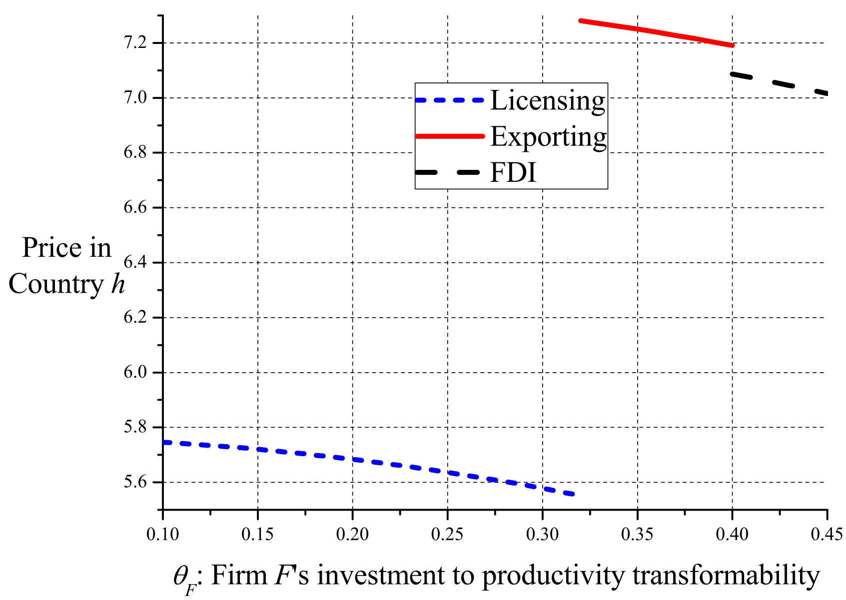

Figure 6: Market price in country h

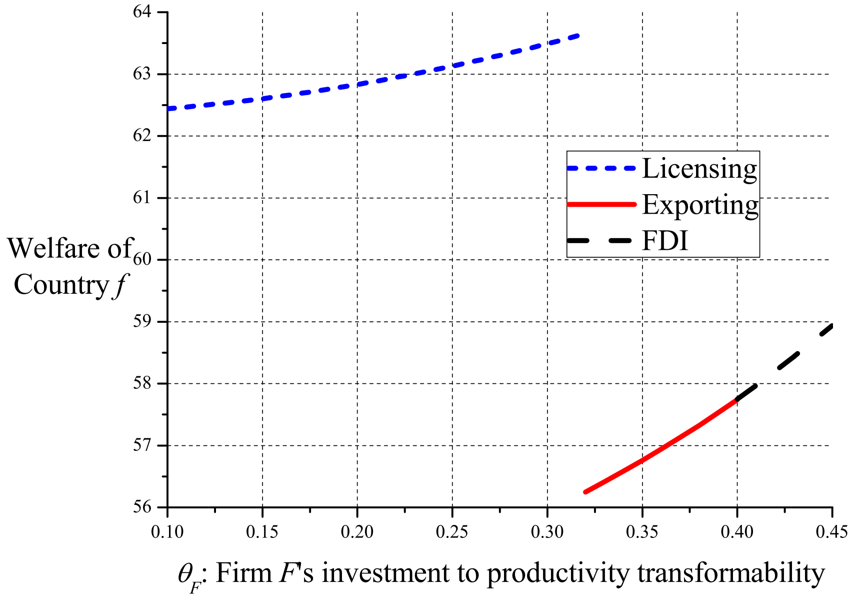

Figure 7: Welfare in country f

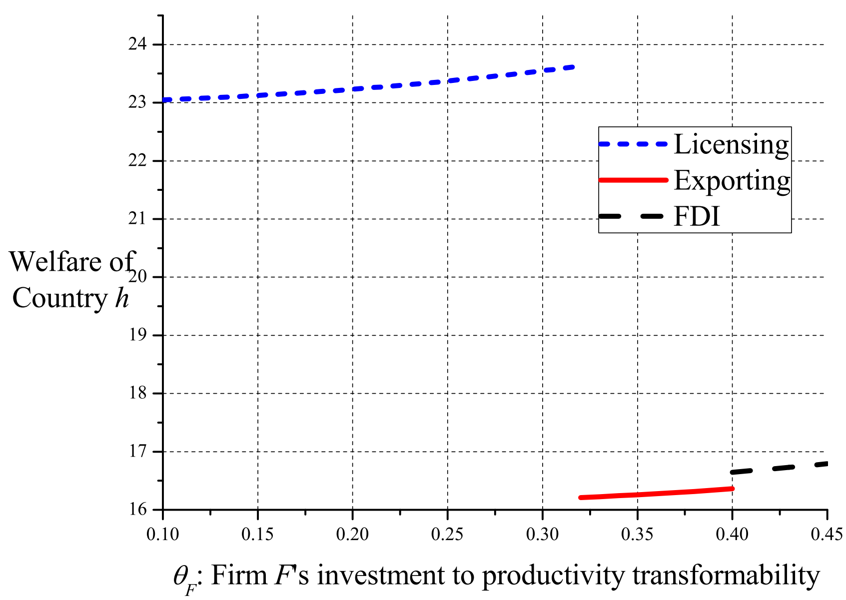

Figure 8: Welfare in country h

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Appendix

A Parameter Restrictions

For θ_F $(\theta_F > \theta_H)$

Given α, β, t, η_H, θ_H and $\eta_F < \eta_H$, in the case of Licensing versus Exporting, $\underline{\theta}$ is implicitly defined by

$$\pi_F^E - \pi_F^{BO} - \left(\pi_H^{BO} - \pi_H^E\right) = \pi_F^E - \left(\pi_F^{BO} + L\right) = \pi_F^E - \pi_F^O = 0 \Rightarrow \theta_F = \underline{\theta}.$$

Given α, β, t, D, η_H, θ_H and $\eta_F < \eta_H$, in the case of Exporting versus FDI, $\bar{\theta}$ is implicitly defined by

$$\pi_F^M - \pi_F^E = 0 \Rightarrow \theta_F = \bar{\theta}.$$

In order to have all three modes are chosen for different values of θ_F, we need to have

$$\underline{\theta} < \bar{\theta}.$$

B Proof of Proposition

Given firm H's cost function efficiency parameters η_H and θ_H, and firm F's base marginal cost η_F $(\eta_F < \eta_H)$, with the change of firm F's cost-reducing investment to productivity transformability θ_F which is larger than θ_H, there exists $\underline{\theta}$ and $\overline{\theta}$ that the mode choice of firm F can be expressed as following:

when $\theta_H < \theta_F \leq \underline{\theta}$, the optimal mode choice is Licensing;

when $\underline{\theta} < \theta_F \leq \overline{\theta}$, the optimal mode choice is Exporting;

when $\theta_F > \overline{\theta}$, the optimal mode choice is FDI.

1. Licensing V.S. Exporting

Licensing is a special case of exporting with firm H sharing the same ex-ante cost function as firm F.

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

where

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

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

Step 1:

$$\frac{\partial \pi_F^E}{\partial \theta_F} > 0$$

$$\frac{\partial \pi_F^E}{\partial \theta_F} = \frac{2}{9\beta} \left(2\sqrt{I_F^E} - \theta_H \frac{\partial \sqrt{I_H^E}}{\partial \theta_F} \right) \left(2\alpha - 4\eta_F + 2\eta_H - t + 4\theta_F \sqrt{I_F^E} - 2\theta_H \sqrt{I_H^E} \right)$$

Since

$$\frac{\partial \sqrt{I_H^E}}{\partial \theta_F} < 0, \text{ and thus } \left(2\sqrt{I_F^E} - \theta_H \frac{\partial \sqrt{I_H^E}}{\partial \theta_F} \right) > 0,$$

then

$$\frac{\partial \pi_F^E}{\partial \theta_F} > 0.$$

Step 2:

$$\text{Given } \eta_F \text{ and } \theta_F, \ \frac{\partial \pi_F^E}{\partial \theta_F} |_{\theta_H = \theta_F, \eta_H = \eta_F} \ < \ \frac{\partial \pi_F^E}{\partial \theta_F} |_{\theta_H < \theta_F, \eta_H > \eta_F}$$

$$\frac{\partial \pi_F^E}{\partial \theta_F} = \frac{\sqrt{I_F^E}}{\theta_F} \left(2\sqrt{I_F^E} - \theta_H \frac{\partial \sqrt{I_H^E}}{\partial \theta_F} \right)$$

$$2\sqrt{I_F^E} = \frac{8\theta_F \left[\left(9\beta - 12\theta_H^2\right) \left(\alpha - \eta_H - 0.5t\right) + \left(18\beta - 12\theta_H^2\right) \left(\eta_H - \eta_F\right) \right]}{\left(9\beta - 8\theta_H^2\right) \left(9\beta - 8\theta_F^2\right) - 16\theta_F^2\theta_H^2}$$

$$\begin{aligned} -\theta_H \frac{\partial \sqrt{I_H^E}}{\partial \theta_F} \quad = \quad & \frac{8\theta_F \left[12\theta_H^2 \left(\alpha - \eta_H - 0.5t\right) \right]}{\left(9\beta - 8\theta_H^2\right) \left(9\beta - 8\theta_F^2\right) - 16\theta_F^2\theta_H^2} \\ & - \frac{8\theta_F \left[8\theta_H^2 \left(9\beta - 6\theta_H^2\right) \left(9\beta - 12\theta_F^2\right) \left(\alpha - \eta_H - 0.5t\right) \right]}{\left[\left(9\beta - 8\theta_H^2\right) \left(9\beta - 8\theta_F^2\right) - 16\theta_F^2\theta_H^2 \right]^2} \\ & + \frac{8\theta_F \left[72\beta\theta_H^2 \left(9\beta - 6\theta_H^2\right) \left(\eta_H - \eta_F\right) \right]}{\left[\left(9\beta - 8\theta_H^2\right) \left(9\beta - 8\theta_F^2\right) - 16\theta_F^2\theta_H^2 \right]^2} \end{aligned}$$

$$\begin{aligned} \left(2\sqrt{I_F^E} - \theta_H \frac{\partial \sqrt{I_H^E}}{\partial \theta_F} \right) \quad = \quad & \frac{8\theta_F \left[9\beta \left(\alpha - \eta_F - 0.5t\right) + \left(9\beta - 12\theta_H^2\right) \left(\eta_H - \eta_F\right) \right]}{\left(9\beta - 8\theta_H^2\right) \left(9\beta - 8\theta_F^2\right) - 16\theta_F^2\theta_H^2} \\ & - \frac{8\theta_F \left[8\theta_H^2 \left(9\beta - 6\theta_H^2\right) \left(9\beta - 12\theta_F^2\right) \left(\alpha - \eta_F - 0.5t\right) \right]}{\left[\left(9\beta - 8\theta_H^2\right) \left(9\beta - 8\theta_F^2\right) - 16\theta_F^2\theta_H^2 \right]^2} \\ & + \frac{8\theta_F \left[8\theta_H^2 \left(18\beta - 12\theta_F^2\right) \left(9\beta - 6\theta_H^2\right) \left(\eta_H - \eta_F\right) \right]}{\left[\left(9\beta - 8\theta_H^2\right) \left(9\beta - 8\theta_F^2\right) - 16\theta_F^2\theta_H^2 \right]^2} \end{aligned}$$

$$\frac{\sqrt{I_F^E}}{\theta_F} = 4 \cdot \frac{\left(9\beta - 12\theta_H^2\right)\left(\alpha - \eta_F - 0.5t\right) + 9\beta\left(\eta_H - \eta_F\right)}{\left(9\beta - 8\theta_H^2\right)\left(9\beta - 8\theta_F^2\right) - 16\theta_F^2\theta_H^2}$$

Comparing to $\eta_H > \eta_F$, with $\eta_H = \eta_F$, both the last term in $\left(2\sqrt{I_F^E} - \theta_H \frac{\partial\sqrt{I_H^E}}{\partial\theta_F}\right)$ and $9\beta\left(\eta_H - \eta_F\right)$ in $\frac{\sqrt{I_F^E}}{\theta_F}$ go to zero and decrease the magnitude of $\frac{\partial\pi_F^E}{\partial\theta_F}$, so we drop them and multiply the above two terms.

With θ_H increasing and equal to θ_F; η_H decreasing and equal to η_F,

$9\beta\left(\alpha - \eta_F - 0.5t\right) + \left(9\beta - 12\theta_H^2\right)\left(\eta_H - \eta_F\right)$ decreases faster than $\left(18\beta - 12\theta_H^2\right)\left(\alpha - \eta_F - 0.5t\right)$.

Term 1:

$$\frac{64\theta_F\left[\left(9\beta - 12\theta_H^2\right)\left(9\beta - 6\theta_H^2\right)\left(\alpha - \eta_F - 0.5t\right)^2\right]}{\left[\left(9\beta - 8\theta_H^2\right)\left(9\beta - 8\theta_F^2\right) - 16\theta_F^2\theta_H^2\right]^2} \text{ decreases.}$$

Term 2:

$$-\frac{32\theta_F\left[8\theta_H^2\left(9\beta - 6\theta_H^2\right)\left(9\beta - 12\theta_H^2\right)\left(9\beta - 12\theta_F^2\right)\left(\alpha - \eta_F - 0.5t\right)^2\right]}{\left[\left(9\beta - 8\theta_H^2\right)\left(9\beta - 8\theta_F^2\right) - 16\theta_F^2\theta_H^2\right]^3} \text{ also decreases.}$$

$$\text{And thus, } \frac{\partial\pi_F^E}{\partial\theta_F} = \frac{\sqrt{I_F^E}}{\theta_F}\left(2\sqrt{I_F^E} - \theta_H\frac{\partial\sqrt{I_H^E}}{\partial\theta_F}\right) \text{ decreases.}$$

Then,

$$\text{given } \eta_F \text{ and } \theta_F,\ \frac{\partial\pi_F^E}{\partial\theta_F}\Big|_{\theta_H=\theta_F,\eta_H=\eta_F} < \frac{\partial\pi_F^E}{\partial\theta_F}\Big|_{\theta_H<\theta_F,\eta_H>\eta_F}.$$

Step 3: When $0 < \eta_H - \eta_F < \varepsilon$ and $\theta_H = \theta_F$, $\pi_F^E < \pi_F^O$.

When $\eta_H = \eta_F$ and $\theta_H = \theta_F = \theta$, $\pi_F^E = \pi_H^E = \pi_F^O$. Let η_H increase by ε and become less efficient. The profit of firm F under the licensing case before licensing fee paid does not change ($d\pi_F^{BO} = 0$).

The increase in the profit of firm F under the exporting case is $d\pi_F^E$.
The increase in the profit of firm F under the licensing case is $L = \pi_H^O - \pi_H^E = -d\pi_H^E$.

$$\frac{d\pi_F^E}{d\eta_H}\Big|_{\eta_H=\eta_F} = \frac{\sqrt{I_F^E}}{\theta}\left(1 - \theta\frac{\partial\sqrt{I_H^E}}{\partial\eta_H}\right) = \frac{\sqrt{I_F^E}}{\theta}\left(1 + \frac{8\theta^2\left(9\beta - 6\theta^2\right)}{\left(9\beta - 8\theta^2\right)^2 - 16\theta^4}\right)$$

$$\frac{d\pi_H^E}{d\eta_H}\Big|_{\eta_H=\eta_F} = -\frac{\sqrt{I_H^E}}{\theta}\left(2 + \theta\frac{\partial\sqrt{I_F^E}}{\partial\eta_H}\right) = -\frac{\sqrt{I_H^E}}{\theta}\left(1 + \frac{\left(9\beta - 6\theta^2\right)^2 + 12\theta^4}{\left(9\beta - 8\theta^2\right)^2 - 16\theta^4}\right)$$

$$\Rightarrow -d\pi_H^E > d\pi_F^E \Rightarrow \pi_F^E < \pi_F^O.$$

According to Step 1, 2 and 3, we can conclude that $\exists\bar{\theta}$, given η_H, θ_H and η_F, when

$\theta_H < \theta_F \leq \underline{\theta}$, $\pi_F^E \leq \pi_F^O$; when $\theta_F > \underline{\theta}$, $\pi_F^E > \pi_F^O$.

Step 4: Solve $\underline{\theta}$
Given α, β, t, η_H, θ_H and $\eta_F < \eta_H$, in the case of Licensing versus Exporting,

$$y(\theta_F) = \pi_F^E + \pi_H^E - \pi_F^{BO} - \pi_H^{BO}$$
$$\theta_F = y^{-1}\left(\pi_F^E + \pi_H^E - \pi_F^{BO} - \pi_H^{BO}\right)$$
$$\underline{\theta} = y^{-1}(0)$$

2. Exporting V.S. FDI

Step 1:

$$\frac{\partial \pi_F^E}{\partial \theta_F} > 0 \text{ as in Licensing V.S. Exporting}$$

Step 2:

$$\frac{\partial \pi_F^M}{\partial \theta_F} > 0$$

$$\frac{\partial \pi_F^M}{\partial \theta_F} = \frac{2}{9\beta}\left(2\sqrt{I_F^M} - \theta_H \frac{\partial \sqrt{I_H^M}}{\partial \theta_F}\right)\left(2\alpha - 4\eta_F + 2\eta_H - t + 4\theta_F\sqrt{I_F^M} - 2\theta_H\sqrt{I_H^M}\right)$$

Since

$$\frac{\partial \sqrt{I_H^M}}{\partial \theta_F} < 0, \text{ and thus } \left(2\sqrt{I_F^M} - \theta_H \frac{\partial \sqrt{I_H^M}}{\partial \theta_F}\right) > 0,$$

then

$$\frac{\partial \pi_F^M}{\partial \theta_F} > 0.$$

Step 3:

$$\frac{\partial \pi_F^M}{\partial \theta_F} > \frac{\partial \pi_F^E}{\partial \theta_F}$$

Since

$$\left|\frac{\partial \sqrt{I_H^M}}{\partial \theta_F}\right| > \left|\frac{\partial \sqrt{I_H^E}}{\partial \theta_F}\right|, \ +t > -t, \ \sqrt{I_F^M} > \sqrt{I_F^E}, \text{ and } \sqrt{I_H^M} < \sqrt{I_H^E},$$

then

$$\frac{\partial \pi_F^M}{\partial \theta_F} > \frac{\partial \pi_F^E}{\partial \theta_F}.$$

Step 4: There exists a $D > 0$ so that $\pi_F^M < \pi_F^E$.

According to Step 1 to Step 4, given η_H, θ_H and η_F, we can conclude that $\exists\bar{\theta}$, when $\theta_H < \theta_F \leq \bar{\eta}$, $\pi_F^M \leq \pi_F^E$; when $\theta_F > \bar{\theta}$, $\pi_F^M > \pi_F^E$.

Step 5: Solve $\bar{\theta}$
Given α, β, t, D, η_H, θ_H and $\eta_F < \eta_H$,

$$z\left(\theta_F\right) = \pi_F^M - \pi_F^E$$
$$\theta_F = z^{-1}\left(\pi_F^M - \pi_F^E\right)$$
$$\bar{\theta} = z^{-1}\left(0\right)$$

With **1** and **2**, as long as we have $\underline{\theta} = y^{-1}\left(0\right) < \bar{\theta} = z^{-1}\left(0\right)$, **Q.E.D.**