*On welfare reducing technological change in a North-South framework**

H. Benchenkroun^a and S. Vishwasrao^b

Abstract

Northern firms with patented technology can export goods to Southern markets and incur tariff costs or choose FDI and avoid the tariff. We examine the welfare effects of intellectual property protection under this scenario. When it is beneficial to do so, South offers a patent protection to induce FDI. We show that a technological improvement in the North can reduce South's welfare. After a technological improvement, the South still prefers that North does FDI, however a longer patent protection may be required to induce FDI which can result in an overall decrease of South's welfare. We also show that a more effective technology does not necessarily require a longer patent protection to induce FDI. **JEL Classification:** O14, O33, O44, F13, F23. **Keywords:** Technology Improvements, Trade Policy, Foreign Direct Investment, Intellectual Property Rights, Technology Transfers.

---

*Acknowledgements: We would like to thank Sonia Laszlo, Shih-Tse Lo, Ngo Van Long and Dhanoos Sutthiphisal for very helpful comments. The first author acknowledges the financial support of the Social Sciences and Humanities Research Council of Canada. Please address all correspondence to Hassan Benchenkroun, Department of Economics, McGill University, Montreal, QC, Canada H3A-2T7. Tel: 514-398-2776. Fax: 514-398-4938. E-mail: hassan.benchekroun@mcgill.ca.

(a) *Department of Economics and CIREQ, McGill University*

(b) *Department of Economics, Florida Atlantic University.*

1 Introduction

One of the primary benefits of foreign direct investment (FDI) for developing countries is its association with technology transfer. For the host country, the benefits of technology transfer are not limited to access to new goods or lower prices for consumers but also extend to domestic firms through the dissemination of cost reducing technologies through learning and imitation. In an attempt to capture these benefits, developing countries have sought to tailor policies to attract FDI and increase technology transfer. This paper investigates the welfare effects of technology improvements when Southern countries use intellectual property protection and tariffs to influence technology transfer and FDI.

In our paper, Northern firms with patented technology can export goods to Southern markets and incur tariff costs or choose FDI and avoid the tariff. We examine the welfare effects of intellectual property protection under this scenario. When it is beneficial to do so, South offers a patent protection to induce FDI. We consider technological change which impacts the marginal costs of production and thus affects the choice of the quantities to be produced. We show that a more effective technology does not necessarily require a longer patent protection to induce FDI. We find that technology improvements can influence the choice of FDI and IPRs in ways which may be immiserizing for Southern countries: a technological improvement in the North can reduce South's welfare. After a technological improvement, the South still prefers that North does FDI, however a longer patent protection may be required to induce FDI which can result in an overall decrease of South's welfare.

Our paper is related to a body of literature on FDI and technology transfer which looks at policies other than intellectual property rights. Mattoo et al (2004) consider a Northern firm's choice between FDI and acquisition of domestic firms and find that when technology transfer is costly, the interaction between scale and competition effects provides incentives for Southern governments to limit the degree of foreign ownership. In a similar vein Brander and Spencer, 1987, Haufler and Wooton, 1999 and Fumagalli, 2003 study the welfare effects of tax and tariff policies on FDI and host country welfare. Our

research is also linked to the literature on trade related intellectual property which examines Southern countries' incentives to protect patents based on R&D and technology transfer considerations. Southern countries may have an incentive to protect Northern patents if the resulting research expenditures are very productive or result in innovations that benefit Southern countries (See Chin and Grossman, 1990, Diwan and Reddick, 1991 and Deardorff, 1993). There is also an existing literature which studies the positive impact of IPRs on technology transfer. (Taylor, 1993, Vishwasrao, 1994, and Ziger, 1995). On the other hand, Glass and Saggi (2002a, 2002b), in a model with exogenous innovation and imitation show that tighter IPRs in the South can crowd out FDI and reduce innovation because of resources wasting¹. Arguments that IPRs affect the FDI decision enjoy theoretical as well as empirical support. Ferrantino (1999) finds that multinationals firms will prefer to locate production where IPRs are well recognized. In addition, Ferrantino also finds a tendency for U.S. firms to have higher sales for exports to its affiliates in countries that do not protect IPRs possibly in an attempt to conceal production technology. Lee and Mansfield (1996) using survey data from U.S. multinationals show that differences in intellectual property regimes have a significant impact on the volume and composition of FDI. Lower levels of intellectual property protection tend to reduce the volume of FDI and also the funds invested in R&D facilities in the host countries.

We construct a model which captures some of these features. In our model, a Northern firm chooses whether to service a Southern market through exports or FDI. FDI has the beneficial effect of avoiding the Southern tariff on imported goods but exposes the firm to the risk of imitation by Southern rivals. We assume that locating in a Southern country is necessary for imitation. We can think of this as a situation where imitation is costly and where FDI in the South lowers the costs of imitation perhaps because the technology has already been adapted for use in the South². The Southern government can prevent

---

¹In contrast with most other papers, in the Glass and Saggi model, better IPR protection in the South does not offer any special benefits to multinationals as opposed to importers thus tighter IPR protection tends to shift production to the North and reduces resources available for innovation.

²This is formalized in Glass and Saggi (2002), although the aspect of intellectual property protection

imitation through patent protection. We use the length of patent protection as a measure of the level of IPR protection. Thus the Southern government picks the length of time before Southern firms are free to imitate the technology. The model is presented in Section 2. In Section 3 we introduce the technology improvement and determine its impact on the minimum FDI inducing patent length and on the South's welfare.

2 The Model

Consider a good that is only consumed in the South and produced by one Northern firm that supplies the Southern market. There are no other suppliers of the commodity in the South. The Northern firm can supply the Southern market by producing in the North and exporting to the South or by creating a subsidiary in the South (FDI). If the Northern firm exports it has to pay a per unit tariff τ . Let Π^e denote the present value of the stream of profits earned by the Northern firm in the Southern Market if it chooses to export, we have:

$$\Pi^e = \int_0^{\infty} \pi_0^e e^{-\rho t} dt$$

where π_0^e denotes the optimized flow rate of profits of the Northern firm in the Southern market when it supplies the Southern market through exports and when the per unit tariff is τ .

If the Northern firm chooses FDI and sets a subsidiary in the South, it can sell whatever quantity it wishes, without having to pay the tariff. Patent protection in the South, for the Northern firm that chooses FDI, lasts for a period of time L . Until patents expire, the Northern firm's subsidiary has a monopoly in the Southern market and at L , Southern firms are able to reproduce the Northern firm's technology and generate the maximum welfare possible and the Northern firm's profits are zero³. Production in the South is

---

studied is the scope of patents rather than the length.

³The market in the South may be perfectly competitive after patents expire or may be imperfectly competitive. For the results to hold, we only require that there are some gains to domestic consumers after patents expire and that the Northern firm's profits are lower.

necessary for imitation to occur and the good cannot be imitated while it is imported. This can be justified by a lower imitation costs when trying to imitate a technology that has already been adapted for use in the South, or through knowledge spillovers through labor mobility etc. The time horizon is infinite.

Let Π^{FDI} denote the present value of the stream of profits earned by the Northern firm in the Southern market if it chooses FDI. We have

$$\Pi^{FDI} = \int_0^L \pi_0^{FDI} e^{-rt} dt$$

where $r > 0$ denotes the interest rate and where π_0^{FDI} denotes the optimized flow rate of profits of the Northern firm in the Southern market during the period of time that the patent is protected when it chooses FDI and. After L , we assume that the Northern firm's profits are zero.

Given a tariff rate τ and a patent length L , the Northern firm will choose FDI instead of exporting if $\Pi^{FDI} \geq \Pi^e$ which gives

$$1 - \frac{\pi_0^\tau}{\pi_0^{FDI}} > e^{-rL} \quad (1)$$

Note that in the absence of a tariff ($\tau = 0$) and patent protection ($L = 0$), the Northern firm may still choose FDI if the profits from producing in the South π_0^{FDI} are larger than the profits from exports $\pi_0^{\tau=0}$. This difference in profits and the decision to do FDI is then solely motivated by a more profitable environment to supply the Southern market from the South due, for example, to low wages in the South or high transportation costs.

In establishing condition (1) we implicitly assumed that the sunk-cost of setting-up the plant is zero. This assumption is made for simplicity: our results would not be qualitatively changed if we considered a positive sunk-cost. Note however that we do not assume that the fixed costs of operating the plant, or quasi-fixed costs are zero. Quasi fixed costs are costs that do not depend on the level of production but are incurred only when the firm produces a positive quantity of output: maintenance and operating expenses that are incurred regardless of the production level but can be avoided when

production is zero⁴ (see for example Varian (2002)). For simplicity we focus on quasi-fixed costs and assume the sunk-cost is zero, and in the remainder of the paper the term fixed costs will refer to quasi fixed costs.

Let W^e denote the present value of the stream of social welfare enjoyed in the South if the Northern firm chooses to export. We have:

$$W^e = \int_0^\infty w_0^\tau e^{-rt} dt$$

where w_0^τ denotes the flow rate of social welfare in the South when the Northern firm supplies the Southern market through exports and when the per unit tariff is τ .

Let W^{FDI} denote the present value of the stream of social welfare enjoyed in the South if the Northern firm chooses to do FDI. We have

$$W^{FDI} = \int_0^L w_0^{FDI} e^{-rt} dt + \int_L^\infty w_0^s e^{-rt} dt. \quad (2)$$

where w_0^{FDI} denotes the optimized flow rate of social welfare of the South when the Northern chooses FDI during the period of time that the patent is protected and w_0^s denotes the flow rate of social welfare of the South when the Northern firm chooses FDI after the expiration of the patent protection.

The South would prefer that the northern firm chooses FDI instead of exporting if $W^{FDI} \geq W^e$ which yields

$$e^{-rL} \geq \frac{w_0^\tau - w_0^{FDI}}{w_0^s - w_0^{FDI}} \quad (3)$$

Combining (1) and (3) gives that South prefers FDI and North chooses FDI⁵ if (L, τ) are such that

$$\frac{w_0^\tau - w_0^{FDI}}{w_0^s - w_0^{FDI}} \leq e^{-rL} \leq 1 - \frac{\pi_0^\tau}{\pi_0^{FDI}}. \quad (4)$$

---

⁴Other textbooks in microeconomics, managerial economics or industrial organization use different terminology such as operating or avoidable fixed costs to refer to quasi fixed costs (see for example Carlton and Perloff (2005)). For more details see Wang and Yang (2001).

⁵The South prefers exports and the North chooses exports when $1 - \frac{\pi_0^\tau}{\pi_0^{FDI}} < e^{-rL} < \frac{w_0^\tau - w_0^{FDI}}{w_0^s - w_0^{FDI}}$.

The condition 4 is intuitive: if the patent length is too long South no longer has an incentive to attract FDI and when the patent length is too short the Northern firm finds the FDI option unattractive.

We note that for the range of patent of length that makes FDI mutually attractive compared to the export option is non-empty iff

$$\frac{w_0^\tau - w_0^{FDI}}{w_0^s - w_0^{FDI}} \leq 1 - \frac{\pi_0^\tau}{\pi_0^{FDI}} \quad (5)$$

that is

$$\frac{w_0^s - w_0^\tau}{w_0^s - w_0^{FDI}} \geq \frac{\pi_0^\tau}{\pi_0^{FDI}} \quad (6)$$

In the case of a linear demand and an affine cost function we show that for a *significant* set of parameters⁶ this inequality holds and therefore the interval of patent lengths such that FDI is mutually beneficial to both parties is not empty.

3 Technological improvement

A technological improvement in this paper is represented by the reduction in the cost function it creates. It can alternatively be seen as a modification in the profits that depend on the quantity produced⁷. Let q denote the quantity produced, we consider technological improvements that result in an increase in the profits by βq where $\beta \geq 0$. This technology improvement can be viewed as a decrease in marginal cost.

The central question of this paper is: Will the South always benefit from a technological improvement?

We consider the case where the South prefers FDI to export and can modify its patent length to always offer the minimum patent length, denoted $L_\tau(\beta)$, that induces the North-

---

⁶A set of parameters of positive measure where the parameters are the choke price, the slope of the demand function, the fixed cost and the marginal cost.

⁷We assume that the quality of the commodity is not affected by the change in technology.

ern firm to choose FDI over exports⁸. To answer our main question we need to determine the impact of a technological improvement on the minimum FDI inducing patent length.

3.1 The minimum FDI inducing patent length

Given a tariff rate τ and a patent length L , the Northern firm will choose to do FDI instead of exporting if

$$\int_0^L \pi^{FDI} e^{-rt} dt \geq \int_0^\infty \pi^\tau e^{-rt} dt$$

which after simplification yields

$$L \geq L_\tau(\beta) \equiv \ln \left(\frac{\pi^{FDI}}{\pi^{FDI} - \pi^\tau} \right) \quad (7)$$

where π^τ and π^{FDI} denote the profit of the northern firm when there is a technological change under the export regime and under FDI respectively. When $\beta = 0$ we have $\pi^\tau = \pi_0^\tau$ and $\pi^{FDI} = \pi_0^{FDI}$. The minimum FDI inducing patent length prior to a technological improvement is $L_\tau(0)$.

Determining the impact of a technological improvement for any β positive is difficult. The quantities produced in each regime (export, FDI, post patent protection) will in general change due to the technological improvement. Let q^{FDI} denote the quantity chosen by the Northern firm under FDI and q^τ denote the quantity chosen by the Northern firm in the case it chooses to export. Let q^s denote the quantity produced after expiration of the patent protection. When $\beta > 0$, in general $q^\tau \neq q_0^\tau$, $q^{FDI} \neq q_0^{FDI}$ and $q^s \neq q_0^s$. This makes a global analysis (i.e., for any $\beta > 0$) very difficult to conduct. To circumvent this difficulty we study the impact of a *marginal* technological improvement, i.e. in the neighborhood

---

⁸While countries may not actually choose patent length based on technology type there are many countries which actually enforce patent protection selectively and vary the length of protection based on differences in technology. Companies transferring technology to Indian firms (both through subsidiaries and unaffiliated firms) until the mid 1990's were only allowed to charge royalties for a period whose duration varied with the industry and the terms of the agreement. Many countries have loopholes in patent laws allowing non working patents to be appropriated. Thus while stated patent length may not vary by technology or industry, the enforcement of patent length clearly does vary.

of $\beta = 0$. Even a *marginal* technological improvement can have an ambiguous impact on the minimal FDI inducing patent length.

Lemma 1: *A marginal decrease in the total cost by βq will result in a decrease of the minimum FDI inducing patent length if and only if*

$$\frac{\pi_0^{FDI}}{q_0^{FDI}} - \frac{\pi_0^\tau}{q_0^\tau} > 0$$

where $q_0^\tau = q^\tau$ and $q_0^{FDI} = q^{FDI}$ when $\beta = 0$.

Proof: We show in Appendix A that

$$\frac{\partial L_\tau(0)}{\partial \beta} = \frac{e^{rL_\tau(0)}}{r} \frac{q_0^{FDI} q_0^\tau}{(\pi_0^{FDI})^2} \left(\frac{\pi_0^{FDI}}{q_0^{FDI}} - \frac{\pi_0^\tau}{q_0^\tau} \right) \quad \blacksquare \quad (8)$$

The lemma above raises a rather surprising possibility: if $\left(\frac{\pi_0^{FDI}}{q_0^{FDI}} - \frac{\pi_0^\tau}{q_0^\tau} \right) < 0$ the minimum FDI inducing patent length is reduced. A more efficient technology does not necessarily imply that the South will have to give a longer patent length to attract FDI! If for example $q_0^{FDI} > q_0^\tau$, this surprising possibility will arise when the average profit is decreasing with quantities.

If $\left(\frac{\pi_0^{FDI}}{q_0^{FDI}} - \frac{\pi_0^\tau}{q_0^\tau} \right) > 0$ then $\frac{\partial L_\tau(0)}{\partial \beta} > 0$. This is intuitive: to attract a more efficient technology one should offer a more attractive incentive, i.e. a longer patent length. If this is true then the answer to the central question is nontrivial. Consider the three time intervals $[0, L_\tau(0))$, $[L_\tau(0), L_\tau(\beta))$ and $[L_\tau(\beta), \infty)$. During $[0, L_\tau(0))$ the flow of welfare increases due to the technology improvement because the quantity supplied by the Northern firm increases due to a decrease in the marginal cost. During $[L_\tau(\beta), \infty)$ the flow of welfare increases due to technology improvement because the supply in the South increases since the marginal cost of production diminishes: $w^{FDI} > w_0^{FDI}$ where w^{FDI} is the flow of welfare in the South during FDI with the new technology. However, during $[L_\tau(0), L_\tau(\beta))$ the flow rate of welfare in the South prior the technology improvement is w_0^s where as under the new technology it is w^{FDI} , with $w^{FDI} < w_0^s$: a decrease in the flow of welfare. The overall impact of a technology improvement is thus *a priori* to be determined.

3.2 The impact of a technological innovation on South's welfare

To be able to compute the overall impact of the technology improvement on the South's welfare we use specific functional forms for the demand function and the cost function. We argue that a technological improvement can have a negative effect of South's welfare. This possibility can arise even in the very standard framework where the demand and the cost are respectively affine functions of the quantity consumed and produced. This is the case we consider from now on.

Suppose South's demand for the commodity produced by the Northern firm is given by:

$$P(q) = P(0) - cq$$

The marginal cost⁹ is constant and equal to $c > 0$ and the fixed cost is $\phi \geq 0$.

Assume now that a technological innovation took place and the marginal cost drops from c to $c - \beta$, where $\beta \leq c$. The profit maximizing quantity chosen by the Northern firm during an export phase when it is paying a per unit tariff τ is given by:

$$q^\tau = \frac{z - \tau + \beta}{2} \quad (9)$$

where $z \equiv P(0) - c$ is assumed positive¹⁰. The Northern firm's profits are

$$\pi^\tau = (q^\tau)^2 - \phi = \left(\frac{z - \tau + \beta}{2} \right)^2 - \phi \quad (10)$$

from which we infer¹¹

$$\pi^{FDI} = (q^{FDI})^2 - \phi \text{ and } q^{FDI} = \frac{z + \beta}{2} \quad (11)$$

---

⁹We assume identical costs in North and South. Our analysis can be extended to cases where the marginal cost c_S in South and a marginal cost c_N in North differ ($c_N \neq c_S$).

¹⁰In the case of a linear cost function our analysis could be expressed as a comparative static exercise with respect to the marginal cost c . We keep our approach of using the parameter β to be consistent with the analysis of the FDI inducing patent length conducted without assuming the linearity of the cost function.

¹¹by setting $\tau = 0$.

The South's instantaneous social welfare under FDI is given by

$$w^{FDI} = \int_0^{q^{FDI}} P(q) dq - P(q^{FDI}) q^{FDI} = \frac{(q^{FDI})^2}{2} \quad (12)$$

The maximum social welfare that can be generated in the South once patent protection expires is

$$w^s = \int_0^{q^s} P(q) dq - (c - \beta) q^s - (\phi - \gamma) = \frac{(q^s)^2}{2} - \phi \quad (13)$$

where

$$q^s = z + \beta \quad (14)$$

Using Lemma 1, we show in appendix B that a decrease in the marginal cost will require a longer patent protection in South to induce FDI from North.

Let $W^{FDI}(\beta)$ denote the present value of South's welfare,

$$W^{FDI}(\beta) = \int_0^{L_\tau(\beta)} w^{FDI} e^{-rt} dt + \int_{L_\tau(\beta)}^\infty w^s e^{-rt} dt \quad (15)$$

Deriving $W^{FDI}(\beta)$ with respect to β yields

$$\begin{aligned} \frac{dW^{FDI}}{d\beta}(\beta) &= \int_0^{L_\tau(\beta)} \frac{\partial w^{FDI}}{\partial q} \frac{dq^{FDI}}{d\beta} e^{-rt} dt + \\ &\quad \int_{L_\tau(\beta)}^\infty \left(\frac{\partial w^s}{\partial q} \frac{dq^s}{d\beta} + \frac{\partial w^s}{\partial \beta} \right) e^{-rt} dt + (w^{FDI} - w^s) e^{-rL_\tau(\beta)} \frac{\partial L_\tau(\beta)}{\partial \beta} \end{aligned}$$

We have $\left. \frac{\partial w^s}{\partial q} \right|_{\beta=0} = q_0^s$, moreover, using the envelope theorem we have $\left. \frac{\partial w^s}{\partial \beta} \right|_{\beta=0} = 0$ and thus

$$\begin{aligned} \frac{dW^{FDI}}{d\beta}(\beta=0) &= \int_0^{L_\tau(0)} \frac{\partial w^{FDI}}{\partial q} \frac{dq^{FDI}}{d\beta} e^{-rt} dt + \\ &\quad \int_{L_\tau(0)}^\infty q_0^s e^{-rt} dt + (w_0^{FDI} - w_0^s) e^{-rL_\tau(0)} \frac{\partial L_\tau(0)}{\partial \beta} \end{aligned} \quad (16)$$

Note that w^{FDI} does not depend explicitly on β , however it depends on q^{FDI} which is a function of β .

The impact of such a cost reduction is fairly intuitive. The first two terms of the RHS are both positive and represent the increased welfare during the period of FDI because production will increase during FDI and, the increase in welfare "post FDI" after the expiration of the patent. The third term's sign is ambiguous and depends on the impact of the technology improvement. If the minimum FDI inducing patent length is shortened then the impact of the technology improvement is definitely positive (since $w_0^{FDI} - w_0^s < 0$). If the patent protection is lengthened then the third term's sign is negative and the impact of the technology improvement on South's welfare is ambiguous.

For the linear demand and affine cost function as specified above we have:

$$\frac{dw^{FDI}}{d\beta} = q^{FDI} \frac{dq^{FDI}}{d\beta} > 0$$

After substitution of q^{FDI} and q^s we have at $\beta = 0$

$$w_0^{FDI} = \frac{z^2}{8} \text{ and } w_0^s = \frac{z}{2} - \frac{1}{2}$$

and

$$\frac{dw^{FDI}}{d\beta} = q^{FDI} \frac{dq^{FDI}}{d\beta} = \frac{z}{4}$$

Lemma 2 : *The impact on South's welfare due to a change in the marginal cost is given by*

$$\frac{dW^{FDI}}{d\beta}(\beta = 0) = \frac{zN\left(\frac{\phi}{z^2}, \frac{\tau}{z}\right)}{4r\left(4\frac{\phi}{z^2} - 1\right)^2} \quad (17)$$

where

$$N(\phi, \tau) \equiv \left(32\frac{\tau}{z} + 16\right) \left(\frac{\phi}{z^2}\right)^2 + \left(4\left(\frac{\tau}{z}\right)^2 - 28\frac{\tau}{z} - 8\right) \frac{\phi}{z^2} + 3\frac{\tau}{z} + 1 \quad (18)$$

Proof: See appendix C.

Without loss of generality we adopt the following normalization: $z = 1$. The function $N(\phi, \tau)$ becomes

$$N(\phi, \tau) = (32\tau + 16)\phi^2 + (4\tau^2 - 28\tau - 8)\phi + 3\tau + 1.$$

The sign of $\frac{dW^{FDI}}{d\beta}$ will in general depend on ϕ and τ . The signs of $\frac{dW^{FDI}}{d\beta}$ and of $N(\phi, \tau)$ are the same.

We can unambiguously determine the sign of the expression $\frac{dW^{FDI}}{d\beta}(\beta = 0)$ in (17) for the case where $\phi = 0$. From (17) we have $N(0, \tau) = 1 + 3\tau > 0$ for $\tau \geq 0$ and thus $r \frac{dW^{FDI}}{d\beta}(\beta = 0) > 0$. When the fixed cost is zero, a decrease in the marginal cost will increase South's welfare. Using a continuity argument we can state that if the fixed cost ϕ is *small enough*¹² a marginal decrease in the marginal cost increases South's welfare.

Before analyzing the sign of $N(\phi, \tau)$ (and $\frac{dW^{FDI}}{d\beta}(\beta = 0)$ by the same token) for $\phi > 0$ we first specify its domain of definition. We note that any tariff rate τ must not be larger than 1 (for production to take place¹³). Moreover, given a tariff $\tau \leq 1$ we must have $\phi \leq \phi_\tau \equiv \frac{(1-\tau)^2}{4}$ where ϕ_τ represents the upper bound on the fixed costs¹⁴ beyond which, when $\beta = 0$, there would be losses from export ($\pi^\tau < 0$) when the tariff is τ . We therefore limit the domain of the function $N(\phi, \tau)$ to $[0, \phi_\tau] \times [0, 1]$ where $\phi_\tau \equiv \frac{(1-\tau)^2}{4}$.

Proposition 3 : *A lower marginal cost of production can result in a lower welfare in South.*

Proof: See appendix D.

A lower marginal cost of production can reduce welfare in South. More generally, it can be shown that there exists $\bar{\tau} \in (0, 1)$ such that for any $\tau \in (0, \bar{\tau})$ a lower marginal cost of production can result in a lower welfare in South and for $\tau \in (\bar{\tau}, 1)$ a lower marginal cost of production always result in a higher welfare in South. The approximate value of $\bar{\tau}$ is 0.1885.

The intuition behind the results above is that a change in technology modifies the ratio of profits under exports and with FDI, $\frac{\pi^\tau}{\pi^{FDI}}$. The sensitivity of the ratio $\frac{\pi^\tau}{\pi^{FDI}}$ to the cost varies with the level of the fixed cost. For a high level of fixed costs the profits are smaller in absolute value, therefore a change in marginal costs will relatively result in larger percentage changes of the profits if the fixed costs were smaller. In the benchmark case of a linear demand the relative change in π^τ exceeds the relative change in π^{FDI}

¹²More precisely, it can be shown that, for any $0 < \phi < \frac{z^2}{8}$ we have $\frac{dW^{FDI}}{d\beta}(\beta = 0) > 0$.

¹³Recall that $z = 1$. For $z \neq 1$ we should limit the domain of τ to $[0, z]$.

¹⁴Alternatively, τ can be interpreted as the prohibitive tariff that sets exports to zero when $\phi = \phi_\tau$.

leading to an increase of the ratio $\frac{\pi^T}{\pi^{FDI}}$. The increase of $\frac{\pi^T}{\pi^{FDI}}$ requires the offering by South of a longer the patent length needed to induce FDI. The overall effect on welfare of a longer minimum FDI inducing patent length following a decrease in the marginal costs outweighs the positive effect of a lower marginal cost of production.

4 Conclusion

We find that a more effective technologies may not always be necessary to longer patent length in order to induce FDI. Since the Northern firm is more likely to choose FDI when the cost reduction is more effective over large scale production, if a firm has sharply increasing marginal costs, then the patent length offered by the South could potentially be shorter and still promote FDI and result in a higher welfare in South. In the case of a linear demand and affine cost function, we find that a decrease of the marginal cost unambiguously requires offering a longer protection.

In that case, there exists a threshold level of fixed costs beyond which a decrease of the marginal cost results in a lower welfare in South. Technology changes adversely impact Southern welfare for two reasons. To induce FDI, a Southern country has to increase the length of patent protection offered to the Northern firm. While FDI is still the preferred to exports from South's welfare perspective, the extra cost of acquiring FDI diminishes the South's welfare.

References

- [1] Brander, J.A., and Spencer, B.J.,(1987) "Foreign Direct Investment with unemployment and endogenous taxes and tariffs," *Journal of International Economics* 22, 257-279.
- [2] Calton, D.C., and Perloff, J.M. (2005), *Modern Industrial Organization*, Addison Wesley, 4th Edition.
- [3] Chin, Judith C.; Grossman, Gene M., (1990) "Intellectual Property Rights and North-South Trade," in Jones, Ronald W.; Krueger, Anne O., eds.. *The Political Economy of International Trade: Essays in honor of Robert E. Baldwin*. Oxford and Cambridge, Mass.: Blackwell, 90-107.
- [4] Deardorff, Alan V (1993), "Should Patent Protection be Extended to all Developing Countries," in Stern, Robert M., ed.. *The Multilateral Trading System: Analysis and Options for Change*. Studies in International Trade Policy. Ann Arbor: University of Michigan Press, 435-48.
- [5] Diwan, Ishac, and Roderik, Dani, (1991) "Patents, Appropriate Technology, and North-South Trade" *Journal of International Economics*, 30(1-2), 27-47.
- [6] Ferrantino, Michael J. (1993), "The Effect of Intellectual Property Rights on International Trade and Investment," *Weltwirtschaftliches Archiv* 129, 300 - 331.
- [7] Fumagalli, Chiara, (2003), "On the welfare effects of competition for foreign direct investments," *European Economic Review* 47, 963-983
- [8] Glass, Amy Jocelyn and Saggi, Kamal (2001), "Innovation and Wage Effects of International Outsourcing," *European Economic Review* 45, 67-86.
- [9] Glass, Amy Jocelyn and Saggi, Kamal (2002a), "Licensing versus Direct Investment: Implications for Economic Growth," *Journal of International Economics* 56, 131-53.

- [10] Glass, Amy Jocelyn and Saggi, Kamal (2002b), "Intellectual Property Rights and Foreign Direct Investment," *Journal of International Economics* 56, 387-410.
- [11] Haufler Andreas, and Wooton, Ian, (1999) "Country Size and tax competition for foreign direct investment," *Journal of Public Economics* 71,121-139.
- [12] Lee Jeong-Yeon and Mansfield, Edwin (1996), "Intellectual Property Protection and U.S. Foreign Direct Investment", *The Review of Economics and Statistics* 78(2), 181-186.
- [13] Mattoo, Aaditya, Marcelo Olarreaga and Kamal Saggi (2004), "Mode of Foreign Entry, technology transfer and FDI policy," *Journal of Development Economics* 75, 95-111.
- [14] Taylor, M. Scott, (1993) "TRIPS, Trade and Technology Transfer," *Canadian Journal of Economics* 26(3), 625-37.
- [15] Varian, Hal R., (2002) , *Intermediate Microeconomics*, Norton, 6th Edition.
- [16] Vishwasrao, Sharmila (1994), "Intellectual Property Rights and the Mode of Technology Transfer," *Journal of Development Economics* 44(2), 381-402.
- [17] Wang, Henry and B.Z. Yang (2001), "Fixed and sunk costs revisited", *Journal of Economic Education*, 32 (2), 178-85.
- [18] Zigiadis, Kresimir (1998), "Intellectual Property Rights Violations and spillovers in North-South Trade," *European Economic Review* 42, 1779-1799.

Appendix A: Proof of Lemma 1

The minimum FDI inducing patent length is such that

$$e^{-rL_\tau(\beta)} = 1 - \frac{\pi^\tau}{\pi^{FDI}}$$

Taking the derivative with respect to β gives

$$-r \frac{\partial L_\tau(\beta)}{\partial \beta} e^{-rL_\tau(\beta)} = - \frac{\left(\frac{\partial \pi^\tau}{\partial q} \frac{dq^\tau}{d\beta} + \frac{\partial \pi^\tau}{\partial \beta} \right) \pi^{FDI} - \left(\frac{\partial \pi^{FDI}}{\partial q} \frac{dq^{FDI}}{d\beta} + \frac{\partial \pi^{FDI}}{\partial \beta} \right) \pi^\tau}{(\pi^{FDI})^2}$$

or

$$-r \frac{\partial L_\tau(\beta)}{\partial \beta} e^{-rL_\tau(\beta)} = - \frac{\left(\frac{\partial \pi^\tau}{\partial q} \frac{dq^\tau}{d\beta} + q^\tau \right) \pi^{FDI} - \left(\frac{\partial \pi^{FDI}}{\partial q} \frac{dq^{FDI}}{d\beta} + q^{FDI} \right) \pi^\tau}{(\pi^{FDI})^2}$$

At $\beta = 0$, using the envelope theorem : $\frac{\partial \pi^\tau}{\partial q} = \frac{\partial \pi^{FDI}}{\partial q} = 0$ when $\beta = 0$ and thus

$$-r \frac{\partial L_\tau(0)}{\partial \beta} e^{-rL_\tau(0)} = \frac{q_0 \pi_0^{FDI} - q_0^{FDI} \pi_0^\tau}{(\pi_0^{FDI})^2}$$

which gives

$$\frac{\partial L_\tau(0)}{\partial \beta} = \frac{e^{rL_\tau(0)}}{r} \frac{q_0^{FDI} q_0^\tau}{(\pi_0^{FDI})^2} \left(\frac{\pi_0^{FDI}}{q_0^{FDI}} - \frac{\pi_0^\tau}{q_0^\tau} \right) \quad \blacksquare \quad (19)$$

Appendix B: $\frac{\partial L_\tau(0)}{\partial \beta} > 0$

We use (8)

$$\frac{\partial L_\tau(0)}{\partial \beta} = \frac{e^{rL_\tau(0)}}{r} \frac{q_0^{FDI} q_0^\tau}{(\pi_0^{FDI})^2} \left(\frac{\pi_0^{FDI}}{q_0^{FDI}} - \frac{\pi_0^\tau}{q_0^\tau} \right) \quad (20)$$

and substitute q_τ , q^{FDI} , π^τ , π^{FDI} from (9), (11) and (10) when $\beta = 0$ and $\gamma = 0$. This gives

$$\frac{\partial L_\tau(0)}{\partial \beta} = \frac{e^{rL_\tau(0)}}{r} \frac{q_0^{FDI} q_0^\tau}{(\pi_0^{FDI})^2} \left(\frac{(q_0^{FDI})^2 - \phi}{q_0^{FDI}} - \frac{(q_0^\tau)^2 - \phi}{q_0^\tau} \right) \quad (21)$$

Let

$$h(\tau) \equiv \frac{\pi_0^\tau}{q_0^\tau} = \frac{(q_0^\tau)^2 - \phi}{q_0^\tau}$$

we have

$$\frac{\pi_0^{FDI}}{q_0^{FDI}} - \frac{\pi_0^\tau}{q_0^\tau} = h(0) - h(\tau)$$

It is straightforward to show that

$$h'(\tau) = \frac{d\left(q_0^\tau - \frac{\phi}{q_0^\tau}\right)}{d\tau} = \left(1 + \frac{\phi}{(q_0^\tau)^2}\right) \frac{dq_0^\tau}{d\tau} < 0$$

and thus $h(0) - h(\tau) < 0$ for all $\tau > 0$, which gives

$$\frac{\partial L_\tau(0)}{\partial \beta} = \frac{e^{rL_\tau(0)}}{r} \frac{q_0^{FDI} q_0^\tau}{(\pi_0^{FDI})^2} (h(0) - h(\tau)) > 0 \quad (22)$$

Appendix C: Proof of Lemma 4

Substituting w^{FDI} , w^s , $\frac{dw^{FDI}}{d\beta}$ and $\frac{\partial L_\tau(0)}{\partial \beta}$ into (16) yields

$$\begin{aligned} \frac{dW^{FDI}}{d\beta}(\beta=0) &= \frac{z}{4} \frac{(1 - e^{-rL_\tau(0)})}{r} + \frac{e^{-rL_\tau(0)}}{r} + \\ &\quad \left(\frac{z^2}{8} - \frac{z^2}{2} + \phi \right) \frac{q_0^{FDI} q_0^\tau}{(\pi_0^{FDI})^2} \left(\frac{\tau_0^{FDI}}{q_0^{FDI}} - \frac{\pi_0^\tau}{q_0^\tau} \right) \end{aligned}$$

where

$$q_0^\tau = \frac{z - \tau + \beta}{2}, \quad q_0^{FDI} = \frac{z + \beta}{2}, \quad \pi_0^\tau = \left(\frac{z}{2}\right)^2 - (\phi - \gamma) \quad \text{and} \quad \pi_0^{FDI} = (q_0^{FDI})^2 - (\phi - \gamma)$$

When $\beta = 0$, the minimum FDI inducing patent length is given by

$$e^{-rL_\tau(0)} = 1 - \frac{\pi_0^\tau}{\pi_0^{FDI}} = \frac{\tau(2z - \tau)}{4\left(\left(\frac{z}{2}\right)^2 - \phi\right)}$$

Substituting $e^{-rL_\tau(0)}$ into $\frac{dW^{FDI}}{d\beta}(\beta=0)$ gives after factorization

$$\begin{aligned} r \frac{dW^{FDI}}{d\beta}(\beta=0) &= \frac{z}{4} \left(1 - \frac{\tau(2z - \tau)}{4\left(\left(\frac{z}{2}\right)^2 - \phi\right)} \right) + \frac{z}{4} \frac{\tau(2z - \tau)}{\left(\left(\frac{z}{2}\right)^2 - \phi\right)} + \\ &\quad \left(\frac{z^2}{8} - \frac{z^2}{2} + \phi \right) \frac{z(z - \tau)}{4\left(\left(\frac{z}{2}\right)^2 - \phi\right)^2} \left(\frac{\left(\frac{z}{2}\right)^2 - \phi}{\frac{z}{2}} - \frac{\left(\frac{z - \tau}{2}\right)^2 - \phi}{\frac{z - \tau}{2}} \right) \end{aligned}$$

which after simplification yields

$$r \frac{dW^{FDI}}{d\beta}(\beta=0) = \frac{z^5 - 8z^3\phi + 16z\phi^2 + 3z^4\tau - 28z^2\tau\phi + 4z\tau^2\phi + 32\tau\phi^2}{4(-z^2 + 4\phi)^2}$$

The numerator can be written $z^5 N\left(\frac{\phi}{z^2}, \frac{\tau}{z}\right)$ where

$$N(\phi, \tau) = \left(32\frac{\tau}{z} + 16\right) \left(\frac{\phi}{z^2}\right)^2 + \left(4\left(\frac{\tau}{z}\right)^2 - 8 - 28\frac{\tau}{z}\right) \frac{\phi}{z^2} + 3\frac{\tau}{z} + 1 \blacksquare$$

Appendix D: Proof of Proposition 3

We provide an example where a lower marginal cost of production can result in a lower welfare in South. Let $\tau = \frac{1}{8}$. We have $\phi_\tau = \frac{49}{256} \approx 0.19141$ and

$$N\left(\phi, \frac{1}{8}\right) = 20\left(\phi - \frac{11}{64}\right)\left(\phi - \frac{2}{3}\right).$$

Therefore, for $\tau = \frac{1}{8}$ and all $\phi \in \left(\frac{11}{64}, \frac{49}{256}\right)$ we have $N\left(\phi, \frac{1}{8}\right) < 0$ which is equivalent to $\frac{dW^{FDI}}{d\beta}(\beta = 0) < 0$: a lower marginal cost of production implies a lower welfare in South!

When $\phi < \frac{11}{64}$ we have $\frac{dW^{FDI}}{d\beta}(\beta = 0) > 0$. It can be checked that for $\tau = \frac{1}{8}$ and $\phi \in \left(\frac{11}{64}, \frac{49}{256}\right)$, FDI is preferred to exports by South.¹⁵ $\blacksquare$

---

¹⁵Inequality (4), where $L = L_\tau(0)$, holds.