Technology Transfer by Foreign Multinationals, Local Investment, and FDI Policy

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Abstract

We develop a model that considers a number of foreign multinationals transferring technology to their affiliates in a host country where these affiliates also compete with a local firm. We find that in less developed countries local investment is less likely to be fully displaced by multinationals. This is a result of lower technology transfer by multinationals in these countries. The host country government may further nurture local firms by restricting the number of foreign multinational companies, however, we find that this will also reduce host country welfare. Furthermore, we find that product market competition from local firms may induce foreign multinationals to transfer more technology. This in turn enhances the scope for FDI crowding in effects due to possible technological spillovers. Finally, we show that opposing local firm and host country government preferences, concerning entry by the local firm, provide a possible explanation for successful FDI policy initiatives observed in practice.

JEL Classification: F13; F23; L2; O32; Q32; Q37

Keywords: Foreign Direct Investment, Extractive Industries, Multinational Enterprizes, Technology Transfer, FDI Spillovers, Crowding-out effects

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1 Introduction

Foreign Direct Investments (FDI) flows to developing countries have increased rapidly in recent years. Developing countries have taken over the lead from developed nations in attracting the largest amount of FDI.[1] Host country benefits from FDI are likely to depend on the degree to which multinational corporations (MNCs) are involved and the role local firms play. Host countries want to prevent FDI from crowding out local firms. At the same time host countries are increasingly aiming to benefit from technology and knowledge transfer by foreign multinationals. We develop a model that considers a number of multinationals transferring technology to their subsidiaries in a host country where these affiliates also compete with a local firm. The proposed framework allows us to analyze whether FDI crowds out local investment and it allows us to find the effect of local competition on technology transfer by foreign multinationals.

We show that FDI will less likely fully displace local firms in less developed countries. This is in line with the empirical findings of e.g. Blonigen and Wang (2004). They find FDI crowding out effects in advanced countries but not in developing countries.[2] The rationale behind our result is that due to higher cost of technology transfer, in less developed countries, multinational corporations will transfer less technology to their affiliates. This in turn weakens the competitive position of multinational affiliates and improves the competitive position of the local firm. We also find that the often imposed restriction on FDI of limiting the number of foreign multinationals, may protect local firms from crowding out effects, but it will also reduce host country welfare in developing countries.

Furthermore, we find that in competitive markets, technology transfer to the host country increases with competition from the local firm. By transferring more technology to their subsidiaries, multinational corporations provide their affiliates with a technological advantage over the local firm (strategic effect). Hence, as pointed out in the empirical study of Kokko

[1] UNCTAD World Investment Report 2014.

[2] Empirical results in Agosin and Machado (2005) show FDI crowding out effects in Latin America but not in Africa (except in sub-period: 1990s) and also not in East Asia.

and Blomström (1995), policies that promote competition from local firms in order to enhance technology transfer by multinationals can be alternative policy measures to formal technology transfer requirements.[3]

Another often imposed restriction on FDI is the limitation on foreign ownership. Equity restrictions are often imposed in order to maintain national control of resources. However, we found that if foreign companies have to form a joint venture partnership with a local firm as is often the case in e.g. natural resource sectors, it may become unprofitable for the local firm to enter the market. In this case the government can improve host country welfare by taking away joint venture ownership shares from the local firm. A similar measure was taken in Norway's oil and gas sector in the 1980s when the government took away significant ownership shares of Statoil and put them under direct control of the government through the so called States Direct Financial Interest (SDFI).[4]

The exiting theoretical literature mainly considers the entry mode of a foreign multinational in a market dominated by local firms (see e.g. Mattoo et al., 2004; Ethier and Markusen, 1996; Markusen, 2001; Saggi, 1996, 1999). In Mattoo et al. (2004) an advanced multinational enters a host country either directly or by acquiring one of the local firms. In their framework the multinational always transfers less technology to the host country as local competition increases. However, numerous industries such as automobile, electronics, extractive and chemical industries, are dominated by multinationals and national firms play a more minor role (similar point is made by Markusen and Venables, 1998).[5] Multinationals in these industries not only compete in the product market but they also strategically interact in technology transfer. We extend the existing literature by considering the strategic

[3]Kokko and Blomström (1995) show that formal technology transfer requirements are negatively related to technology transfer.

[4]In Nigeria the Oil and Gas Reform Implementation Committee (OGIC) proposed a similar framework. They recommended that the National Petroleum Asset Management Agency (NPAMA) should oversee investments by the state, while, The National Petroleum Corporation (NNPC) would be active as a commercial company (see Thurber and Istad, 2010).

[5]In China's automobile industry multinationals had 65.4 percent market share in the first half of 2014. In 2012 in the Pharmaceutical and in the Chemical industry of the Netherlands, the market share of foreign companies was, respectively, 87.2 percent and 73.5 percent.

interaction between multinationals when they set their level of technology transfer. Taking this strategic interaction in technology transfer into account, generates results which are more in line with empirical findings, given that empirical studies also show an increase in technology transfer by multinationals as local competition increases (see e.g. Kokko and Blomström, 1995; Blomström et al., 1994).

The theoretical model by Wang and Blomström (1992) shows that as local firms increase investment in learning, making the technology gap smaller, a multinational will transfer more technology to its affiliate in the host country. While, Wang and Blomström (1992) look at the effect of local learning capabilities, we analyze the effect of product market competition from local firms on technology transfer by multinationals. Furthermore, they consider only one multinational firm and do not take into account the strategic interaction between multinationals when they transfer technology. Finally, they also do not consider FDI crowding out effects.

FDI crowding out effects have been analyzed separately from technology transfer in a small number of theoretical studies. Driffield and Hughes (2003) study the possibility of FDI crowding out local firms in the domestic capital market. Barry et al. (2005) analyze crowding out effects in the labor market. Similar to our analyzes Markusen and Venables (1999) consider crowding out effects through product market competition. However, they do not consider technology transfer by multinationals under different market structures.

An additional focus of the paper is on the effects of foreign ownership restrictions. Lee and Shy (1992) show that restrictions on foreign ownership reduce the quality of technology transferred by foreign firms. Similarly, theoretical analysis in Javorcik and Saggi (2010) shows that a foreign investor with higher quality technology is less likely to form a joint venture and more likely to enter directly. However, these papers do not consider the relationship between foreign ownership restrictions and FDI crowding out effects, which is one of the main focuses of the current study.

The next section outlines the model. Section 3 studies whether or not FDI displaces

local firm output. Section 4 analyzes the effect of local competition on foreign firm technology transfer. Section 5 analyzes FDI policies by host country governments such as foreign ownership restrictions. The final section concludes.

2 Model

The model is based on the two-stage game adopted in the literature on the economics of R&D where first technology investment is chosen and afterwards firms compete in the product market.[6] One local (emerging market) firm (e) competes with $n-1$ multinational affiliates (m).[7] In the first stage multinationals transfer technology, x_m, to their affiliates in the host country which reduces marginal cost of production c ($0 \leq c \leq a$). The marginal cost of multinationals reduces to $c_m = c - x_m$ due to technology transfer. Technology transfer is costly and the cost function of technology transfer has the standard quadratic form:

$$z_m(x_m) = \frac{\tau x_m^2}{2}. \tag{1}$$

This cost function implies diminishing returns to technology transfer and $\tau = \partial^2 C/\partial x^2$. Total and marginal cost of technology transfer both increase with τ. Thus, the cost function for technology transfer shifts up as τ increases and τ can be related to the level of the cost of technology transfer (see Mattoo et al., 2004). Below we provide the backward induction solution of the two stage game between n firms with quantity competition in the second stage.

2.1 Product Market

Final stage quantity competition is between $n-1$ multinational affiliates and one local company. The linear inverse demand function for the product is given by $p = a - (\sum_{m=1}^{n-1} q_m + q_e)$.

[6] See e.g. Brander and Spencer (1983), d'Aspremont and Jacquemin (1988), Kamien, Muller, and Zang (1992), and Kamien and Zang (2000).

[7] Similar to Wang and Blomström, 1992 we abstain from looking at the mode of entry choice of foreign firms. All foreign firms have entered the country directly.

Where, p is the market price, $a > 0$, $Q_m = \sum_{M=1}^{n-1} q_m$ is total output of all the multinationals operating in the host country and q_e is output of the local firm. Hence, $Q = \sum_{m=1}^{n-1} q_m + q_e$ denotes total output.

The profit function of a representative multinational, net of technology transfer cost, is denoted by:

$$\pi_m(q_m, q_{-m}, q_e) = (a - q_m - q_{-m} - q_e - c_m)\, q_m,\ m \in \{1, ..., n-1\}. \tag{2}$$

Where, q_{-m} is the sum of outputs of all multinational affiliates other than firm m. The profit function of the local firm is given by:

$$\pi_e(q_e, q_m, q_{-m}) = \left(a - q_e - \sum_{m=1}^{n-1} q_m - c\right) q_e. \tag{3}$$

Differentiating foreign firm profit in (2) with respect to q_m gives:

$$a - 2q_m - \sum_{j=1, j\neq m}^{n-1} q_j - q_e - c + x_m = 0,\ m \in \{1, ..., n-1\}. \tag{4}$$

In symmetric equilibrium $\sum_{m=1}^{n-1} q_m = Q_m$. So, rewriting (4) gives

$$a - q_m - Q_m - q_e - c + x_m = 0,\ m \in \{1, ..., n-1\}. \tag{5}$$

Now, taking summations and solving for total output of the multinationals implies:

$$Q_m = \frac{(n-1)(a-c) - (n-1)q_e + \sum_{m=1}^{n-1} x_m}{n},\ m \in \{1, ..., n-1\}. \tag{6}$$

Plugging the best response function of the local firm and function for total output of the multinationals into (5) and solving for q_m gives:

$$q_m = \frac{a - c + 2(n-1)x_m - 2\sum_{j=1, j\neq m}^{n-1} x_j}{n+1},\ m \in \{1, ..., n-1\}. \tag{7}$$

Output of a foreign firm increases with its own technology transfer and decreases with technology transfer of competing firms. Plugging (7) into the best response function for the local firm in symmetric equilibrium gives:

$$q_e = \frac{a - c - \sum_{m=1}^{n-1} x_M}{n+1}. \tag{8}$$

Technology transfer by foreign multinationals enhances competitiveness of multinational subsidiaries and therefore reduces output of the local firm.

2.2 Technology transfer

From (2) and (7) it follows that for a representative multinational the profit net of technology transfer cost can be expressed as q_m^2. So, the equilibrium level of technology transfer by a representative multinational can be obtained by optimizing $q_m^2(x_m) - \frac{\tau x_m^2}{2}$, $m \in \{1, ..., n-1\}$. This gives

$$x_m = \frac{4(n-1)(a-c)}{\tau(n+1)^2 - 8(n-1)},\ m \in \{1, ..., n-1\}. \tag{9}$$

Consequently, the total transfer of technology is given by

$$X_m = \frac{4(n-1)^2(a-c)}{\tau(n+1)^2 - 8(n-1)}. \tag{10}$$

In line with previous research, see e.g. Mattoo et al. (2004), we impose certain restrictions on parameter τ, i.e. $\tau > 1$.[8] Foreign firms transfer less technology to the host country as the cost of technology transfer (τ) increases. Moreover, technology transfer increases with n for relevant parameter values.[9]

3 Does FDI crowd out local firms?

Crowding out effects from FDI on domestic investment occur when multinational companies prevent market entry by local firms or induce local firms to exit the market. By substituting

[8] This restriction ensures non-negative solutions for equilibrium levels of technology transfer under all relevant regimes.

[9] See Appendix 1 for detailed analysis.

the level of technology transfer of a representative multinational in (9) into the output function of the local firm in (8) we obtain local firm equilibrium output:[10]

$$q_e = \frac{(a-c)[(n+1)\tau - 4(n-1)]}{(n+1)^2\tau - 8(n-1)}. \tag{11}$$

If the the local firm is active in the market i.e. $q_e > 0$, local firm output increases with τ and decreases with n (see Appendix 4). So, there will be some displacement of local firm investment as the number of foreign firms increases. Analysis of expression (11) implies the following proposition:

Proposition 1 *FDI fully displaces the local firm if* $\tau \leq \tau^E(n)$*, where*

$$\tau^E(n) = \frac{4(n-1)}{n+1}. \tag{12}$$

Furthermore, $\tau^E(n)$ *increases with* n *and approaches* 4 *as* n *approaches infinity.*

Proof. For detailed proof see Appendix 3. ■

This proposition implies that, if $\tau > 4$ the local firm is active in the market irrespective of the number of multinationals. Hence, for sufficiently high τ, FDI does not completely displace the local firm**.** The solid EMF curve in Fig. 1 illustrates the $\tau^E(n)$ threshold for $\tau < 4$. Where, EMF stands for emerging market firm. For all combinations of n and τ on the EMF locus and all combinations of n and τ under the locus there is complete displacement of the local firm by FDI. For all combinations above this locus FDI does not completely displace the local firm. In section 5 we derive the threshold depicted by the FIP locus. For all values under the FIP locus domestic welfare decreases with the number of foreign multinationals and domestic welfare increases with the number of foreign multinationals for all values above the locus. We will now focus on crowding out effects i.e. the EMF locus.

Fig. 1 is divided into three regions, I, II and III. n regions I and II, FDI there is full (100%) displacement of the local firm (i.e. $q_e = 0$). This happens in case of low cost of technology transfer and a relatively large number of foreign multinationals in the market.

[10] Detailed derivations of equilibrium outputs and profits are provided in Appendix 2.

On the other hand, in region III, where the the cost of technology transfer (τ) is sufficiently high and a small number of foreign multinationals is active in the market, FDI does not completely displace the local firm.

To understand the intuition of this result recall from (9) that a reduction in τ improves the incentives for transferring technology. Also, from (8) it follows that lower technology transfer improves the competitive position of the local firm. As a result complete displacement of the local firm becomes less likely, when technology transfer by multinationals becomes more costly, i.e. when τ increases. Cost of technology transfer are higher in less advanced countries (see e.g. Teece, 1977; Ramachandran, 1993). Hence, full displacement of local firms due to product market competition from multinationals will less likely occur in less advanced countries. Similarly, empirical analyzes by Blonigen and Wang (2004) and by Borensztein et al. (1998) do not find FDI crowding out effects in developing countries. Furthermore, Blonigen and Wang (2004) do find crowding out effects in advanced countries.[11]

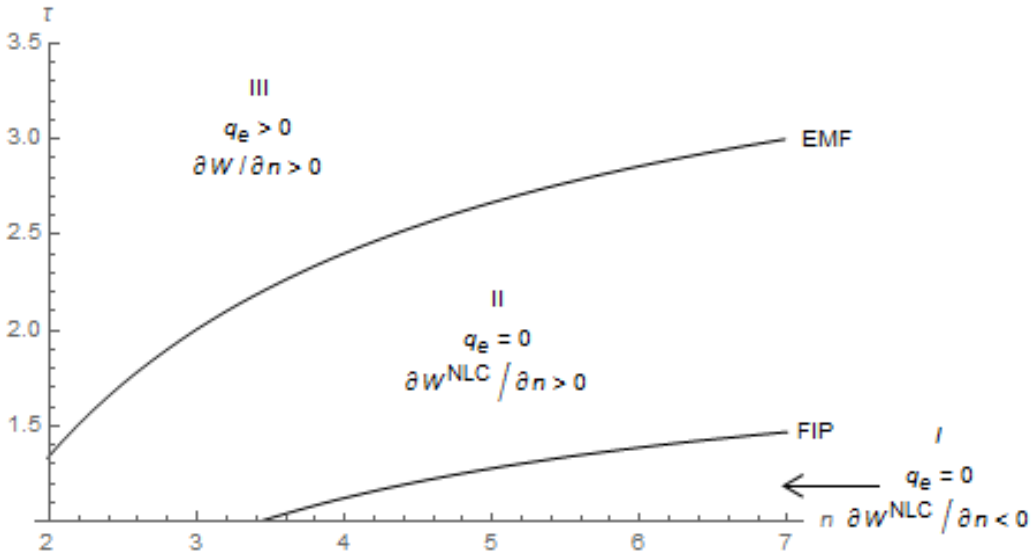

Figure 1: FDI, local investment, and FDI policy.

In addition, our framework also allows to address a different issue where a multinational emerging market firm decides to enter a foreign market, which is dominated by companies

[11] Borensztein et al. (1998) do not look at advanced countries.

from advanced nations. Emerging markets firms are increasingly investing overseas.[12] More than one-third of FDI in developing countries originates in other developing economies.[13] Often mentioned reasons for why emerging market firms mainly enter other developing countries are cultural and geographic proximity (see e.g. Wells, 1983; Buckley et al., 2007). We provide a new rationale for higher investments by emerging market firms in less developed countries which is the higher cost of technology transfer in these nations. In case of higher cost of technology transfer an emerging market firm more easily competes with firms from advanced countries due to lower technology transfer by the latter. As a result emerging market firms are more willing to enter other developing countries than entering more advanced countries.

4 Effect of local competition on technology transfer

If the local firm is fully displaced by FDI, then, only foreign multinationals will be active. Hence, in the product market there is no competition from a local firm anymore, i.e. $q_e = 0$. Local firm output $q_e = 0$, so, $Q = \sum_{m=1}^{n-1} q_m$ denotes total output. When, there is no local firm in the market, the profit function of a representative multinational net of technology transfer cost is denoted by:

$$\pi_m^{NLC}(q_m, q_{-m}) = (a - q_m - q_{-m} - c_m)\, q_m,\ m \in \{1, ..., n-1\}. \tag{13}$$

Where, NLC stands for no local competition. Optimizing the profit function with respect to output and rewriting gives:

$$a - q_m - Q - c + x_m = 0,\ \ m \in \{1, ..., n-1\}. \tag{14}$$

Next, assuming symmetric equilibrium, taking summations and solving for total output implies:

$$Q^{NLC} = \frac{(n-1)(a-c) + \sum_{m=1}^{n-1} x_m}{n}. \tag{15}$$

[12] In 2013 developing countries together made up 32.2 percent of total world FDI outflows. See World Investment Report 2014 UNCTAD.

[13] See World Bank Global Development Horizons, 2011.

Plugging (15) in (14) gives:

$$q_m^{NLC} = \frac{a - c + (n-1)x_m - \sum_{j=1, j\neq m}^{n-1} x_j}{n}, \ m \in \{1, ..., n-1\}. \tag{16}$$

Output of a foreign firm increases with its own technology transfer and decreases with technology transfer by competing firms.

In the first stage, when a representative multinational sets the level of technology transfer, it maximizes $\pi_m^{NLC}(x_m) - \frac{\tau x_m^2}{2}$. Optimizing with respect to x_m and assuming symmetry in equilibrium gives the optimal level of technology transfer by a representative foreign firm.[14]

$$x_m^{NLC} = \frac{2(n-1)(a-c)}{n^2\tau - 2n + 2}, \ m \in \{1, ..., n-1\}. \tag{17}$$

Multiplying the level of technology transfer with the number of multinationals operating in the given country $(n-1)$ gives the total technology transfer to the host country.

$$X_m^{NLC} = \frac{2(n-1)^2(a-c)}{n^2\tau - 2n + 2}. \tag{18}$$

Total technology transfer decreases with the cost of technology transfer (τ) and increases with the number of foreign multinational firms in the market (n).[15]

The effect of local competition on technology transfer by multinationals can be obtained by comparing the level of technology transfer when the local firm is active in the market with the level of technology transfer when the local firm is not active in the market (due to crowding out effects). Comparing the level of technology transfer in case of no local competition in (18) with the level technology transfer under competition from a local firm in (10) implies the following proposition:

Proposition 2 *(i) When $n = 2$, local competition enhances technology transfer by MNCs if $\tau < 4$.*

(ii) When $n \geq 3$, local competition always enhances technology transfer by MNCs (for all levels of τ).

[14] Recall that restriction $\tau > 1$ ensures non-negative solutions for all $n \geq 2$.

[15] See Appendix 1 for detailed analysis.

Proof. For detailed proof see Appendix 5. ■

From (i) it follows that if only one multinational is active in the market and $\tau > 4$ this multinational will transfer more technology to the host country if the multinational affiliate does not have to compete with a local firm. From proposition 1 we know the local firm will not be fully displaced in case of $\tau > 4$ and there will be competition from the local firm. From (ii) it follows that in case there are several firms in the market, then, competition from a local firm increases technology transfer by foreign multinationals irrespective of the level of τ. This implies that if FDI is prevented from displacing the local firm, then, technology transfer by foreign multinationals will increase.

From (7) and (8) it follows that by transferring more technology a multinational increases the output of its affiliate and lowers the output of competing firms including that of the local firm. As a result by transferring technology a multinational will increases the profit of its affiliate. This is the so called strategic effect of technology transfer (see Brander and Spencer, 1983). This effect is stronger when the multinational affiliate also has to compete with a local firm. Furthermore, the higher the output of a foreign firm, the higher its incentive to invest in technology, this is the so called scale effect (see Mattoo et al., 2004). Foreign firm output is lower under local competition as more firms will be in the market. As a result the scale effect is stronger when the local firm is not active in the market. For $n \geq 3$ the strategic effect outweighs the scale effect and technology transfer under local competition is always higher than technology transfer under no local competition. For $n = 2$ the scale effect outweighs the strategic effect when τ is sufficiently large. In this case technology transfer is higher in the absence of local competition.

Mattoo et al. (2004) show that an increase in the number of local firms leads to lower technology transfer by a foreign multinational. However, the current results show an increase in technology transfer due to local competition, for every level of τ in competitive markets and in monopolistic markets in case of sufficiently low τ. The current results are more in line with empirical findings. Blomström et al. (1994) analyzing FDI in Mexican manufacturing

industries show that local competition is positively related to technology imports by foreign owned affiliates. Furthermore, Kokko and Blomström (1995) found that US firms transferred more technology to host countries as local competition increased.

5 Host Country Welfare

Different FDI policy measures are used in practice. In order to prevent foreign firms from crowding-out local firms, governments may restrict foreign direct investment by, for example, restricting the number of foreign firms allowed to enter the host country. Furthermore, in order to obtain higher rents from foreign firm profits, the government may restrict foreign ownership. This can be done either directly or by imposing on foreign firms that they form a joint venture with a local company. In the following sub-sections we discuss these two types of foreign ownership restrictions.

First, we analyze the objective of the host country government based on host country welfare. Host country welfare is the sum of consumer surplus and local firm profit. Host country welfare when the local firm is active in the market and welfare when FDI displaces the local firm are, respectively, given by:

$$W = \frac{(q_e + (n-1)q_m)^2}{2} + \pi_e \text{ and } W^{NLC} = \frac{((n-1)q_m^{NLC})^2}{2}. \tag{19}$$

In Appendix 6 it is shown that welfare always increases with the number of multinationals (n) if the local firm is active in the market. If the local firm is displaced by FDI the derivative of host country welfare w.r.t. the number of multinational firms is given by:

$$\frac{\partial W^{NLC}}{\partial n} = \frac{-n\tau^2 (a-c)^2 (n-1)(2n^2 - n^2\tau - 4n + 2)}{(\tau n^2 - 2n + 2)^3} \tag{20}$$

Analysis of (20) shows that restricting the number of foreign firms in the host country, enhances host country welfare if $\frac{\partial W^{NLC}}{\partial n} < 0$. This proofs the following proposition:

Proposition 3 *Restricting the number of foreign multinationals increases welfare if* $\tau \leq \tau^W(n)$*, where*

$$\tau^W(n,\tau) = \frac{2(n-1)^2}{n^2}. \tag{21}$$

Furthermore, $\tau^W(n)$ increases with n and approaches 2 as n approaches infinity.

This proposition implies that restricting the number of multinationals may increase host country welfare if the cost of technology transfer (τ) is sufficiently low. Threshold $\tau^W(n, \tau)$ is depicted in Figure 1 by the FIP locus, where, FIP stands for foreign investment policy. For all values under the locus welfare decreases with the number of foreign multinationals in the host country. For all values above the locus host country welfare increases with the number of foreign multinational firms in the market.

Hence, in Fig. 1 in region I the local firm is fully displaced and host country welfare decreases with n. In region II the local firm is also displaced by FDI, but host country welfare increases with n. In region III the local firm is not displaced by FDI and welfare increases with the number of foreign multinational firms. From Propositions 1 it can be seen that in case of a smaller number of foreign firms in the market, FDI will less likely displace the local firm. Hence, host country governments may restrict the number of multinationals in the market in order to prevent crowding out effects. This provides a possible rationale for the often used FDI policy measure of limiting the number of foreign firms. For example, in South Korea the government successfully limited FDI in high technology sectors in order to nurture local firms (see e.g. Wade, 1990). From proposition 3 it follows, however, that this policy of nurturing local firms will reduce host country welfare in countries where the cost of technology transfer is not sufficiently low. Besides restricting the number of foreign firms, host country governments often apply foreign ownership restrictions, which will be addressed in the next subsection.

5.1 Foreign ownership restrictions

The most obvious restriction on foreign direct investment is the restriction on foreign ownership. Foreign ownership restrictions are a common practice in developing countries, and emerging market economies such as Brazil, Indonesia, and India. These countries restrict

foreign ownership in a wide span of industries.[16] In developed countries foreign ownership restrictions are being imposed less often but are still present in different industries.[17]The government can directly restrict foreign ownership. In Norway's oil and gas industry, for example, the state takes a share of ownership through the so called State's Direct Financial Interest (SDFI) portfolio. The government may also demand that multinationals form joint ventures with local companies. In Nigeria, international oil companies are obliged to form joint ventures with the national oil company. The national oil company has an ownership share of 55-60 percent. We now assume the government imposes foreign ownership restrictions and the share of foreign ownership is θ with $0 < \theta < 1$. Hence, the profit function of the multinationals, now, will also depend on the share of foreign ownership. When, FDI displaces the local firm and there is no local competition, technology transfer by a representative multinational is denoted by $x_m^{NLC}(\theta) \equiv \arg\max\{\theta\pi_m^{NLC}(x_m) - \frac{\tau x_m^2}{2}\}$.[18]

Under local competition the solution of the game under direct foreign ownership restrictions differs from the solution under restrictions through joint ventures. First, we consider direct foreign ownership restrictions by the government. Second, we consider the case of foreign ownership restrictions by imposing joint ventures with the local firm.

5.1.1 Direct restrictions by the government

Equilibrium level of technology transfer by a representative foreign firm under direct foreign ownership restrictions is denoted by $x_m^{DR}(\theta) \equiv \arg\max\{\theta\pi_m(x_m) - \frac{\tau x_m^2}{2}\}$ (see Appendix 7). Where, DR means direct foreign ownership restrictions. By substituting this level of technology transfer into the function for local firm output in (8), we obtain the equilibrium output of the emerging market firm. We need to obtain the equilibrium output of the local firm in order to see whether crowding out effects from FDI increase or decrease due to foreign

[16]In India the limit of foreign ownership in insurance, is recently raised from 26 percent to 49 percent. In China's automobile industry, international car manufacturers can have an ownership share of up to 50 percent.

[17]In the airline industry foreign firms can own 49 percent in the European Union and 25 percent in the USA. In Japans telecommunications sector foreign firm ownership is limited to 33 percent.

[18]Detailed derivations when foreign ownership is restricted and the local firm is displaced by FDI are provided in Appendix 7.

ownership restrictions. Output of the emerging market firm is:

$$q_e^{DR}(\theta) = \frac{(a-c)[(n+1)\tau - 4\theta(n-1)]}{(n+1)^2\tau - 8\theta(n-1)}. \tag{22}$$

The local firm will be active in the market if $q_e^{DR}(\theta) > 0$. Threshold $\tau^E(n)$ in (12) is now multiplied by the share of foreign ownership, θ, i.e. $\tau^{ER}(n,\theta) = \frac{4\theta(n-1)}{n+1}$ is increasing in θ. Hence, in terms of Figure 1 lower foreign ownership shares (θ) shift the EMF curve downwards (see locus $EMF(DR)$ in Figure 2). This implies that the region in which FDI does not fully displace the local firm expands. This proves the following proposition.

Proposition 4 *Due to direct foreign ownership restrictions the possible crowding out effects of FDI will be reduced.*

The intuition for the above result is based on the fact that higher foreign ownership restrictions create an improvement in the competitive position of the local firm relative to foreign companies. This, in turn, makes it less likely that the local firm will exit the market due to FDI. Often suggested reasons for foreign ownership restrictions are that host country governments use them to increase rents and to maintain local control of resources. In addition, Mattoo et al. (2004) show that a host country government may impose foreign ownership restrictions in order to influence the entry choice of a foreign firm.[19] We show that, besides these often mentioned reasons, the government may impose restrictions on foreign ownership in order to prevent FDI from displacing the local firm.

However, governments should take into account that these restrictions on foreign ownership also reduce technology transfer by foreign multinationals (as $x_m^{DR}(\theta)$ is increasing in θ, see Appendix 7). This in turn will reduce the scope for FDI technology spillovers and subsequent crowding in effects. Moreover, these foreign ownership restrictions will also reduce host country welfare.[20]

[19] Mattoo et al. (2004) show that in case of high cost of technology transfer the government imposes restrictions in order to induce acquisition instead of direct entry. While, in case of low cost of technology transfer the government imposes restrictions in order to induce direct entry instead of acquisition.

[20] For detailed derivations see Appendix 7.

5.1.2 Restrictions by imposing joint ventures with the local firm

In practice foreign firms often have to form joint ventures with local companies. Now, we consider a host country government that imposes on $n-1$ multinational affiliates that they form a joint venture with the local firm. The local firm chooses whether it also wants to enter the market by starting its wholly-owned operations in which case there will be n companies active in the market: $n-1$ joint ventures and one local firm. If the local firm does not enter, its payoff will be: $(n-1)(1-\theta)\pi_m^{NLC}(\theta)$. Profit of a foreign company when there is no local competition ($\pi_m^{NLC}(\theta)$) is provided in Appendix 7. The local firm chooses to establish its wholly-owned operations if:

$$\Delta\pi_e \equiv (n-1)(1-\theta)\pi_m^{JV}(\theta) + \pi_e^{JV}(\theta) - (n-1)(1-\theta)\pi_m^{NLC}(\theta) > 0. \tag{23}$$

Where, JV stands for foreign ownership restrictions by imposing joint ventures. Derivations in case of entry by the local firm are provided in Appendix 8. It follows that the expression for $\Delta\pi_e$ is quite cumbersome and non-linear in τ, θ, and n. However, dividing $\Delta\pi_e$ by $(a-c)^2$ and fixing θ allows for convenient graphical analysis in (n,τ) space. The contour of the function $\Delta\pi_e/(a-c)^2 = 0$ is illustrated in Fig. 2 by the $EMF(JV)$ locus (for $\theta = 0.5$). For all values of n and τ on the $EMF(JV)$ curve the local firm is indifferent between entering and not entering. In the (n, τ) parameter space under the $EMF(JV)$ locus, the local firm prefers entering (regions I and II) and above the locus the local firm prefers not to enter (regions III and IV). Furthermore, higher restrictions on foreign ownership, a decrease in θ, shifts the $EMF(JV)$ locus in Figure 2 upwards. This implies that entry becomes more likely as foreign ownership restrictions increase.

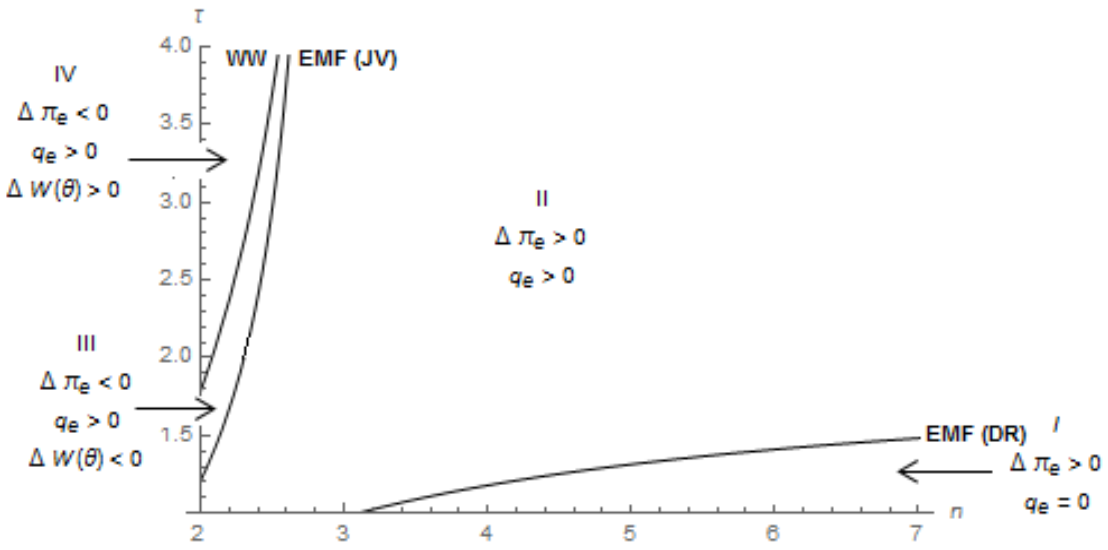

Figure 2: Local firm investment under different types of foreign ownership restrictions

5.1.3 Welfare under the two types of foreign ownership restrictions

Imposing on all foreign companies that they form a joint venture with the same local firm, closely resembles the extractive industry in a number of countries. In other industries more than one local firm may be active in the market and foreign multinationals form joint ventures with different local firms (see e.g. automobile industry in China). In extractive industries such as the oil & gas sector, typically a small number of firms is active in the market, hence, region where $\Delta\pi_e^{JV} < 0$ and the local firm only takes joint venture shares but does not enter the market. In this region where $\Delta\pi_e^{JV} < 0$ host country welfare is given by $W^{JV}(\theta)$ if foreign ownership is restricted through joint venture. If foreign ownership is directly restricted, welfare will be given by $W(\theta)$, where,

$$\begin{aligned} W^{JV}(\theta) &= \frac{[(n-1)q_m^{NLC}(\theta)]^2}{2} + (1-\theta)(n-1)\pi_m^{NLC}(\theta) \text{ and} \\ W(\theta) &= \frac{[(n-1)q_m(\theta) + q_e(\theta)]^2}{2} + \pi_e(\theta) \end{aligned} \tag{24}$$

The host country government improves welfare by restricting foreign ownership directly instead of through joint venture if the following inequality holds.

$$\Delta W(\theta) = W(\theta) - W^{JV}(\theta) > 0 \tag{25}$$

Graphical analysis of the above inequality is possible by dividing $\Delta W(\theta)$ by $(a-c)^2$ and fixing θ. The WW locus in Fig. 2 shows the contour of the function $\Delta W(\theta)/(a-c)^2 = 0$ when $\theta = 0.5$. In region III welfare is higher under joint venture foreign ownership restrictions and in region IV welfare is higher under direct foreign ownership restrictions. Hence, in region IV, the government can improve welfare by taking away local firm joint venture ownership shares and directly control these equity shares as in section 5.1.1.[21] The latter policy measure would mean that the relevant threshold changes from $EMF(JV)$ to $EMF(DR)$ and welfare increases in region IV where cost of technology transfer are high and there is a small number of firms in the market (e.g. natural resource sectors). This provides a possible rationale for a policy measure taken by the Norwegian government in the oil & gas sector. In the 1980s the government took away joint ventrue ownership shares of the national oil company and started to manage these shares directly through the Ministry of Oil and Energy. The Nigerian Oil and Gas Reform Implementation Committee (OGIC) proposed a similar framework for Nigeria's oil & gas sector.

6 Concluding Remarks

In this paper we have analyzed whether FDI crowds out local firms and whether technology transfer by multinationals increases with local competition. We found that in less developed countries FDI will not fully displace local firms, while, in more advanced countries this may happen. Empirical studies by e.g. Blonigen and Wang (2004) and Borensztein et al. (1998) also show that FDI will not fully crowd-out local firms in developing countries. This seems counterintuitive as one would expect that multinationals will more easily outcompete local firms in developing countries than in more advanced countries. We provide a possible explanation for this seemingly counterintuitive result, through the cost of technology transfer. Due to higher cost of technology transfer in less developed countries (see e.g. Teece, 1977; Ramachandran, 1993) multinational corporations transfer less technology to their subsidiaries

[21] The government can establish a department to manage these ownership shares, whereby, it separates the local firm from government interest in the industry.

in these countries. This lower transfer of technology by multinational corporations in less developed countries will reduce the competitive pressure on local firms and prevent the local firm from being fully displaced by FDI. This may also explain why most outward greenfield investment by emerging market firms is done in other developing countries instead of in more advanced countries where cost of technology transfer are low. In the latter case emerging market firms may not be able to compete with technologically more advanced firms.

Furthermore, we found that in competitive markets, multinationals will transfer more technology to their affiliates if they have to compete with a local firm. When, one considers a market with only one multinational affiliate that competes with a number of local firms, such as in e.g. Mattoo et al. (2004), then, local competition will reduce multinational technology transfer. However, in most industries a multinational subsidiary not only competes with local firms but also with other multinational affiliates that also import technology from multinational headquarters. We extend the existing framework by considering strategic interaction between a number of foreign multinationals, in both the product market stage and the technology transfer stage. In line with our findings, empirical results by e.g. Blomström et al. (1994) indeed show that local competition leads to an increase in technology transfer by multinational enterprizes.

Some host country governments restrict the number of foreign multinationals in the host country in order to protect local firms. While, this policy measure may reduce crowding out effects, we find that it also reduces host country welfare in less advanced countries. Another policy measure often imposed is the restriction on foreign ownership shares. In extractive industries foreign multinationals often have to form a joint venture with a national resource firm. Instead of imposing joint ventures, the government may also choose to directly restrict foreign ownership, whereby, it separates the local firm from government interest in the industry. A similar measure was taken in 1984 by the Norwegian government. The government took away significant ownership shares from the local company Statoil. The government started to manage these equity shares which it calls State's Direct Financial

Interest (SDFI) through the Ministry of Oil and Energy.[22] Taking such a policy measure is in line with our theoretical finding which shows that the government may improve host country welfare by taking away local firm equity shares in joint ventures.

Hence, this paper shows that local competition is likely to enhance technology transfer by foreign multinationals. As a result policies that stimulate market entry by local firms may provide a policy alternative to formal performance and technology transfer requirements.[23] By increasing technology transfer through local competition, host country governments may enhance the scope for technology spill-overs. Furthermore, it is shown that FDI is less likely to fully crowd-out local investment in less developed countries. In these countries FDI restrictions may further reduce crowding-out effects. However, restricting the number of foreign multinationals and restricting foreign ownership will also lower host country welfare. Hence, host country governments considering FDI restrictions in order to protect local firms should take these effects on host country welfare into account.

We also find that in developed countries FDI will likely crowd-out local investment. However, the static framework that we apply does not allow to analyze long-run effects from FDI on local investment. Backer and Sleuwaegen (2003) analyzing Belgium manufacturing companies show that FDI displaces local investment in the short-run, but in the long-run this effect is moderated or even reversed. Hence, also in more advanced countries crowding out effects may be prevented. Considering long-run effects of FDI on domestic investment is beyond the scope of our model and should be addressed in further research.[24]

[22] Since 2001 Petoro a state holding company manages the government's interest. Statoil is responsible for selling Petoro's share of oil and gas but the revenue go's to the state.

[23] Also pointed out by Kokko and Blomström (1995).

[24] Theoretical model by Markusen and Venables (1999) shows that FDI benefits local investment through backward-forward linkages. Through backward linkages local upstream firms benefit from FDI and then in turn through forward linkages local downstream firms benefit also.

Appendix 1: Technology transfer

The derivatives of technology transfer w.r.t. the number of firms in the market (n) under no competition from the local firm and under competition from the local firm are respectively:

$$\frac{\partial X_m}{\partial n} = \frac{16\,(a-c)\,(n-1)\,(\tau-2n+n\tau+2)}{(\tau-8n+2n\tau+n^2\tau+8)^2} \text{ and } \frac{\partial X_m^{NLC}}{\partial n} = \frac{4\,(a-c)\,(n-1)\,(n\tau-n+1)}{(\tau n^2-2n+2)^2}. \tag{26}$$

If the local firm is not displaced by FDI, $q_E > 0$, technology transfer (X_m) increases with n if $\tau > \tau^{TT}(n)$, where $\tau^{TT}(n) = \frac{2(n-1)}{n+1}$. We will show later in the proof of proposition 1 that if $\tau < \tau^{TT}(n)$ we have $q_E = 0$. When $q_E = 0$ the relevant level of technology transfer is X_m^{NLC}. From (26) it follows that technology transfer when there is no local firm in the market (X_m^{NLC}), increases with the number of foreign multinationals, when $n \geq 2$ and $\tau > 1$. Hence, technology transfer by multinationals increases with n when FDI crowds the local firm out and also when FDI does not crowd the local firm out.

Appendix 2: Equilibrium outputs and profits

1. Derivations for the case without competition from the local firm

By substituting (17) into (16) we obtain the equilibrium output of any given foreign firm in the host country:

$$q_m^{NLC} = \frac{(a-c)n\tau}{n^2\tau-2n+2}. \tag{27}$$

Equilibrium profit of a foreign firm is given by:

$$\Pi_m^{NLC} = \frac{(a-c)^2\,\tau(\tau n^2-2n^2+4n-2)}{(\tau n^2-2n+2)^2} \tag{28}$$

2. Derivations for Competition from emerging market firm case

By substituting (9) into (7) and into (8) we obtain output of any given advanced firm in the host country and output of the local firm:

$$q_m = \frac{(a-c)(n+1)\tau}{(n+1)^2\tau-8(n-1)} \text{ and } q_e = \frac{(a-c)((n+1)\tau-4(n-1))}{(n+1)^2\tau-8(n-1)} \tag{29}$$

Equilibrium profit of a foreign firm and of the local firm are, respectively, given by:

$$\Pi_m = \frac{(a-c)^2\tau((n+1)^2\tau - 4(n-1)^2)}{((n+1)^2\tau - 8(n-1))^2} \text{ and } \pi_e = \frac{(a-c)^2((n+1)\tau - 4(n-1))^2}{((n+1)^2\tau - 8(n-1))^2}. \quad (30)$$

Appendix 3: Proof of Proposition 1

The local firm will be active in the market if $q_e > 0$. Restriction on $\tau > 1$ ensures that denominator of the expression is positive. Hence, we need to ensure only $(n+1)\tau - 4(n-1) > 0$. This implies that FDI will not fully displace the local firm if parameter τ is sufficiently high, i.e. $\tau > \tau^E(n) = \frac{4(n-1)}{n+1}$. This proves the first part of Proposition 1. Furthermore, $\lim_{n\to\infty} \frac{4(n-1)}{n+1} = 4$. Finally, $\frac{\partial \tau^E(n)}{\partial n} = \frac{8}{(n+1)^2} > 0$. This proves the second part of Proposition 1.

Appendix 4: Comparative statics of local firm output

The derivative of local firm output w.r.t. n and τ is, respectively, given by:

$$\frac{\partial q_e}{\partial n} = \frac{-\tau(a-c)\left(8n + \tau + 2n\tau + n^2\tau - 4n^2 - 4\right)}{\left(\tau - 8n + 2n\tau + n^2\tau + 8\right)^2} \text{ and } \frac{\partial q_e}{\partial \tau} = \frac{(n+1)4\left(a-c\right)\left(n-1\right)^2}{\left(\tau - 8n + 2n\tau + n^2\tau + 8\right)^2} > 0 \quad (31)$$

It follows that local firm output decreases with n if $\tau > \tau^{DR}$ where $\tau^{DR} = \frac{4(n-1)^2}{(n+1)^2}$. From the proof of proposition 1 it follows that $q_e > 0$ if $\tau > \frac{4(n-1)}{n+1}$. Since, $\tau^{DR} < \frac{4(n-1)}{n+1}$ local firm output decreases with n for $q_e > 0$.

Appendix 5: Proof of Propositions 2

Foreign firms transfer more technology under local competition than under no local competition iff:

$$\Delta X \equiv X - X^{NLC} = \frac{4(n-1)^2(a-c)}{\tau(n+1)^2 - 8(n-1)} - \frac{2(n-1)^2(a-c)}{n^2\tau - 2n + 2} > 0 \text{ or} \quad (32)$$

$$\Delta X = \frac{2(n-1)^2(a-c)\left[\tau(n^2 - 2n - 1) + 4n - 4\right]}{(n^2\tau - 2n + 2)(\tau(n+1)^2 - 8(n-1))} > 0. \quad (33)$$

Recall $\tau > 1$ and $n \geq 2 > 0$, hence, the above inequality implies that $\Delta X > 0$ if $\tau(n^2 - 2n - 1) + 4n - 4 > 0$. We can conclude that

$\tau < \frac{4(n-1)}{2n+1-n^2}$, when $n \leq 1 + \sqrt{2} \approx 2.4$

$\tau > \frac{4(n-1)}{2n+1-n^2}$, when $n > 1 + \sqrt{2} \approx 2.4$

This also shows that, when $0 < n < 1 + \sqrt{2}$, $\tau^T(n) = \frac{4(n-1)}{2n+1-n^2} > 0$. Hence, technology transfer is higher under local competition if

$$\tau < \tau^T(n) = \frac{4(n-1)}{2n+1-n^2}. \tag{34}$$

Note that for $n = 2$, $\tau^T(n) = 4$. This implies the result in part (i) of proposition 2. Furthermore, when $n > 1+\sqrt{2} \approx 2.4$, $\tau^T(n) = \frac{4(n-1)}{2n+1-n^2} < 0$. Hence, for $n > 1+\sqrt{2}$ technology transfer is always higher under local competition for any $\tau > 1$. $\tau^T(n)$ is depicted by the solid loci TT in Figure 3**.** This completes the proof of proposition 2.

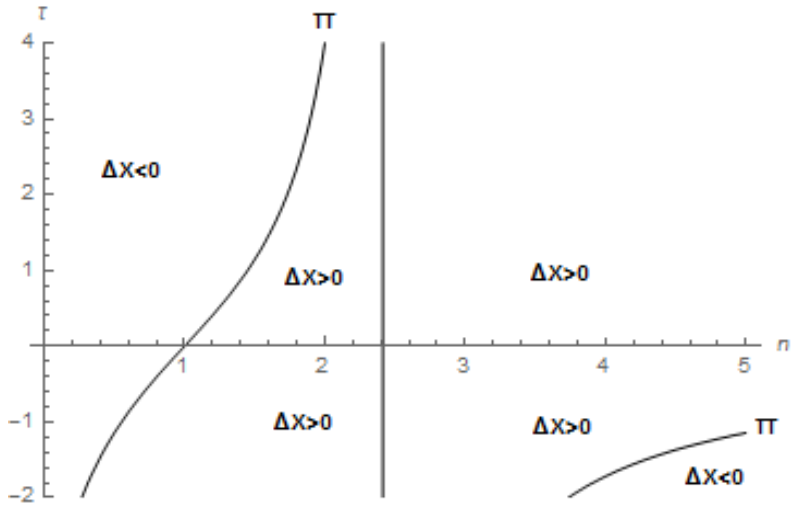

Figure 3: Effect of local competition on technology transfer

Appendix 6: Proof of Proposition 3

Host country welfare when the local firm is active in the market is:

$$W = CS(Q) + \pi_e = \frac{(a-p)Q}{2} + \pi_e$$

$$W = \frac{(a-(a-q_e-(n-1)q_m))(q_e+(n-1)q_m)}{2} + \pi_e = \frac{(q_e+(n-1)q_m)^2}{2} + \pi_e \tag{35}$$

This implies:

$$W = \frac{(a-c)^2((n+1)\tau n - 4(n-1))^2}{2((n+1)^2\tau - 8(n-1))^2} + \frac{(a-c)^2((n+1)\tau - 4(n-1))^2}{((n+1)^2\tau - 8(n-1))^2}. \tag{36}$$

Host country welfare increases with the number of foreign multinational firms if $\frac{\partial W}{\partial n} > 0$, where

$$\frac{\partial W}{\partial n} = \frac{-\tau(a-c)^2\left(-n^4\tau^2+4n^4\tau-n^3\tau^2-16n^3\tau+16n^3+3n^2\tau^2-48n^2+5n\tau^2+16n\tau+48n+2\tau^2-4\tau-16\right)}{(\tau-8n+2n\tau+n^2\tau+8)^3}$$

Graphical analysis of the function $(\frac{\partial W}{\partial n})/(a-c)^2 = 0$ is provided in Fig. 4 in (n,τ)-space, where, it is depicted by the locus $\partial W/\partial n = 0$. It can be seen that welfare increases with n when $q_e > 0$, $\tau > 1$, and $n > 2$.

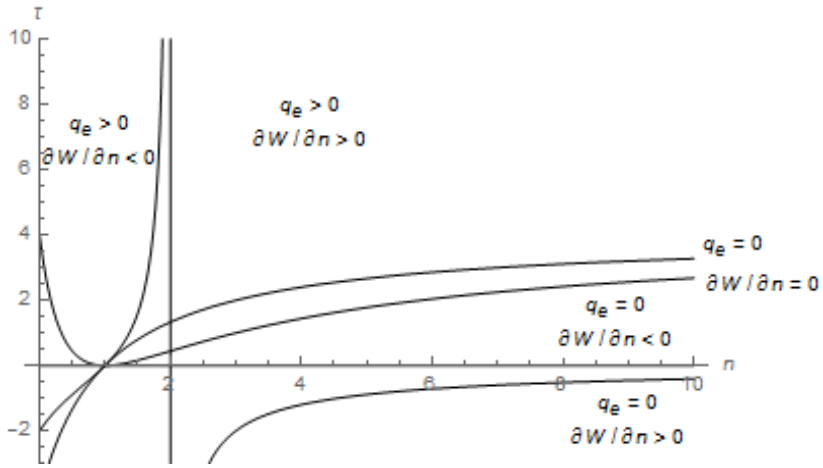

Figure 4: FDI and host country welfare

When, the local firm is displaced by foreign multinationals ($q_e = 0$), welfare is given by

$$W^{NLC} = \frac{(a-(a-(n-1)q_m^{NLC})(n-1)q_m^{NLC}}{2} = \frac{(n-1)^2(a-c)^2n^2\tau^2}{2(n^2\tau-2n+2)^2} \tag{37}$$

Appendix 7: Derivations under foreign ownership restrictions

1. Derivations for the case with no local firm in the market

Maximizing: $\theta\pi_m(x_m) - \frac{\tau x_m^2}{2}$, $m \in \{1, ..., n-1\}$, gives foreign firm technology transfer:

$$x_m^{NLC}(\theta) = \frac{2\theta(n-1)(a-c)}{n^2\tau - 2\theta(n-1)}. \tag{38}$$

Foreign firm equilibrium output, $q_m^{NLC}(\theta)$, is found by plugging technology transfer in (38) into (16) and assuming symmetry in equilibrium:

$$q_m^{NLC}(\theta) = \frac{(a-c)n\tau}{n^2\tau - 2\theta(n-1)}. \tag{39}$$

It follows that the profit function of a representative foreign firm net of technology transfer cost is given by:

$$\pi_m^{NLC}(\theta) = [\frac{(a-c)n\tau}{n^2\tau - 2\theta(n-1)}]^2. \tag{40}$$

Welfare is now given by:

$$W^{NLC}(\theta) = \frac{(n-1)^2(a-c)^2n^2\tau^2}{2(n^2\tau - 2\theta(n-1))^2} \tag{41}$$

It follows from (41) that welfare decreases with foreign equity restrictions i.e. a decrease in θ.

2. Derivations for the case the local firm is active in the market and direct foreign ownership restrictions

Maximizing: $\theta\pi_m(x_m) - \frac{\tau x_m^2}{2}$, $m \in \{1, ..., n-1\}$, gives technology transfer by a representative multinational:

$$x_m^{DR}(\theta) = \frac{4\theta(n-1)(a-c)}{\tau(n+1)^2 - 8\theta(n-1)} \tag{42}$$

By substituting (42) into functions for output in (7) and (8), we obtain the equilibrium output of, respectively, a foreign multinational and the local firm:

$$q_m^{DR}(\theta) = \frac{(a-c)(n+1)\tau}{(n+1)^2\tau - 8\theta(n-1)} \text{ and } q_e^{DR}(\theta) = \frac{(a-c)[(n+1)\tau - 4\theta(n-1)]}{(n+1)^2\tau - 8\theta(n-1)}. \tag{43}$$

This implies

$$\pi_e^{DR}(\theta) = \frac{(a-c)^2[(n+1)\tau - 4\theta(n-1)]^2}{[(n+1)^2\tau - 8\theta(n-1)]^2} \text{ and } \Pi_m^{DR}(\theta) = \frac{\theta\tau(a-c)^2[(n+1)^2\tau - 8\theta(n-1)^2]}{[(n+1)^2\tau - 8\theta(n-1)]^2}.$$

Host country welfare is given by

$$W(\theta) = \frac{(a-c)[((n+1)n\tau - 4\theta(n-1))^2 + 2((n+1)\tau - 4\theta(n-1))^2]}{2[(n+1)^2\tau - 8\theta(n-1)]^2}$$

The derivative of host country welfare w.r.t. foreign ownership is:

$$\frac{\partial W(\theta)}{\partial \theta} = \frac{-4\tau\,(a-c)\,(n-1)^2\,(n+1)\,(4\theta+2\tau-4n\theta+n\tau-n^2\tau)}{(8\theta+\tau-8n\theta+2n\tau+n^2\tau)^3}$$

Host country welfare decreases with foreign ownership if: $4\theta+2\tau-4n\theta+n\tau-n^2\tau>0$. Given that inequality $\frac{\tau(n+2-n^2)}{4\theta(n-1)}>1$ does not hold, welfare increases with θ.

Appendix 8: Derivations entry under joint venture regime

In this appendix we provide detailed derivations of the expressions under the joint venture regime for the case of entry by the local firm. Under entry, the best response function of the local firm is obtained by differentiating the following objective function:

$$\max_{q_e}(n-1)(1-\theta)\pi_m(q_e,q_m)+\pi_e(q_e,q_m) \text{ which is equivalent to} \tag{44}$$

$$\max_{q_e}(n-1)(1-\theta)\left(a-q_e-\sum_{m=1}^{n-1}q_m-c_m\right)q_m+\left(a-q_e-\sum_{m=1}^{n-1}q_m-c\right)q_e. \tag{45}$$

Plugging the best response function of the local firm and function for total output of foreign firms in (6) into (5) and solving for q_m implies:

$$q_m^{JV}(\theta)=\frac{a-c+2(n-1)x_m-2\sum\limits_{j=1,j\neq m}^{n-1}x_j}{2+\theta(n-1)}\ ,\ m\in\{1,...,n-1\}. \tag{46}$$

Plugging (46) into the best response function of the local firm in symmetric equilibrium gives:

$$q_e^{JV}(\theta)=\frac{(a-c)(2-n+\theta(n-1))-(2-\theta)\sum\limits_{m=1}^{n-1}x_m}{2+\theta(n-1)}. \tag{47}$$

From (2) and (46) it follows that for a representative multinational from an advanced country, the profit net of cost of technology transfer can be expressed as $\theta(q_m^{LCJV}(\theta))^2$. Hence, foreign firm technology transfer under entry is given by:

$$x_m^{JV}(\theta)=\frac{4\theta(n-1)(a-c)}{\tau(2+\theta(n-1))^2-8\theta(n-1)}. \tag{48}$$

Plugging value for technology transfer in (48) under entry into expressions for output in (46) and (47) gives equilibrium output of, respectively, a foreign firm and of the local firm:

$$q_m^{JV}(\theta) = \frac{(a-c)(2+\theta(n-1))\tau}{\tau(2+\theta(n-1))^2 - 8\theta(n-1)} \text{ and} \quad (49)$$

$$q_e^{JV}(\theta) = \frac{(a-c)((2-n+\theta(n-1))(2+\theta(n-1))\tau - 4\theta(n-1))}{\tau(2+\theta(n-1))^2 - 8\theta(n-1)} \quad (50)$$

This implies that:

$$\pi_m^{JV}(\theta) = [\frac{(a-c)(2+\theta(n-1))\tau}{\tau(2+\theta(n-1))^2 - 8\theta(n-1)}]^2 \text{ and} \quad (51)$$

$$\pi_e^{JV}(\theta) = [\frac{(a-c)((2-n+\theta(n-1))(2+\theta(n-1))\tau - 4\theta(n-1))}{\tau(2+\theta(n-1))^2 - 8\theta(n-1)}]^2 \quad (52)$$

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