FDI and Technology Spillover under Vertical Product Differentiation*

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Abstract

This paper explores consequences of technology spillover that is accompanied by a Northern firm's FDI in the South and enhances a Southern firm's product quality. To this end, we explore an international duopoly model of vertical product differentiation in which a Northern firm and a Southern firm compete in the Southern market. By undertaking FDI, Northern firm can reduce its production costs and avoid tariff, but its advanced technology spills over to Southern firm and enhances Southern firm's product quality. We find that, under certain range of parameterizations, Northern firm strategically reduces the level of its product quality upon FDI. In such cases, the level of spillover rate that maximizes global welfare could be strictly higher than North-optimal level and strictly lower than South-optimal level. This result supports the roles played by the World Trade Organization (WTO) in reconciling North-South conflict concerning Intellectual Property Rights.

JEL classification: F12, F13, F21, L13

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1 Introduction

Foreign direct investment (FDI) induces technology spillover, which often enhances local firm's quality standards. That is, if a foreign firm builds its manufacturing plant in a less developed country, local competitors can enhance their product quality by learning the foreign firm's performance, or by employing workers with experience in the foreign firm.[1] Throughout the present paper, this phenomenon is referred to as quality-enhancing technology spillover. For example, Chery Automobile, a Chinese automaker, hired a number of engineers from Nissan-Dongfeng joint venture which was established upon Nissan's FDI in China. Technology spillover through these engineers has significantly improved Chery's car quality (Luo 2005). Similarly, the investments of U.S. software firms in Bangalore in 1984 created technological and information externalities to Indian software firms, enabled these local firms to produce softwares which meet international standard (Patibandla, Kapur and Petersen 1999, and Pack and Saggi 2006). In section 2, we present more real-world examples of quality-enhancing technology spillover.

Anticipating potential benefits of technology spillover from Northern firms (including quality-enhancing spillover), many Southern governments have actively induced FDI in industries where local firms need to learn advanced production know-how from foreign firms. In the case of Chinese automotive industry, the government imposed very high tariff rates on imports of foreign cars and induced foreign automakers to manufacture cars in China.[2] Likewise, Indian government promoted FDI in software sector by enforcing the copyright act, which has strengthened the protection of both local and foreign firms' technologies upon production in India.[3]

In their views, North countries often claim that infringement of Intellectual Property Rights (IPR) in the South, one form of spillover, has resulted in billions of dollars loss in their revenue. Recently, Australian Chamber of Commerce and Industry (2006) estimated that IPR infringements in China cost foreign firms a total of US$50 billions annually. This issue has become so important that the Trade Related Aspects of Intellectual Property Rights (TRIPS) agreement was signed in the Urugoay Round of the World Trade Organization (WTO). The agreement stated that it establishes minimum IPR protection in member

[1] In *World Investment Report*, UNCTAD (1997) argued that, Transnational Corporations (TNCs) are often more cost-efficient and produce higher quality products than domestic firms in developing countries. To survive, domestic firms need to learn or imitate production performance of TNCs. This leads to production efficiency gains in which domestic manufacturers have to offer less expensive products or improve quality to win consumers back from the TNCs.

[2] Chinese automobile industry developed quickly in late 1990s and early 2000s following investment of foreign automakers. High levels of trade barrier, evidenced by average tariff rate for complete vehicles of around 50% in 1999 and 30% in 2005 even China has become a member of WTO since 2001, have induced foreign automakers to set up production in China (Gallagher 2003, Luo 2005).

[3] With the enforcement of the copyright act, in 1989-1990 domestic firms launched about 120 new software products and foreign firms about 160 (Patibandla *et al* 1999).

countries. According to many scholars, the main purpose of TRIPS was to put a pressure on South countries to strengthen their IPR protection, creating a level playing field for both local and foreign firms upon FDI in the South (Lai and Qiu 2003, Grossman and Lai 2004, Naghavi 2007, among others). However, until recently, the implementation of this agreement has become difficult in practice with many South countries being reluctant to abide TRIPS with the fear that foreign firms would be the only beneficiaries of such strong IPR policies.[4]

Under what circumstances would a Northern firm undertake FDI in the South where quality-enhancing technology spillover is unavoidable consequence of FDI? What is the optimal quality level the Northern firm would choose for its product under FDI? Does FDI improve Southern welfare and global welfare in this context? What are the optimal level of IPR protections for the South and the world?

This paper addresses these questions by exploring an international duopoly model of vertical product differentiation, based on the standard product-line pricing framework of Mussa and Rosen (1978) and focusing on two-type consumer case. The two-type consumer approach in models of vertical product differentiation has been adopted to analyze durable good pricing (Waldman 1996, 1997), international technology transfer with quality ladders (Glass and Saggi 1998), or entry impacts on product design (Davis, Murphy and Topel 2004). In our model, a Northern firm (firm N) and a Southern firm (firm S) compete in the Southern market which consists of high-valuation and low-valuation consumers. Firm S is located in the South, while firm N can locate itself in the North (home-production) or in the South (FDI). By undertaking FDI, firm N can reduce its production costs and avoid tariff. However, firm N's technology spills over to firm S under FDI that extends the upper bound of quality level firm S can choose for its product. We find that, when the spillover rate is lower than a threshold, firm N undertakes FDI, and resulting technology spillover increases not only firm S's profitability but also Southern consumers' surplus. This is because the amount of rents captured by Southern consumers, as a result of quality competition between firms N and S, increases as firm S's product quality increases.

In this context, we find that, when firm N undertakes FDI, it may strategically reduce the level of its product quality in order to reduce the amount of technology that spills over to firm S. That is, the equilibrium level of firm N's product quality is lower under FDI than under home-production in a range of parameterizations. In reality, Northern firms often bring dated technologies to the South and use these technologies to produce goods with lower quality levels compared to similar products they produce at home. As an example, Gallagher (2003) documented that Chrysler and Ford brought with them dated technologies to China and, as a result, the quality of cars manufactured and sold in China by these firms were below that of cars they manufactured and sold in Japan or the U.S. markets. Our analysis, therefore, captures this type of real world phenomena.

Consequently, the above result leads to new policy implications. First, we demonstrate

[4] Naghavi (2007) showed an example in which South Africa refused to abide TRIPS in pharmaceutical drugs.

that, the spillover rate which maximizes global welfare can be strictly between North-optimal and South-optimal levels. In other words, the social planner, by reconciling North-South conflict concerning IPR protection in the South, can maximize global welfare. Second, we show that FDI does not necessarily improve Southern welfare. This is because when firm N decreases its product quality, net social benefits associated with the consumption of firm N's products decline and it may result in total welfare loss for the South even though Southern firm always benefits from FDI. These policy implications are unique to our framework of quality-enhancing technology spillover, and the driving force is that, firm N strategically reduces its product quality upon FDI under a range of parameterizations.

Our analysis suggests that WTO should enforce IPR protection in South countries, where the level of protection is weaker than that in North countries. However, too strong IPR protection in South countries might not be the best choice, since it could result in a loss in social welfare. The TRIPS agreement said that protection of IPR should "contribute to the promotion of technological innovation and to the transfer and dissemination of technology... in a manner conducive to social and economic welfare". On one hand, the present paper gives a support to TRIPS in this regard. On the other hand, we propose a framework under which WTO can maximize the social benefits of technology spillover that is induced by Northern firm's FDI in the South. The organization can do so by choosing the global optimal level of IPR protection for the South, rather than simply tightening IPR protection. In our model, this global optimal IPR protection level tends to fall between what demanded by the North and what often offered by the South.

Technology spillover from Northern firms to Southern firms has previously been discussed in the trade literature (see, for example, Chin and Grossman 1990). Most papers along this line, however, focused on technology spillover from Northern firms to Southern firms that decreases the later's marginal costs and this is referred to as cost-reducing technology spillover in our paper. Several authors have incorporated technology spillover that is induced by FDI in this context to study the impacts of a change in Southern IPR environment on welfare (Glass and Saggi 2002, Naghavi 2007, Helpman 1993). They demonstrated that, FDI usually improves Southern welfare.[5] However, the impacts of a change in Southern IPR policy on global welfare have not been explicitly addressed in this literature.

The paper by Nguyen (2010) was an exception, in which the author investigated global optimal IPR policy in an international Cournot duopoly model with cost-reducing spillover. Nguyen pointed out that, with cost-reducing spillover, the Northern firm always chooses the minimum level of marginal cost, regardless of whether it locates at home or in the South. This means that FDI improves both Southern welfare and global welfare thanks to the impacts of technology spillover that reduces the Southern firm's cost. Furthermore, the level

[5] Glass and Saggi (2002) considered an international duopoly model with a source firm and a FDI hosting country firm, and the host country in their model could be regarded as the South. Glass and Saggi pointed out that, unless production elsewhere is very costly, FDI improves host country's welfare. Naghavi (2007) argued that FDI always improves Southern welfare.

of spillover rate that maximizes global welfare equals to either zero (North-optimal level) or some positive value which maximizes Southern welfare (South-optimal), rather than falling in between them. Therefore, comparing between quality-enhancing and cost-reducing spillover, it is clear that the two methods yield different implications.[6]

To summarize, the present paper concentrates on new policy implications of quality-enhancing technology spillover. To this end, we construct an North-South duopoly model of vertical product differentiation with technology spillover and study the impacts of FDI induced by a change in Southern IPR policy. The paper proceeds as follows. Section 2 presents real-world examples of quality-enhancing technology spillover, followed by literature review in Section 3. The model and its equilibrium characterizations are laid out in Section 4. Section 5 studies welfare impacts of FDI and discuss new policy implications of quality-enhancing technology spillover. Section 6 offers some concluding remarks.

2 Quality-enhancing technology spillover: Examples

UNCTAD (2000) identified various channels for technology spillover from foreign to domestic firms to take place, which include (i) labor mobility between foreign firms and local firms, and (ii) proximity between foreign firms and local firms which leads to upgrading of technological level in the host country.[7] UNCTAD also argued that, multinational firms' entry leads to an increase in product quality, variety and innovation in host economies, but little evidence that it leads to lower prices. Along this line, in this section, we consider real world cases of quality-enhancing technology spillover that is induced by FDI.

Let us first take Bangladesh garment industry as an example. Rhee (1990) documented that, only a few years after collaboration between Desh (a Bangladesh firm) and Daewoo (a Korean firm) in 1980 under which 130 workers in Desh were trained to manufacture high quality clothing products, 115 workers have left the company to either work for other competing firms or run their own business.[8] As a result, not only Desh could produce high

[6]Glass and Saggi (1998) examined a quality ladders product cycle model with high-type and low-type consumers. In their model, the North has state-of-the-art technology which is one or two level above the technology base of the South. A Northern multinational undertakes FDI in the South by assumption and she brings state-of-the-art technology to the South if the gap in quality between two regions is one level and second-best technology otherwise. If Northern firm brings the best technology to the South, a Southern firm imitates this technology to produce products targeting the low-end market. Glass and Saggi called this "high quality FDI" outcome, which arises as a result of the South's effort to improve its technology base.

[7]It also defined FDI which leads to strong links to the domestic economy, such as that associated with advanced technology and/or spillover effects, as "high quality" FDI. See also a discussion on international technology diffusion in Keller (2004).

[8]Rhee pointed out that, prior to 1980, the clothing industry in Bangladesh was outdated and could not export to the world market. In 1979, Desh signed an agreement with Daewoo, which was then a leading firm in the world for clothing products, under which Daewoo invested in technical training, plant start-up, and marketing activities for Desh. Desh then produced clothing products under supervision and consultancy

quality clothes but firms who benefited from these workers were also capable of manufacturing high quality clothing products. In its discussion on this famous technology spillover example, UNCTAD (1992) argued that, these 115 workers were major agents for imparting the skills throughout the whole garment industry in Bangladesh.[9]

Quality-enhancing technology spillover from foreign to local firms has not only been observed in sectors that are labor intensive such as garment and textile, but also in other sectors such as information technology and manufacturing. Patibandla *et al* (1999) documented that, the investment of Texas Instruments in Bangalore in 1984 and other U.S. software firms in late 1980s created significant technological and information externalities to Indian firms. As such, this gave the Indian firms access to the trend in the software market in the world and enabled them to move to higher-end market (see also Pack and Saggi 2006).

Recently, as pointed out by various authors, Chinese car manufacturers have learned from foreign competitors how to manufacture high quality cars and/or improve the quality of cars to be sold in the local market upon the competitors' FDI in China (Gallagher 2003, Luo 2005).[10] Specifically, employing workers with experience from foreign firms was the practice used by many Chinese automakers. For instance, Chery Automobile, during its early development time, was hiring engineers from Nissan-Dongfeng joint venture which was set up upon Nissan's investment in China, to develop new products (Luo 2005). This is a typical example for what has often been observed in Chinese automobile industry that, quality of cars made by Chinese manufacturers has increased sharply since they learned from more advanced foreign automakers upon their FDI in China. The 2007 survey of J.D. Power in China's automobile market indicated that the average number of problems per 100 vehicles produced by local firms in China was 368, comparing to the average of 800 in 2000.

What are the strategies for multinationals to deal with quality-enhancing technology spillover upon FDI? It was observed that, in many cases, Northern firms strategically brought dated technologies to the South to produce goods with lower quality levels comparing to similar products they produce at home factories. As such, they could decrease the amount of technologies that spillover to local competitors. Gallagher (2003) showed

from Daewoo. Daewoo trained 130 Desh workers in Korea in 7 months which enabled them to produce high quality products, and later sent a team to train other workers in Desh factory in 1980. Consequently, Desh successfully produced high quality clothing products and exported them under Daewoo's network, where Desh also learned marketing skills, quality upgrading from Daewoo. Desh experienced significant increase in its product quality: its value per piece increased from $1.3 in 1980 to $2.3 in 1986.

[9]Along this line, UNCTAD (1992) also documented technology spillover from Yamaha-Escorts collaboration in India to other local firms through the channel of labor mobility. Similarly, Thompson (2003) found that labor mobility as a channel for quality-enhancing technology spillover from foreign (mainly Hong Kong firms) to local firms has also been observed in garment industry in China. His survey showed that, local firms have attempted to copy Hong Kong firms' production processes and techniques, learn their managerial practices, and particularly hire Hong Kong firms' employees. In his survey, about 13,000 workers per annum left Hong Kong firms and many of these workers later worked for local firms.

[10]China only allows foreign automakers to form joint venture with local firms but not wholly owned foreign company, as the government wants foreign firms to share technologies with local partners (Qiu 2005).

that Chrysler and Ford brought dated technologies to China's to produce cars which do not meet quality requirement of Japan, the United States or Europe and thus can only be sold in China's market. Ernst & Young (2005) also documented that, Volkswagen initially brought obsolete models along with factories and engines needed to build them from Europe to China. Similarly, Japanese firms often brought technologies at their mature period to Malaysian electronics industry (Praussello 2005). As these examples reveal, choosing low quality level for their products is an usual practice that many Northern firms use to cope with quality-enhancing technology spillover in the South that is induced by FDI.

In summary, Northern firms' production in the South often created positive externalities to local firms and help improve local firms' product quality. How does this affect optimal location choice of Northern firms and North/South/global welfare? This paper considers a theoretical model that captures these phenomena, and explores policy discussions of quality-enhancing technology spillover.

3 Relationships to the literature

Technology spillover from Northern firms to Southern firms upon FDI usually improves the performance of the later and intensifies competition between them (UNCTAD, 1997). Several papers have theoretically addressed this issue in international trade and FDI literature under cost-reducing technology spillover frameworks (Naghavi 2007, Glass and Saggi 2002, and Helpman 1993). By surveying these papers, this section outlines the key differences and similarities between cost-reducing and quality-enhancing types of technology spillover.[11]

In a close set up to the model we present in this paper, Naghavi (2007) considered a cost-reducing technology spillover model in which a Northern firm can choose to either export or undertake FDI in a Southern country which has a potential competitor.[12] The game has five stages, starting with South government choosing its IPR policy, represented by spillover rates. In second stage, Northern firm chooses its mode of entry. If it chooses export, it will be the monopolist in the Southern market and the game proceeds to third stage where South government chooses its optimal tariff rate. If Northern firm chooses FDI instead, a Southern

[11] Many authors have empirically investigated technology spillover from foreign firms to local firms upon FDI, where technology spillover is often measured by the change in local firms' productivity. The findings along this line are mixed. For instance, Aitken and Harrison (1999) found negative impact of FDI on local firms' productivity using data from 4,000 Venezuelan firms; Djankov and Hoekman (2000) found negative spillover in Czech Republic; while Haddad and Harrison (1993) found positive relationship between FDI and productivity in manufacturing sector in Morocco. See also Carluccio and Fally (2007) for a survey.

[12] Helpman (1993) focused on the impacts of tightening Southern IPR regime on Northern and Southern welfare in a general equilibrium model where Northern firms innovate while Southern firms imitate. He showed that tightening Southern IPR protection always hurts the South. When imitation rate is low, tightening Southern IPR protection hurts the North if Northern firms are not allowed to undertake FDI, and it benefits the North if Northern firms are allowed to undertake FDI in the South. However, technology imitation is not induced by FDI in his framework, which is different from ours.

firm could emerge and benefits from technology spillover from Northern firm. In forth stage, Northern firm chooses the level of R&D investment. Finally, production and competition take place and the game closes.

With the above framework, Naghavi found that, stringent IPR regime in the South (low level of spillover rate) induces the Northern firm to undertake FDI. Resulting FDI improves Southern welfare whenever Northern firm's FDI induces entry of the Southern firm, that is, when duopoly is the prevailing form of competition. Hence, the South government can maximize Southern welfare by choosing the highest possible value of spillover rate which still induces Northern firm to undertake FDI. These results are, in general, different from the findings of the present paper. The differences come from the fact that Naghavi investigated cost-reducing technology spillover while we examine quality-enhancing technology spillover and the mechanism under these two approaches are different. Furthermore, we discuss the implications on both Southern welfare and global welfare of quality-enhancing technology spillover, while Naghavi mainly focused on Southern welfare.

Glass and Saggi (2002) also developed a cost-reducing technology spillover model in which a superior-technology source firm chooses to produce elsewhere (such as home production) or undertake FDI in a competing host firm's country. By undertaking FDI, source firm can save production cost but its workers may switch to work for host firm and decrease host firm's marginal cost from Θ to $\theta(< \Theta)$.[13] To prevent this technology transfer, source firm can pay a wage premium to retain workers. Interestingly, Glass and Saggi found that, upon FDI, the more cost reduction host firm could enjoy by hiring workers from the source firm, the more incentive source firm has toward making technology transfer available. That is, when θ is under a threshold value θ_S, the equilibrium with technology transfer will occur. The driving force is that, high technology diffusion (low θ) increases the level of wage host firm is willing to offer workers from source firm. This increases wage premium source firm needs to incur to retain workers, thus reduces its incentive to prevent technology transfer. Glass and Saggi also found that, unless production elsewhere is very costly, FDI improves host country's welfare.

Similar to Naghavi (2007), the model of Glass and Saggi (2002) can explain why in many cases, for Southern countries to attract FDI, it is better to strengthen their IPR protection for foreign firms upon production in the South. However, since these authors have not considered the impacts of technology spillover on global welfare, the following question remains unexplored: *Which level of IPR protection in the South would maximize global welfare?* In this paper, by developing a new international duopoly model with quality-enhancing technology spillover, we show that the social planner could choose a spillover rate that lies between the level desired by the North and that desired by the South to maximize global welfare. The necessary condition for this result to hold is that, Northern firm chooses lower quality level for its product under FDI than under home production.

[13]In their analysis, technology can be transferred at no cost to the local firm, so it can also be categorized as technology spillover.

Does this result arise in a cost-reducing technology spillover framework? Nguyen (2010) considered an augmented cost-reducing technology spillover model with similar structure to the model we present in this paper. Nguyen found that, the Northern firm chooses its minimum marginal cost level for its product in both FDI and home-production equilibrium, and consequently FDI improves both South and global welfare. At the same time, the social planner (such as WTO) should either support the North by choosing a zero spillover, or support the South by choosing some positive spillover level to maximize global welfare, rather than choosing something in between. It is worth pointing that Nguyen's augmented cost-reducing technology spillover model without R&D process also confirms that most results of Naghavi (2007) are robust. Especially, FDI induced by strengthening of IPR protection in the South always benefits the South.[14] In other words, the policy implications of quality-enhancing technology spillover of the present paper are unique.

The issue of whether strengthening Southern IPR regime is welfare beneficial for the world has received considerable attention in the international IPR literature, where FDI was absent. Diwan and Rodrik (1991) considered a model in which some Northern firms innovate while some Northern firms and Southern firms imitate. Diwan and Rodrik pointed out that, a social planner who values North welfare and South welfare equally should choose same level of IPR protection in both North and South. If she values the South more than the North then IPR should be protected more strongly in the North than in the South.[15] Lai and Qiu (2003) explored a model where firms in both the North and the South can innovate, and IPR protection in each region is represented by the length of product cycles. Assuming this length is higher in the North than in the South in a pre-TRIPS regime, Lai and Qiu showed that, to maximize global welfare under post-TRIPS regime, the South should adopt a stronger IPR protection compared to that in the North under pre-TRIPS regime. Since this benefits the North, the North should open its market for other competitive products as a compensation for the South.[16]

Finally, in their seminal contribution to the cost-reducing technology spillover literature, Chin and Grossman (1990) developed a Cournot duopoly model in which a Northern firm competes with a Southern firm in an integrated world market. They assumed that both firms

[14]Meanwhile, a number of authors have discussed quality competition in the context of North-South trade. For instance, Das and Donnenfeld (1989) analyzed an international duopoly model of vertical product differentiation in which two firms in different countries compete against each other by producing products with different qualities. They showed that trade policy influences the firms's choice of equilibrium quality levels (see also Falvey 1979, Das and Donnenfeld 1987; Boccard and Wauthy 2005; Toshimitsu 2005; and Gonzalez and Viaene 2005). In these papers, however, neither the Northern firm's choice of modes of entry into Southern market, nor technology spillover have been examined.

[15]Deardorff (1992) studied the impact of extending patent protection from innovating country to another country. He showed that, if the size of the innovating country is large, this spreads of patent protection benefits innovating country, harms the other country and the total impacts on global welfare is negative.

[16]With a closely related framework, Grossman and Lai (2004) demonstrated that, if the North's human capital endowment is higher than the South and its market is larger, it always has incentive to provide stronger IPR than that in the South.

have access to a standard technology, and only Northern firm can invest in R&D in order to lower its marginal cost. If Southern IPR regime is weak, Southern firm can copy Northern firm's technology. Zigic (1998) extended this framework with a continuous spillover rate that represents the strength of Southern IPR policy.[17] Under this type of set up, previous authors found that stringent Southern IPR regime always benefits the North, while it has ambiguous impacts on Southern welfare. However, these previous framework did not capture the case technology spillover is induced by FDI, thus their focus are different from ours.

As pointed out by Helpman (1993), FDI is crucial in determining the impacts of a change in Southern IPR environment on welfare. In light of this argument, we show that, when quality-enhancing technology spillover is unavoidable consequence of FDI, the quality level Northern firm chooses for its product in the equilibrium will determine how a change in IPR environment affects welfare. Specifically, if Northern firm chooses the same level of quality for its product that the social planner would choose upon FDI, FDI necessarily improves Southern welfare and global welfare. In this case, it follows that the social planner and South government would choose the same IPR policy, the loosest one that still induces FDI. If the equilibrium quality level Northern firm chooses for its product is lower than that the social planner would choose, then FDI could hurt the South, benefits the world, making the optimal IPR policy for the South be different from that of the social planner. In this later case, it is possible that the level of spillover rate that maximizes global welfare falls between zero, which maximizes Northern welfare and some positive value, which maximizes Southern welfare. This result is unique to our framework of vertical product differentiation with quality-enhancing technology spillover.

4 Technology Spillover under Vertical Product Differentiation

In this section, we first present a model of vertical product differentiation and technology spillovers under international duopoly, where we adopt standard framework of product-line pricing (Mussa and Rosen 1978) and focus on two-type consumer case (Davis *et al* 2004, Glass and Saggi 1998, Waldman 1996, 1997). We then characterize Subgame Perfect Nash Equilibria (SPNEs) of the model.

[17] Zigic (2000) augmented this cost-reducing spillover framework focusing on Northern market only to discuss optimal trade policy. He showed that, a positive tariff on Southern firm's product is better for Northern firm, but it has ambiguous effects on consumers. Kim and Lapan (2008) considered spillover from a Northern firm to many firms in different South countries and found that, in a non-cooperative equilibrium, all South countries choose loose IPR regime, while collectively, they tend to protect Northern technology.

4.1 Model

We consider an international duopoly model of vertical product differentiation in which a Northern firm (firm N) and a Southern firm (firm S) compete in the South market. Firm S is located in the South, while firm N can locate itself in the North (home-production, denoted HP) or in the South (FDI). Let q_k (≥ 0, $k = N$, S) denote the quality of firm k's product.

On the demand side, there are two groups of consumers, denoted H (type H consumers) and L (type L consumers), where group j consists of a continuum of nonatomic consumers of mass m_j, $j = H$, L. A representative individual in group j consumes either zero units or one unit of the products, and derives a gross benefit of $v_j q_k$ from the consumption of one unit of quality q_k product, where $v_H > v_L > 0$.

We assume that, firm N can choose any quality level for its product, q_N. Meanwhile, firm S, using less advanced technology, can only choose quality level for its product up to a certain upper bound level, which differs between FDI and HP. Specifically, when firm N locates itself in the North, the maximum possible quality level firm S can choose is given by $\bar{q}_S$. When firm N undertakes FDI, technology spillover extends this upper bound quality level and the maximum quality level firm S can choose for its product is given by $\hat{q}_S(q_N) = max(\bar{q}_S + \theta(q_N - \bar{q}_S), \bar{q}_S)$, $\theta \in [0, 1)$.[18] In our model, θ captures the degree of technology spillover from firm N to firm S, which can only happen upon firm N's FDI in the South. Hence, when firm N undertakes FDI and chooses $q_N > \bar{q}_S$, higher θ enables firm S to choose higher quality level.

Each firm k can produce product of quality q_k at constant marginal cost $c_k(q_k)$ and zero fixed costs. Firm S incurs a marginal cost of $c_S(q_S) = c(q_S)$, and firm N incurs a marginal cost of $c_N(q_N) = c(q_N) + w$ under HP and $c_N(q_N) = c(q_N)$ under FDI, where w captures Northern country's cost disadvantages (eg., higher labor costs) and $c(\cdot)$ is a twice-continuously differentiable, convex cost function with $c'(\cdot) > 0$ and $c''(\cdot) > 0$. To derive closed form solutions, we assume that $c(q_k) = \frac{1}{2}q_k^2$ holds. A specific tariff, t (≥ 0) is imposed on imports of firm N's product.

We consider a three-stage game, described below.

[**Stage 1**] Firm N determines whether to locate itself in the North (HP) or in the South (FDI).

[**Stage 2**] Firm N chooses quality level q_N for its product. Having observed q_N, firm S chooses quality level q_S, subject to $q_S \leq \hat{q}_S(q_N)$, for its product.

[**Stage 3**] Firm N and firm S simultaneously set prices for their own product, and then consumers make purchase decisions.

Notice that the game described above has two stage 2 subgames, one is HP subgame in

[18] In other words, we assume firm S has some limitation concerning quality while firm N can choose any quality level.

which firm N locates itself in the North, while the other is FDI subgame in which firm N locates itself in the South.

4.2 Equilibrium characterization

Throughout the analysis in this paper, we assume that $\bar{q}_S < v_L$ holds. This assumption helps us to reduce a number of cases to be considered and focus on deriving meaningful economic implications of technology spillover. If $\bar{q}_S \geq v_L$, then $\bar{q}_S$ does not impose a binding constraint on firm S's choice of quality level, since firm S can choose its profit-maximizing level of quality v_L without technology spillover as is shown later in this section.

Let us now derive Subgame Perfect Nash Equilibria of the model described above. We focus on a range of parameterizations in which firm N sells its product to all type H consumers and firm S sells its product to all type L consumers in the equilibrium. Following Davis *et al* (2004) and Glass and Saggi (1998), we define this type of equilibrium as a *separating equilibrium.* Note that all proofs are presented in the Appendix.

Proposition 1. *There exists an unique value $\tilde{m}_H > 0$ such that the game has a separating equilibrium if and only if $m_H > \tilde{m}_H$. Furthermore, if $m_H > \tilde{m}_H$, the separating equilibrium is the unique equilibrium of the game.*

To understand the logic behind Proposition 1, let us first consider the case in which the spillover rate θ is equal to zero, so that technology does not spillover from firm N to firm S even when firm N chooses to locate itself in the South. In this case, firm N's optimal choice at Stage 1 is to locate itself in the South to reduce the production cost and avoid the tariff.

Suppose that the game has a separating equilibrium when $\theta = 0$. In the equilibrium, firm N sells its product with quality q_N at the price of p_N to m_H type H consumers, while firm S sells its product with quality q_S at the price of p_S to m_L type L consumers. We find that

$$p_N = v_H q_N - (v_H - v_L) q_S, \tag{1}$$

$$p_S = v_L q_S, \tag{2}$$

where $q_N > q_S$.[19] Firm S extracts all surplus from type L consumers by charging $p_S = v_L q_S$. If a type H consumer purchases firm S's product at p_S, the consumer's net benefit is $v_H q_S - p_S = (v_H - v_L) q_S$. Then, in order for firm N to sell its product to type H consumers, it must leave the same amount of surplus, $(v_H - v_L) q_S$, to be captured by the consumers, and

[19] Market separating constraints are: $v_H q_N - p_N \geq v_H q_S - p_S \rightarrow p_N - p_S \leq v_H(q_N - q_S)$ and $v_L q_S - p_S \geq v_L q_N - p_N \rightarrow p_N - p_S \geq v_L(q_N - q_S)$. Combining these and given one constraint must hold with strict inequality, we have $v_L(q_N - q_S) < v_H(q_N - q_S) \rightarrow q_N > q_S$.

hence $p_N = v_H q_N - (v_H - v_L)q_S$. Then, the equilibrium profits of firms N and S, denoted respectively $\pi_N(q_N)$ and $\pi_S(q_S)$, are

$$\pi_N(q_N) = m_H[p_N - c(q_N)] = m_H[v_H q_N - (v_H - v_L)q_S - \frac{1}{2}q_N^2], \tag{3}$$

$$\pi_S(q_S) = m_L[p_S - c(q_S)] = m_L[v_L q_S - \frac{1}{2}q_S^2]. \tag{4}$$

At stage 2, firm N chooses $q_N = v_H$ that maximizes $\pi_N(q_N)$, while firm S chooses $q_S = min\{v_L, \bar{q}_S\}$ that maximizes $\pi_S(q_S)$ subject to $q_S \leq \hat{q}_S(q_N)$. Note that if $\theta = 0$ then $\hat{q}_S(q_N) = \bar{q}_S$, so that firm S chooses $q_S = \bar{q}_S$ in this case, even though $q_S = v_L$ is its profit maximizing level of quality.

Proposition 1 tells us that the number of type H consumers, m_H, must be greater than a threshold value $\tilde{m}_H$ for the game to have a separating equilibrium. This is because, if m_H is lower than the threshold, ignoring type L consumers is no longer firm N's optimal choice, and firm N is strictly better-off by selling its product to both types of consumers.

In the case of $\theta > 0$, the positive spillover rate can negatively affect firm N's profitability. The maximum possible quality firm S can choose is $q_S = \bar{q}_S$ without technology spillover, while firm S's profit-maximizing level of quality is $q_S = v_L > \bar{q}_S$. An increase in θ mitigates this constraint, and hence increases the equilibrium level of firm S's quality. This in turn increases the amount of surplus, $(v_H - v_L)q_S$, that firm N must offer to type H consumers to ensure they purchase firm N's product, resulting in the reduction of firm N's equilibrium profit.

Firm N continues to undertake FDI when the value of θ is relatively small, but may switch to home-production when θ becomes higher. In any case, Proposition 1 again tells us that m_H must be greater than a threshold for the game to have a separating equilibrium, because, otherwise, firm N will be strictly better-off by selling its product to both types of consumers.

Next, Proposition 2 tells us that, under $m_H > \tilde{m}_H$, the unique equilibrium of the game is an FDI equilibrium if θ is relatively small, and it is an HP equilibrium otherwise.

Proposition 2. *Suppose $m_H > \tilde{m}_H$. There exist a value $\theta^* \in (0, 1]$ such that the equilibrium of the game is an FDI equilibrium if $\theta \leq \theta^*$, and it is an HP equilibrium if $\theta > \theta^*$. Furthermore, there exists a value $\Psi \geq 0$ such that $\theta^* (< 1)$ is strictly increasing in t if $t + w < \Psi$, and $\theta^* = 1$ otherwise.*

As mentioned above, firm N chooses to undertake FDI if $\theta = 0$. An increase in θ reduces firm N's profitability because higher rate of technology spillover increases the equilibrium quality of firm S's product. Note that firm N's disadvantage of home-production is captured by $t + w$. Proposition 2 tells us that if the disadvantage of home-production is small enough, there exists a threshold $\theta^* < 1$ such that firm N switches from FDI to home-production if

θ becomes greater than θ^*. In this case, higher tariff increases θ^* because disadvantage of home-production is higher, so that firm N has less incentive to switch from FDI to HP. On the other hand, if the disadvantage is relatively large, firm N undertakes FDI for all $\theta \in [0, 1)$ (Proposition 2 captures this case by setting $\theta^* = 1$ if $t + w \geq \Psi$ holds.)

Finally, Proposition 3 below characterizes the level of product quality that firm N chooses in the equilibrium.

Proposition 3. *Suppose $m_H > \tilde{m}_H$. There exists a threshold $\hat{\theta}$, $\hat{\theta} \in (0, \theta^*]$, such that, in the equilibrium of the game firm N chooses $q_N^* = (1-\theta)v_H + \theta v_L$ $(< v_H)$ if $\theta \leq \hat{\theta}$ and $q_N^* = v_H$ if $\theta > \hat{\theta}$.*

When firm N's product is consumed by type H consumers, $q_N = v_H$ maximizes the net social benefit associated with the consumption of firm N's product.[20] If the spillover rate θ is high enough satisfying $\theta > \theta^*$, then firm N chooses home-production to avoid technology spillover. In this case, firm N chooses the socially optimal quality level $q_N^* = v_H$, which maximizes its profit $m_H[v_H q_N - (v_H - v_L)\bar{q}_S - \frac{1}{2}q_N^2 - (w + t)]$. If $\theta \leq \theta^*$, firm N undertakes FDI to save production cost and avoid tariff, but FDI reduces firm N's profitability by inducing technology spillover. Proposition 3 tells us that, in order to mitigate this problem, firm N may choose a lower level of quality to reduce the amount of technology that spills over from firm N to firm S. In other words, FDI may reduce the quality of firm N's product from the socially optimal level $q_N^* = v_H$ to a suboptimal level $q_N^* = (1-\theta)v_H + \theta v_L \leq v_H$. This result leads to new policy implications of our analysis, as we elaborate in subsequent sections.

Proposition 3 says that FDI induces firm N to choose a socially suboptimal level of quality if the spillover rate θ is relatively small. This result can be explained as follows. Let us consider the equilibrium of the FDI subgame. Given firm N's quality choice q_N, firm S chooses q_S to maximize $\pi_S(q_S) = m_L[v_L q_S - \frac{1}{2}q_S^2]$ subject to $q_S \leq \hat{q}_S(q_N) \equiv max(\bar{q}_S + \theta(q_N - \bar{q}_S), \bar{q}_S)$. Let $q_S^*(q_N)$ denote firm S's best response function. Anticipating firm S's response to q_N, firm N chooses q_N to maximize its profit in the subsequent equilibrium, which is

$$\pi_N(q_N) \equiv m_H[v_H q_N - (v_H - v_L)q_S^*(q_N) - \frac{1}{2}q_N^2]. \tag{5}$$

We find that the candidates for the profit-maximizing level of firm N's product quality are $q_N = v_H$ and $q_N = (1-\theta)v_H + \theta v_L$. If the level of q_N does not impose a binding constraint on firm S's choice of q_S in the equilibrium, firm N chooses $q_N^* = v_H$ that maximizes $[v_H q_N - \frac{1}{2}q_N^2]$. In contrast, if the level of q_N does impose a binding constraint in the equilibrium, firm N chooses $q_N^* = (1-\theta)v_H + \theta v_L$, which is lower than v_H, to reduce the amount of technology spillover from firm N to firm S.

[20] The net social benefit is $m_H[v_H q_N - \frac{1}{2}q_N^2]$ in the FDI subgame and $m_H[v_H q_N - \frac{1}{2}q_N^2 - w]$ in the HP subgame.

Note that, without the constraint $q_S \leq \hat{q}_S(q_N)$, firm S would choose $q_S = v_L$ to maximize its profit $m_L[v_L q_S - \frac{1}{2}q_S^2]$. If the spillover rate θ is large enough so that $v_L < \hat{q}_S((1-\theta)v_H + \theta v_L)$ $\Leftrightarrow \theta > \frac{v_L - \bar{q}_S}{v_H - v_L}$ holds, the constraint is not binding at both candidates $q_N = (1-\theta)v_H + \theta v_L$ and $q_N = v_H$. In such cases, firm N chooses $q_N^* = v_H$ in the equilibrium. In contrast, if θ is small enough so that $v_L \geq \hat{q}_S(v_H) \Leftrightarrow \theta \leq \frac{v_L - \bar{q}_S}{v_H - \bar{q}_S}$, the constraint is binding at both candidates $q_N = (1-\theta)v_H + \theta v_L$ and $q_N = v_H$. In such cases, firm N chooses $q_N^* = (1-\theta)v_H + \theta v_L$ in the equilibrium. We find that there exists a unique value $\dot{\theta} \in (0,1)$ such that, in the equilibrium of the FDI subgame, firm N chooses $q_N^* = v_H$ if $\theta > \dot{\theta}$ and $q_N^* = (1-\theta)v_H + \theta v_L$ if $\theta \leq \dot{\theta}$. Finally, we define $\hat{\theta} \equiv min\{\dot{\theta}, \theta^*\}$ in order to state this result in terms of the equilibrium of the entire game, leading to Proposition 3.

In reality, when Northern firms undertake FDI in Southern countries, they often choose products with lower quality to reduce the amount of technology that spills over to local firms, as examples presented in Section 2 illustrate. Proposition 3 provides an explanation for this real world observations. This is one of the important findings of our analysis.

Lemma 1. *$\hat{\theta} < \theta^* = 1$ if $t + w \geq \Psi$, and $\hat{\theta} = \theta^* < 1$ otherwise.*

Recall from Proposition 2 that, when $t + w \geq \Psi$ then $\theta^* = 1$ which implies that firm N undertakes FDI for all $\theta \in [0,1)$. Lemma 1 says that $\hat{\theta} < \theta^*$ holds in this case. This means that if $\theta \in [0, \hat{\theta}]$ then $q_N^* = (1-\theta)v_H + \theta v_L \leq v_H$ and hence, $q_S^* = \hat{q}_S(q_N^*) < v_L$ (see Proposition 3). In order to impose a binding constraint on firm S's quality choice, firm N chooses a quality level below v_H in the equilibrium of the game. If $\theta \in (\hat{\theta}, 1)$ then firm N does not attempt to impose a binding constraint on firm S's quality, which leads to $q_N^* = v_H$ and $q_S^* = v_L$.

On the other hand, if $t + w < \Psi$ then $\theta^* < 1$ by Proposition 2. Lemma 1 says that $\hat{\theta} = \theta^*$ in this case. This means that if $\theta \in [0, \theta^*]$ then firm N undertakes FDI and chooses $q_N^* = (1-\theta)v_H + \theta v_L \leq v_H$ followed by firm S's choice of $q_S^* = \hat{q}_S(q_N^*) < v_L$, while if $\theta \in (\theta^*, 1)$ then firm N undertakes HP and $q_N^* = v_H$ and $q_S^* = \bar{q}_S$. To understand why $\hat{\theta} = \theta^*$ holds in this case, suppose $\hat{\theta} < \theta^*$. Then, for all $\theta \in (\hat{\theta}, \theta^*]$, the equilibrium of the game is an FDI equilibrium with $q_N^* = v_H$, and $q_S^* = v_L$. But since firm N chooses FDI over HP for all $\theta \in (\hat{\theta}, \theta^*]$, it also chooses FDI for all $\theta \in (\theta^*, 1)$, which leads to $\theta^* = 1$, a contradiction. Therefore, $\hat{\theta} = \theta^*$ must hold.

In summary, in this section we have shown that the game has a separating equilibrium if and only if the population of type H consumers is large enough. The separating equilibrium is the unique equilibrium, which is an FDI equilibrium if the spillover rate θ is low enough and a HP equilibrium otherwise. Importantly, FDI induces the equilibrium quality of firm N's product from the socially optimal level v_H to a suboptimal level $(1-\theta)v_H + \theta v_L$ under a range of parameterizations. This is because, by reducing its product quality, firm N can reduce the amount of technology that spills over to firm S, and this in turn increases firm N's profitability.

5 Welfare consequences and policy implications

This section starts to explore welfare impacts of FDI induced by a stringent IPR policy in the South. In our set up, stringent IPR policy is represented by spillover rate decrease. We then relate our findings to the literature and discuss new policy implications of quality-enhancing technology spillover.

5.1 Welfare consequences of FDI

We first undertake comparative statics concerning technology spillover, θ, and focus on parameterizations under which the equilibrium of the game is a separating equilibrium for all $\theta \in [0, 1)$.[21] Recall from Proposition 2 that, the equilibrium of the game is an FDI equilibrium for all $\theta \in [0, \theta^*]$, and it is an HP equilibrium for all $\theta \in (\theta^*, 1)$. In the later case, a change in θ does not affect welfare since technology does not spill over in the HP equilibrium. Hence, we will focus our analysis on welfare impacts of a change in $\theta \in [0, \theta^*]$ (within FDI equilibrium) and of a decrease in θ from $\theta' > \theta^*$ to θ^* (comparing FDI equilibrium and HP equilibrium). This analysis helps us to understand if Northern firm's FDI, induced by low levels of spillover, is better for the South and the world, and to identify the optimal rates of spillover for the South and the world.

Let us denote by $\pi_N(\theta)$ the level of profit for Northern firm, and by $\pi_S(\theta)$ the level of profit for Southern firm. Also, $CS(\theta)$, $WS(\theta)$ and $WW(\theta)$ respectively represent consumer surplus, Southern welfare and global welfare. We find that, there exists an unique, positive value of spillover rate, $\tilde{\theta}$, that maximizes $WW(\theta)$ for all $\theta \in [0, \hat{\theta}]$.

Lemma 2. *There exists a value $\tilde{\theta} \in (0, \hat{\theta}]$ such that $WW(\theta)$ is strictly increasing in θ for all $\theta \in [0, \tilde{\theta}]$ and it is strictly decreasing in θ for all $\theta \in [\tilde{\theta}, \hat{\theta}]$, where $\tilde{\theta} < \hat{\theta}$ holds under a range of parameterizations.*

When $\theta \in [0, \hat{\theta}]$, firm N undertakes FDI (recall that $\hat{\theta} \leq \theta^*$) and it imposes a binding constraint on firm S's quality choice by Proposition 3. We find that, an increase in θ when $\theta \in [0, \hat{\theta})$ decreases firm N's equilibrium quality level, $q_N^* = (1-\theta)v_H + \theta v_L$, but increases firm S's equilibrium quality level, $q_S^* = \bar{q}_S + \theta(q_N^* - \bar{q}_S)$. This is because the marginal impacts of a direct increase in spillover rate on firm S's equilibrium quality level outweighs the (negative) impacts of a narrower quality gap between q_N^* and $\bar{q}_S$.

Consider the global welfare function. In our set up, global welfare is the sum of net social benefits associated with the consumption of firm N's products, $v_H q_N - \frac{{q_N}^2}{2}$, and of firm S's products, $v_L q_S - \frac{{q_S}^2}{2}$, thus global welfare in the equilibrium of the game is given by $[v_H q_N^* - \frac{{q_N^*}^2}{2} + v_L q_S^* - \frac{{q_S^*}^2}{2}]$. It is easy to verify that $q_N^* = v_H$ and $q_S^* = v_L$ are global welfare-maximizing levels of firm N's quality and firm S's quality in the equilibrium of the

[21] The condition can be written as $m_H > \lim_{\theta \to \theta^*} \tilde{m}_H$, see the proof of Proposition 1.

game, respectively. Based on these specifications, a decrease in $q_N^*(< v_H)$, induced by an increase in $\theta \in [0, \hat{\theta})$, reduces global welfare. In contrast, since higher spillover induces firm S to choose a higher quality level in the equilibrium (note that $q_S^* < v_L$), it improves global welfare. Interestingly, we find that, the former effect overshadows the later for all $\theta \in [\tilde{\theta}, \hat{\theta})$, while the later effect dominates for all $\theta \in [0, \tilde{\theta}]$, where $0 < \tilde{\theta} \leq \hat{\theta}$ holds. In other words, for all $\theta \in [0, \hat{\theta}]$, global welfare function increases in θ when θ is relatively small, and it decreases in θ when θ is relatively high. This leads to Lemma 2.

With the help of Lemma 2, we can now investigate the impacts of a change in $\theta \in [0, 1)$ on each firm's profitability, consumer surplus, Southern welfare and global welfare. Let us first explore the case of $t + w \geq \Psi$, in which $\theta^* = 1$ by Proposition 2 and firm N undertakes FDI for all θ. The following proposition suggests that a high enough level of spillover would maximize the benefits of firm S and Southern consumers.

Proposition 4. *Suppose $t + w \geq \Psi$ so that $\hat{\theta} < \theta^* = 1$. Then,*
(i) $\pi_N(\theta)$ is strictly decreasing in θ for all $\theta \in [0, \hat{\theta}]$ and $\pi_N(\theta)|_{\theta \in (\hat{\theta}, 1)} = \pi_N(\hat{\theta})$, and
(ii) $\pi_S(\theta)$ and $CS(\theta)$ are strictly increasing in θ for all $\theta \in [0, \hat{\theta}]$, and $\pi_S(\theta)|_{\theta \in (\hat{\theta}, 1)} > \pi_S(\hat{\theta})$ and $CS(\theta)|_{\theta \in (\hat{\theta}, 1)} > CS(\hat{\theta})$ hold, where $\pi_S(\theta)$ and $CS(\theta)$ are constant for all $\theta \in (\hat{\theta}, 1)$.

When $\theta \in [0, \hat{\theta})$, as discussed above, an increase in θ decreases firm N's equilibrium quality level, q_N^*, and increases firm S's equilibrium quality level, q_S^*. This decreases firm N's profitability and increases firm S's profitability. At the same time, the amount of rents that firm N has to give to each of type H consumer in the equilibrium of the game, $q_S^*(v_H - v_L)$, increases and in turn that improves consumer surplus. Once θ exceeds $\hat{\theta}$, it becomes too costly for firm N to impose a binding constraint on firm S's quality choice and it chooses $q_N^* = v_H$. Since firm S's equilibrium quality level in this case is equal to its profit-maximizing level of quality, $q_S^* = v_L$ (see more in the analysis of Proposition 3), a further increase in θ does not change firm S's equilibrium quality even though it would choose a higher level (recall that $q_S^* = min\{v_L, \bar{q}_S + \theta(q_N^* - \bar{q}_S)\}$).

Proposition 4 then tells us that, any value of $\theta \in (\hat{\theta}, 1)$ would maximize firm S's profit and consumer surplus, while $\theta = 0$ maximizes firm N's profit. Which level of spillover would maximize Southern welfare and world welfare? This is one of the key questions of this section, which we will explore in what follows.

Proposition 5. *Suppose $t + w \geq \Psi$ so that $\hat{\theta} < \theta^* = 1$. Then,*
(i) $WS(\theta)$ is strictly increasing in θ for all $\theta \in [0, \hat{\theta}]$ and $WS(\theta)|_{\theta \in (\hat{\theta}, 1)} > WS(\hat{\theta})$ for all $\theta \in (\hat{\theta}, 1)$, where $WS(\theta)$ is constant for all $\theta \in (\hat{\theta}, 1)$, and
(ii) $WW(\theta)|_{\theta \in (\hat{\theta}, 1)} > WW(\tilde{\theta})$ holds.

For all $\theta \in (\hat{\theta}, 1)$, firms N and S choose their profit-maximizing level of quality, $q_N^* = v_H$ and $q_S^* = v_L$. These are also the socially optimal levels of product quality for these firms, as we mentioned above. Hence, global welfare is unambiguously maximized for any $\theta \in (\hat{\theta}, 1)$. Furthermore, $\theta \in (\hat{\theta}, 1)$ also maximizes Southern welfare, which consists of firm S's profit and consumer surplus, by Proposition 4. Let θ^S and θ^W respectively denote optimal spillover rate for the South and global optimal spillover rate, these results are restated below.

Collolary 1. *Suppose $t + w \geq \Psi$ so that $\hat{\theta} < \theta^* = 1$, then $\theta^S \in (\hat{\theta}, 1)$ and $\theta^W \in (\hat{\theta}, 1)$.*

When the disadvantages of home-production is relatively high, that is when $t + w \geq \Psi$ holds, firm N always chooses FDI. Our analysis suggests that in this case, high enough values of spillover rate, $\theta \in (\hat{\theta}, 1)$, would not only be socially optimal, but also be desirable by the South government, whereas Northern firm strictly prefers a spillover rate that equals zero.

We next turn to explore the impacts of a change in θ on each firm's profitability, consumer surplus, Southern welfare and global welfare in the case of $t+w < \Psi$. In this case, $\hat{\theta} = \theta^* < 1$ by Lemma 1, and the equilibrium of the game is an FDI equilibrium for all $\theta \in [0, \theta^*]$, and it is an HP equilibrium if θ exceeds θ^* by Proposition 2. The interesting features of our model is that, firm N chooses a less-than-socially-optimal quality level under FDI (or when $\theta \in [0, \theta^*]$) and it chooses socially-optimal quality level under HP. This leads to several new results of our analysis.

Proposition 6. *Suppose $t + w < \Psi$ so that $\hat{\theta} = \theta^* < 1$. Then,*
(i) $\pi_N(\theta)$ is strictly decreasing in θ for all $\theta \in [0, \theta^*]$, and $\pi_N(\theta) = \pi_N(\theta^*)$ for all $\theta \in (\theta^*, 1)$, and
(ii) $\pi_S(\theta)$ and $CS(\theta)$ are strictly increasing in θ for all $\theta \in [0, \theta^*]$, and $\pi_S(\theta^*) > \pi_S(\theta)|_{\theta \in (\theta^*, 1)}$ and $CS(\theta^*) > CS(\theta)|_{\theta \in (\theta^*, 1)}$ hold, where $\pi_S(\theta)$ and $CS(\theta)$ are constant for all $\theta \in (\theta^*, 1)$.

Firm N undertakes FDI for all $\theta \in [0, \theta^*]$, and since $\hat{\theta} = \theta^*$, by Proposition 3, firm N imposes a binding constraint on firm S's choice of quality level by choosing $q_N^* = (1-\theta)v_H + \theta v_L$. Hence, in this case, an increase in $\theta \in [0, \theta^*)$ decreases firm N's equilibrium quality level and increases firm S's equilibrium quality level, causing firm N's profit to fall and firm S profit and consumer surplus to rise in a similar way as we have analyzed above (for the case of $\hat{\theta} < \theta^* = 1$).

Suppose instead that the level of spillover becomes relatively high satisfying $\theta \in (\theta^*, 1)$, then firm N chooses HP and there is no technology spillover. In this case, by taking firm S's choice of quality level as given, firm N chooses its profit-maximizing level of product quality, $q_N^* = v_H$. Firm S reacts the same way and it chooses $q_S^* = min\{v_L, \bar{q}_S\} = \bar{q}_S$. A change in spillover rate does not affect these equilibrium quality levels and thus it does not affect each of the firms' profitability or consumer surplus.

Now, let us focus the analysis on the borderline of the two cases, $\theta \in [0, \theta^*]$, and $\theta \in (\theta^*, 1)$. Consider a decrease in spillover rate from $\theta = \theta'(> \theta^*)$ to $\theta = \theta^*$. This switches the equilibrium of the game from HP to FDI. Technology spillover raises firm S's highest possible quality level from $\bar{q}_S$ to $\bar{q}_S + \theta(q_N^* - \bar{q}_S)$ and firm S chooses $q_S^* = min\{v_L, \bar{q}_S + \theta(q_N^* - \bar{q}_S)\} > \bar{q}_S$ in the equilibrium. This implies that FDI induced by the spillover decrease would raise firm S's equilibrium profit (that is, $\pi_S(\theta^*) > \pi_S(\theta)|_{\theta \in (\theta^*, 1)}$ holds). Also, since technology spillover increases firm S's equilibrium product quality, firm N has to leave a larger amount of rent to type H consumers for them to purchase firm N's product. Hence, induced FDI increases the equilibrium consumer surplus as well (that is, $CS(\theta^*) > CS(\theta)|_{\theta \in (\theta^*, 1)}$ holds).

It follows immediately from Proposition 6 that, $\theta = \theta^*$ maximizes South welfare for all $\theta \in [0, \theta^*]$. Can $\theta = \theta^*$ maximize South welfare for all $\theta \in [0, 1)$? Proposition 7 below tells us that, $\theta = \theta^*$ is optimal for the South under certain ranges of parameterization only, since FDI could decrease Southern welfare. The driving force of this result is that, firm N strategically reduces its product quality level upon FDI.

Proposition 7. *Suppose $t + w < \Psi$ so that $\hat{\theta} = \theta^* < 1$. Then, $WS(\theta)$ is strictly increasing in θ for all $\theta \in [0, \theta^*]$, and there exist values $\hat{m}_{H1}$ and $\hat{m}_{H2} (\geq \hat{m}_{H1})$ with following properties:*
(i) $WS(\theta^*) > (=, <)\ WS(\theta)|_{\theta \in (\theta^*, 1)}$ if $m_H < (=, >)\ \hat{m}_{H1}$, and
(ii) $WW(\tilde{\theta}) > (=, <)\ WW(\theta)|_{\theta \in (\theta^*, 1)}$ if $m_H < (=, >)\ \hat{m}_{H2}$,
where $\hat{m}_{H1} > \lim_{\theta \to \theta^*} \tilde{m}_H$ holds under a range of parameterizations, and $WS(\theta)$ and $WW(\theta)$ are constant for all $\theta \in (\theta^*, 1)$.

Socially optimal levels of product quality are $q_N = v_H$ and $q_S = v_L$ when firm N's product is consumed by type H consumers while firm S's product is consumed by type L consumers. In the HP equilibrium, firm N chooses $q_N^* = v_H$ and firm S chooses $q_S^* = \bar{q}_S$, where the level of firm S's product quality $\bar{q}_S$ is less than the socially optimal level v_L because of firm S's limited technological expertise.

Consider a decrease in θ from $\theta' > \theta^*$ to θ^* that switches the equilibrium of the game from HP to FDI. In the FDI equilibrium, technology spillover increases firm S's product quality, and this increases the equilibrium level of global welfare. At the same time, however, technology spillover induces firm N to choose less-than-socially-optimal level of product quality. As shown by Proposition 3, if $\theta \leq \hat{\theta}$, firm N chooses $q_N^* = (1 - \theta)v_H + \theta v_L < v_H$ in the FDI equilibrium, and this creates a trade-off. That is, technology spillover improves the net social benefits associated with the consumption of firm S's product at the expense of the reduction of the net social benefit associated with the consumption of firm N's product. If the population of type H consumers is relatively large, the latter negative welfare effect overshadows the former positive effect and hence FDI induced by the low spillover reduces global welfare. If the population of type H consumers is relatively small, FDI increases global welfare by an opposite argument. Note that firm N is indifferent between $\theta = \theta'$ and $\theta = \theta^*$, we have that $WW(\theta') > (=, <)\ WW(\theta^*)$ if and only if $WS(\theta') > (=, <)\ WS(\theta^*)$.

Above analysis suggests that, Northern firm's FDI could hurt the South when $t + w < \Psi$. The logic behind this result can be explained as follows. Assume that firm N always chooses the socially-optimal level of product quality $q_N^* = v_H$ when $\theta \in [0, \theta^*]$. Then, comparing between HP and FDI, it follows that FDI improves global welfare since induced technology spillover enables firm S to chooses higher quality levels which in turn improves net social benefit of purchasing firm S's product. This outcome, however, does not arise in the equilibrium of our framework, because firm N strategically reduces its product quality level upon FDI. This strategic reduction of product quality reduces the net social benefits of purchasing firm N's product, and could result in a total welfare loss for the society.

We are now ready to relate the global optimal level of spillover (θ^W) with South-optimal level of spillover (θ^S) when disadvantage of home-production is relatively low ($t + w < \Psi$). Our analysis suggests that there are certain parameterizations for $\theta^W < \theta^S$ to hold in this case. First, when FDI improves South welfare, $\theta = \theta^*$ is optimal for the South and $\tilde{\theta}$, which maximizes global welfare, could be strictly less than $\hat{\theta}(= \theta^*)$ by Lemma 2. Second, if FDI decreases South welfare, it could be established that $\theta^S \in (\theta^*, 1)$ holds. In this case, if the level of global welfare evaluated at $\theta = \tilde{\theta}$ (maximum global welfare under FDI equilibrium) is higher than global welfare under HP equilibrium then $\theta^W = \tilde{\theta}(< \theta^S)$ holds.

In any case, the necessary condition for $\theta^W < \theta^S$ to hold is that firm N reduces the quality level for its product when it undertakes FDI. To see this more intuitively, suppose instead that firm N does not reduce the level of product quality when it undertakes FDI (that is $q_N = v_H$ for all θ) then in the FDI equilibrium, $\theta = \theta^*$ maximizes both South welfare and global welfare. This is because a change in $\theta \in [0, \theta^*)$ affects net social benefits of consuming firm S's product in this case (which in turn depends merely on firm S's product quality) while it does not affect the benefits associated with consuming firm N's product. Hence, $\theta^W < \theta^S$ cannot hold when firm N does not decrease its product quality upon undertaking FDI. We summarize these findings in Collolary 2.

Collolary 2. *Suppose* $t + w < \Psi$ *so that* $\hat{\theta} = \theta^* < 1$, *then*
(i) $\theta^S \in (\theta^*, 1)$ *if* $m_H > \hat{m}_{H1}$ *and* $\theta^S = \theta^*$ *otherwise, and*
(ii) $\theta^W \in (\theta^*, 1)$ *if* $m_H > \hat{m}_{H2}$, *and* $\theta^W = \tilde{\theta}$ *otherwise.*

In summary, several new results have been found concerning welfare consequences of FDI that is induced by spillover rate decrease. When the disadvantage of home-production is relatively high, we find that, in the equilibrium, firm N always undertakes FDI. Under FDI, it chooses less-than-socially-optimal level of product quality if spillover rate is under a critical value, $\hat{\theta}$, and it chooses socially-optimal level of product quality when spillover rate becomes higher than $\hat{\theta}$. Consequently, a high enough level of spillover rate would maximize both South welfare and global welfare.

In contrast, when the disadvantage of home-production is relatively low, firm N undertakes FDI if spillover rate does not exceed a threshold value, θ^*. In this case, firm N chooses less-than-socially-optimal level of product quality when it undertakes FDI in order to limit the negative impacts of technology spillover. This strategic reduction of product quality reduces net social benefits associated with the consumption of firm N's product. Hence, FDI could harm the South. At the same time, the level of spillover rate that maximizes global welfare tends to be lower than than the value which maximizes Southern welfare (see more in Figure 1 below).

<<Insert Figure 1 somewhere around here>>

In reality, when a Northern firms undertake FDI in South countries, Northern firms often choose product quality levels below that that they would choose with home-production in order to reduce the amount of technology that spills over to local firms, as examples presented in Section 2 illustrate. Our analysis captures this phenomena and indicates that such an FDI may reduce Southern welfare, and thus a stringent IPR policy adopted in the South to attract FDI might not be a good choice for South governments. Furthermore, since global optimal spillover rate tends to be less than the level desirable by South governments, our analysis supports the role playing by international organization, such as WTO, in reconciling North-South IPR conflict. As will be demonstrated in what follows, these new policy implications are unique to quality-enhancing technology spillover.

5.2 Quality-enhancing versus cost-reducing technology spillover

This section relates the findings of the present paper with cost-reducing spillover literature, focusing on the results of Nguyen (2010), who examined a model which captures cost-reducing technology spillover in a similar fashion to the model introduced in section 4.1. In his set up if firm N chooses FDI, there is technology spillover that decreases firm S's marginal cost from c_0 to $min(c_0 - \theta(c_0 - c_N^f), c_0)$ where c_N^f is firm N's choice of marginal cost level and where $\theta \in [0, 1)$ is spillover rate. Nguyen found that, firm N chooses FDI if the spillover rate is low enough, and it chooses HP if spillover rate is relatively high.[22] Furthermore, in the equilibrium, regardless of firm N's location choice, it always chooses the minimum marginal cost level, which equals to zero, and at the same time firm S chooses its lowest possible marginal cost level.[23].

Since firm N always chooses its minimum cost level with cost-reducing spillover, Nguyen showed that FDI improves global welfare and Southern welfare. This leads to the result in which optimal IPR policy for the South is represented by the highest value of spillover that still induces FDI. More importantly, the level of spillover that maximizes global welfare is either zero (North-optimal) or some positive value which maximizes Southern welfare (South-optimal).

It has been made clear that quality-enhancing and cost-reducing spillover yield a number of different policy implications. First, the cost-reducing spillover framework says that FDI improves Southern welfare and global welfare, and thus both South government and the social

[22] The supplementary note accompanying this paper contains a summary as well as proofs of main results of Nguyen (2010).

[23] If the minimum marginal cost level for firm N is $\tilde{c}_N > 0$ then firm N chooses $c_N = \tilde{c}_N$ in the FDI equilibrium. However, this does not change the qualitative nature of the results.

planner would prefer FDI over HP. This is not the case with quality-enhancing spillover since FDI could result in a total loss in social welfare as detailed in previous subsection. Second, with cost-reducing spillover, the social planner either supports the North or the South in setting South IPR regime. With quality-enhancing spillover, however, the social planner tends to balance North-South conflict concerning IPR regime in the South. Hence, the new policy implications of quality-enhancing technology spillover, as discussed in what follows, are unique.

5.3 Policy implications

With the presence of quality-enhancing technology spillover in the South, Northern firm could strategically reduce its product quality level when it undertakes FDI in the South. This result leads to a number of new policy implications of our analysis.

Firstly, we demonstrate that FDI induced by stringent IPR policy can benefit or hurt the South. In the traditional cost-reducing technology spillover literature, previous authors argued that FDI always improves South welfare, as discussed above. We show that, in the case of quality-enhancing technology spillover, if Northern firm reduces its product quality level upon FDI and the population of consumers who buy Northern firm's product is relatively large, then FDI could decrease South welfare. This finding suggests that the policy to induce Northern firms with advanced technology to undertake FDI that many developing countries implemented in recent years may not be efficient if welfare is the concern.

It should be kept in mind however that we share the similar findings with cost-reducing technology spillover literature that FDI may improve Southern welfare in a range of parameterizations. This includes, for instance, when the trade cost is high and IPR environment in the South is weak - so that Northern firm still finds itself in a better position undertaking FDI rather than producing at home. In such a case, Northern firm chooses FDI but does not decrease the quality level for its product and thus FDI raises Southern welfare.

Secondly, our framework helps to identify optimal IPR policy not only for the South but also for the world. Nguyen (2010) demonstrated with a cost-reducing technology spillover model that the optimal IPR policy from global welfare standpoint tends to be either zero (North-optimal) or converge to South-optimal. We show with quality-enhancing spillover, however, when Northern firm chooses less-than-socially-optimal quality level upon FDI, the global optimal IPR policy tends to be more stringent than South-optimal and more lax than North-optimal levels. Hence, beside providing an analysis of North-South conflict concerning Southern IPR regime, this paper also suggests an optimal solution from social welfare standpoint.

In real world setting, IPR is governed by WTO under its TRIPS agreement, which establishes minimum levels of protection that each government has to give to the intellectual property of fellow WTO members. The implementation of this agreement often aims to strengthen IPR environment in South countries. However, in its original form, TRIPTS says that the objective of IPR protection is to "contribute to promotion of technological innovation and to the transfer and dissemination of technology... in a manner conducive to social and economic welfare." Our model provides a support to WTO in this regards. The central recommendation is that, by playing the role of a social planner, WTO could choose an IPR policy for the South which is not too lax or too stringent in order to maximize the social benefits of Northern firm's FDI in the South.

Since the establishment of TRIPS in 1995, there has been tremendous improvement in trade liberalization in the world. More importantly, many developing (South) countries have recently become member of WTO, whereby they need to abide the organization's rule, including TRIPS. It is thus important to understand how a change in IPR environment in South countries affect North/South/global welfare. Our framework of quality-enhancing technology spillover captures this idea and suggests that some positive spillover from Northern firms to Southern firms is good for the society. However, there tends to be differences concerning the optimal level of IPR protection in the South not just between North and South but also between South and global organizations such as WTO.

6 Conclusion

Technology spillover induced by FDI usually improves performance of the local firms at the cost of the foreign firms. This has become an important issue in the international trade literature. Various papers have analyzed technology spillover from Northern firms to Southern firms that reduces the later's marginal cost (Chin and Grossman 1990, among others). Incorporating FDI in such cost-reducing technology spillover framework, previous authors found that, Northern FDI usually benefits the South (Naghavi 2007, Nguyen 2010).

The present paper departs from this literature by exploring an international duopoly model of vertical product differentiation with technology spillover. We show that, the conventional argument that FDI with technology spillover benefits the South does not necessarily hold in the presence of quality-enhancing technology spillover. The driving force of this result is that, to limit the impacts of technology spillover, Northern firm could intentionally reduce the level of quality it chooses for its product when undertaking FDI. This strategic reduction of product quality reduces net social benefits associated with the consumption of Northern firm's product, thus it is harmful for the South. In this context, we also show that the the social planner would choose an IPR policy for the South which is not too lax or too strong to maximize social benefits of FDI with technology spillover. This supports the role played by WTO in reconciling North-South conflict concerning Southern IPR environment.

It is worth mentioning that several implications for trade policy are embodied in our analysis. For instance, since FDI could hurt the South, implementing a high trade barrier to attract FDI with technology transfer might not be a good choice for South countries. The best outcome for the society is when the social planner chooses both trade and IPR

policies for the South. Then, a combination of high tariff barrier (e.g., $t + w \geq \Psi$) and lax IPR regime would maximize the social benefits of FDI with technology spillover.

In summary, the present paper contributes to the literature in a number of ways. First, we construct an international duopoly model of vertical product differentiation with technology spillover to study the location choice of a Northern firm between home-production and FDI. We then analyze the equilibrium quality levels that Northern firm and Southern firm would choose for their product. By exploring these strategic choices of product quality, we discover novel policy implications of quality-enhancing technology spillover, which are also consistent with reality.

Appendix

Proof of Proposition 1.

Let us denote by p_k^i and q_k^i respectively price and quality levels chosen by firm $k(= N, S)$ in subgame $i(=HP, FDI)$. Also, define ${q_k^i}^*$ as quality level chosen by firm k in the separating equilibrium of subgame i. The proof contains 6 claims.

Claim 1. *Consider HP subgame. Assume that firm N chooses ${q_N^{HP}}^*$, then firm S only sells to type L consumers in this subgame if and only if $m_H < \bar{m}_{H1}$, $\bar{m}_{H1} \equiv m_L \frac{\bar{q_S}(v_L - v_H) + \frac{v_H^2}{2} - t - w}{\frac{-(v_H - \bar{q_S})^2}{2} + t + w}$ if $\frac{(v_H - \bar{q_S})^2}{2} + v_L \bar{q}_S - \frac{\bar{q}_S^2}{2} > t + w > \frac{(v_H - \bar{q}_S)^2}{2}$, $\bar{m}_{H1} \equiv 0$ if $t + w \geq \frac{(v_H - \bar{q_S})^2}{2} + v_L \bar{q}_S - \frac{\bar{q}_S^2}{2}$, and $\bar{m}_{H1} \equiv +\infty$ otherwise.*

Proof. Consider separating equilibrium of HP subgame. Pricing constraints are:

$$v_H q_N^{HP} - p_N^{HP} \geq 0 \tag{6}$$

$$v_L q_S^{HP} - p_S^{HP} \geq 0 \tag{7}$$

$$v_H q_N^{HP} - p_N^{HP} \geq v_H q_S^{HP} - p_S^{HP} \tag{8}$$

$$v_L q_S^{HP} - p_S^{HP} \geq v_L q_N^{HP} - p_N^{HP} \tag{9}$$

From (7) and (8), it follows that $v_H q_N^{HP} - p_N^{HP} \geq v_H q_S^{HP} - p_S^{HP} \geq 0$. So that (6) holds and can be excluded. Next, if (7) does not hold with equality, we can increase both p_S^{HP} and p_N^{HP} by some small amount without affecting any other constraints, a contradiction, so that (7) should hold with equality. Then, if (8) does not hold with equality, we can increase p_N^{HP} by a small amount without affecting any other constraints, a contradiction. So (8) holds with equality. Last, plug p_N^{HP} from (8) to (9), we see that (9) always holds and can be excluded. So that we end up with only two constraints being held with equality, (7) and (8). Thus, $p_S^{HP} = v_L q_S^{HP}$, and $p_N^{HP} = v_L q_S^{HP} + v_H(q_N^{HP} - q_S^{HP})$.

Note that under separating equilibrium of HP subgame, $q_N^{HP} > q_S^{HP}$ holds because from (8) and (9), we have $v_H(q_S^{HP} - q_N^{HP}) \leq p_S^{HP} - p_N^{HP} \leq v_L(q_S^{HP} - q_N^{HP}) \rightarrow v_H(q_S^{HP} - q_N^{HP}) \leq v_L(q_S^{HP} - q_N^{HP}) \rightarrow q_N^{HP} \geq q_S^{HP}$ and the equality can not hold (when both firms choose same quality level then there does not exist separating equilibrium). Therefore, $q_N^{HP} > q_S^{HP}$.

The problem facing firm S becomes:

$$\underset{q_S^{HP}}{\text{Max}}\ m_L[v_L q_S^{HP} - \frac{q_S^{HP2}}{2}] \tag{10}$$

$$\text{subject to: } q_S^{HP} \leq \bar{q_S}$$

Firm N takes firm S's quality level as given to solve his problem:

$$\underset{q_N^{HP}}{\text{Max}}\ m_H[v_L q_S^{HP} + v_H(q_N^{HP} - q_S^{HP}) - \frac{q_N^{HP2}}{2} - t - w] \tag{11}$$

The solutions are given by: $q_S^{HP*} = \bar{q_S}$ and $q_N^{HP*} = v_H$. The profits accrued to firm N and firm S in the separating equilibrium of HP subgame are respectively given by $\pi_N^{HP*} = m_H[v_L\bar{q}_S + \frac{v_H^2}{2} - v_H\bar{q}_S - t - w]$, and $\pi_S^{HP*} = m_L[v_L\bar{q}_S - \frac{\bar{q}_S^2}{2}]$.

- Suppose firm S deviates from this separating equilibrium, selling to type H consumers under HP. Then its $[quality, price]$ menu, $[q_S^{HP}, p_S^{HP}]$, satisfies:

$$v_H q_S^{HP} - p_S^{HP} \geq v_H q_N^{HP*} - p_N^{HP} \tag{12}$$

  That is, firm S will choose $p_S^{HP} = v_H q_S^{HP} - v_H q_N^{HP*} + p_N^{HP}$. Then, since $v_H q_S^{HP} - v_H q_N^{HP*} + p_N^{HP} < v_L q_S^{HP} - v_L q_N^{HP*} + p_N^{HP} \rightarrow v_L q_S^{HP} - p_S^{HP} > v_L q_N^{HP*} - p_N^{HP}$, type L consumers still purchase from firm S, so that it sells to all consumers and firm N sells nothing. Since firm N never chooses a price below its average cost, $\frac{q_N^{HP*2}}{2} + t + w$, for firm S to sell to all consumers then $p_N^{HP} = \frac{q_N^{HP*2}}{2} + t + w$ must hold. Firm S then chooses $p_S^{HP} = v_H q_S^{HP} - v_H q_N^{HP*} + \frac{q_N^{HP*2}}{2} + t + w$, obtaining profit $\pi_S^{HP'} = (m_H + m_L)(t + w - \frac{(q_N^{HP*} - q_S^{HP})^2}{2})$ which can be maximized at $q_S^{HP} = \bar{q_S}$ and thus $\pi_S^{HP'} = (m_H + m_L)(t + w - \frac{(v_H - \bar{q_S})^2}{2})$. If $t + w \leq \frac{(v_H - \bar{q_S})^2}{2}$ this profit is non-positive so that firm S will not deviate. If $t + w > \frac{(v_H - \bar{q_S})^2}{2}$, for firm S to be better-off under separating equilibrium, we need $\pi_S^{HP'} < \pi_S^{HP*}$, or $(m_H + m_L)(t + w - \frac{(v_H - \bar{q_S})^2}{2}) < m_L(v_L\bar{q_S} - \frac{\bar{q_S}^2}{2}) \rightarrow m_H < m_L \frac{v_L\bar{q_S} - \frac{\bar{q_S}^2}{2} + \frac{(v_H - \bar{q_S})^2}{2} - t - w}{t + w - \frac{(v_H - \bar{q_S})^2}{2}} \equiv \bar{m}_{H1}$, which also requires $t + w < \frac{(v_H - \bar{q_S})^2}{2} + v_L\bar{q}_S - \frac{\bar{q}_S^2}{2}$. *QED.*

Claim 2. *Consider HP subgame. In this subgame, firm N only sells to type H consumers if and only if $m_H > \tilde{m}_{H1}$, where $\tilde{m}_{H1} = m_L \frac{\frac{(v_L - \bar{q_S})^2}{2} - t - w}{\frac{v_H^2}{2} - \bar{q_S}(v_H - v_L) - \frac{(v_L - \bar{q_S})^2}{2}}$ if $t + w < \frac{(v_L - \bar{q_S})^2}{2}$, and $\tilde{m}_{H1} = 0$ otherwise.*

Proof. Assume firm N deviates from separating equilibrium of HP subgame, choosing $q_N^{HP} \neq q_N^{HP*}$ to sell to type L consumers under HP. Then, $v_L q_N^{HP} - p_N^{HP} \geq v_L q_S^{HP} - p_S^{HP}$ holds, so that $p_N^{HP} = v_L q_N^{HP} - v_L q_S^{HP} + p_S^{HP}$ and since $v_L q_N^{HP} - v_L q_S^{HP} + p_S^{HP} < v_H q_N^{HP} - v_H q_S^{HP} + p_S^{HP} \rightarrow v_H q_N^{HP} - p_N^{HP} > v_H q_S^{HP} - p_S^{HP}$ so that type H consumers still purchase firm N's products. It then sells to all consumers and firm S sells nothing. Firm S's reservation price is $\frac{q_S^{HP^2}}{2}$, so that deviation implies firm N chooses a $[quality, price]$ menu, $[q_N^{HP}, p_N^{HP}]$, satisfying:

$$v_L q_N^{HP} - p_N^{HP} \geq max(v_L q_S^{HP} - \frac{q_S^{HP^2}}{2}) \tag{13}$$

Firm S's per consumer profit, $v_L q_S^{HP} - \frac{q_S^{HP^2}}{2}$, is concave in q_S^{HP} and since $v_L \geq \bar{q}_S$, firm S's profit is maximized at $q_S^{HP} = \bar{q}_S$. This in turn implies that for firm N to sell to all consumers then $p_N^{HP} = v_L q_N^{HP} - v_L \bar{q_S} + \frac{\bar{q_S}^2}{2}$ must hold. The profit of firm N under such a deviation will be $\pi_N^{HP'} = (m_H + m_L)(v_L q_N^{HP} - v_L \bar{q_S} + \frac{\bar{q_S}^2}{2} - \frac{q_N^{HP^2}}{2})$, which could be maximized at $q_N^{HP} = v_L$, and firm N obtains profit $\pi_N^{HP'} = (m_H + m_L)(\frac{(v_L - \bar{q_S})^2}{2} - t - w)$. If $t + w \geq \frac{(v_L - \bar{q_S})^2}{2}$, this profit is non-positive and firm N will not deviate. If $t + w < \frac{(v_L - \bar{q_S})^2}{2}$, for firm N to be better-off under separating equilibrium, we need $\pi_N^{HP'} < \pi_N^{HP*}$, or $(m_H + m_L)(\frac{(v_L - \bar{q_S})^2}{2} - t - w) < m_H[\frac{v_H^2}{2} - \bar{q_S}(v_H - v_L) - t - w] \rightarrow m_H > m_L \frac{\frac{(v_L - \bar{q_S})^2}{2} - t - w}{\frac{v_H^2}{2} - \bar{q_S}(v_H - v_L) - \frac{(v_L - \bar{q_S})^2}{2}} \equiv \tilde{m}_{H1}$. *QED.*

Claim 3. *Consider FDI subgame. Assume that firm N chooses q_N^{FDI*}, then in this subgame firm S always sells to type L consumers only.*

Proof. In FDI subgame, firm S has the response function $q_S^{FDI} = v_L$ if $\hat{q_S}(q_N^{FDI}) = \bar{q_S} + \theta(q_N^{FDI} - \bar{q_S}) \geq v_L$, and $q_S^{FDI} = \bar{q_S} + \theta(q_N^{FDI} - \bar{q_S})$ otherwise. Anticipating this, firm N solves its problem:

$$\underset{q_N^{HP}}{\text{Max}}\; m_H[v_L q_S^{FDI} + v_H[q_N^{FDI} - q_S^{FDI}] - \frac{q_N^{FDI^2}}{2}] \tag{14}$$

There are two relevant options for firm N. The first option is to make the constraint $\hat{q_S}(q_N^{FDI}) = \bar{q_S} + \theta(q_N^{FDI} - \bar{q_S})$ bind, by choosing $q_N^{FDI*} = q'_N = (1-\theta)v_H + \theta v_L$ so that firm S chooses $q_S^{FDI*} = \hat{q_S}(q'_N)$. The second option is to choose $q_N^{FDI*} = v_H$, allowing firm S to choose $q_S^{FDI*} = v_L$. Note that the possibility in which firm N chooses $q_N^{FDI} = v_H$ and firm S chooses $q_S^{FDI} = \hat{q_S}(v_H) < v_L$ does not arise because it is then more profitable for firm N to choose $q_N^{FDI} = q'_N$. Similarly, the possibility in which firm N chooses $q_N^{FDI} = q'_N$ and firm S chooses $q_S^{FDI} = v_L$ does not arise because it is then more profitable for firm N to choose $q_N^{FDI} = v_H$.

Since $q_N^{FDI} = v_H$ gives firm N's profit $\pi_{N1}^{FDI} = m_H[\frac{v_H^2}{2} + v_L^2 - v_H v_L]$ whereas $q_N^{FDI} = (1-\theta)v_H + \theta v_L$ gives it profit $\pi_{N2}^{FDI} = m_H[v_L q_S^{FDI} + v_H(q_N^{FDI} - q_S^{FDI}) - \frac{q_N^{FDI^2}}{2}]$ where $q_N^{FDI} = (1-\theta)v_H + \theta v_L$, and $q_S^{FDI} = (1-\theta)\bar{q_S} + \theta[(1-\theta)v_H + \theta v_L]$. Comparing these two profit levels we find that if $\theta > \hat{\theta} = \frac{v_H - \bar{q}_S - \sqrt{(v_H - \bar{q}_S)^2 - 2(v_H - v_L)(v_L - \bar{q_S})}}{v_H - v_L}$ then firm N chooses $q_N^{FDI} = v_H$, and it chooses $q_N^{FDI} =$

q'_N otherwise. Under separating equilibrium of FDI subgame, firm N then gets profit $\pi_N^{FDI*} = m_H[v_L q_S^{FDI*} + v_H(q_N^{FDI*} - q_S^{FDI*}) - \frac{q_N^{FDI*2}}{2}]$ and firm S obtains profit $\pi_S^{FDI*} = m_L[v_L q_S^{FDI*} - \frac{q_S^{FDI*2}}{2}]$.

- Assume that firm S deviates from this separating equilibrium by selling to type H consumers in separating equilibrium of FDI subgame. It then chooses a $[quality, price]$ menu, $[q_S^{FDI}, p_S^{FDI}]$, satisfying equation (15) below:

$$v_H q_S^{FDI} - p_S^{FDI} \geq v_H q_N^{FDI*} - p_N^{FDI} \tag{15}$$

  That is, firm S will choose $p_S^{FDI} = v_H q_S^{FDI} - v_H q_N^{FDI*} + p_N^{FDI}$. However, since $v_H q_S^{FDI} - v_H q_N^{FDI*} + p_N^{FDI} < v_L q_S^{FDI} - v_L q_N^{FDI*} + p_N^{FDI} \rightarrow v_L q_S^{FDI} - p_S^{FDI} > v_L q_N^{FDI*} - p_N^{FDI}$, firm S then sells to all consumers and firm N sells nothing. Note that firm N never charges price below $\frac{q_N^{FDI*2}}{2}$, its unit cost, thus, for firm S to sell to all consumers then $p_S^{FDI} = v_H q_S^{FDI} - v_H q_N^{FDI*} + \frac{q_N^{FDI*2}}{2}$ must hold, and firm S's profit is $\pi'_S = (m_H + m_L)(-\frac{(q_N^* - q_S^{FDI})(2v_H - q_N^{FDI*} - q_S^{FDI})}{2}) < 0$. Therefore, firm S will not deviate. *QED.*

Claim 4. *Consider FDI subgame. In this subgame, firm N only sells to type H consumers if and only if $m_H > \tilde{m}_{H2}$, where* $\tilde{m}_{H2} = m_L \frac{\frac{(1-\theta)(v_L - \bar{q_S})^2}{2(1+\theta)}}{\frac{v_H^2}{2} - v_H v_L + v_L^2 - \frac{(1-\theta)(v_L - \bar{q_S})^2}{2(1+\theta)}}$ *if $\theta \geq \hat{\theta}$, and* $\tilde{m}_{H2} = m_L \frac{\frac{(1-\theta)(v_L - \bar{q_S})^2}{2(1+\theta)}}{-(1-\theta)(v_H - v_L)\bar{q_S} + \frac{((1-\theta)v_H + \theta v_L)^2}{2} - \frac{(1-\theta)(v_L - \bar{q_S})^2}{2(1+\theta)}}$ *otherwise, and* $\hat{\theta} = \frac{v_H - \bar{q}_S - \sqrt{(v_H - \bar{q}_S)^2 - 2(v_H - v_L)(v_L - \bar{q}_S)}}{v_H - v_L}$.

Proof. Assume firm N deviates from the separating equilibrium of FDI subgame by selling to type L consumers under FDI. Then, firm N chooses a $[quality, price]$ menu, $[q_N^{FDI}, p_N^{FDI}]$, satisfying:

$$v_L q_N^{FDI} - p_N^{FDI} \geq max(v_L q_S^{FDI} - \frac{q_S^{FDI^2}}{2}) \tag{16}$$

That is, firm N will choose $p_N^{FDI} = v_L q_N^{FDI} - max(v_L q_S^{FDI} - \frac{q_S^{FDI^2}}{2})$. Since $v_L q_S^{FDI} - \frac{q_S^{FDI^2}}{2}$ is concave in q_S^{FDI}, its maxima is obtained at $q_S^{FDI} = min(\hat{q}_S(q_N^{FDI}), v_L)$. Can firm S chooses $q_S^{FDI} = v_L$ after firm N deviates? If this happens then $p_N^{FDI} = v_L q_N^{FDI} - \frac{v_L^2}{2}$, so that profit of firm N from deviation will then be $\pi_N = (m_H + m_L)(v_L q_N^{FDI} - \frac{v_L^2}{2} - \frac{q_N^{FDI^2}}{2}) \leq 0$, contradiction. Therefore, if firm N deviates then $q_S^{FDI} = \hat{q}_S(q_N^{FDI})$ must hold. In such a deviation, firm N chooses $p_N^{FDI} = v_L q_N^{FDI} - v_L \hat{q}_S(q_N^{FDI}) + \frac{\hat{q}_S^2(q_N^{FDI})}{2}$. Then, $v_H q_N^{FDI} - p_N^{FDI} > v_H q_S^{FDI} - \frac{q_S^{FDI^2}}{2}$, so that firm N sells to all consumers and firm S sells nothing.

The profit of the firm N from deviation will be $\pi_N^{FDI'} = (m_H + m_L)(v_L q_N^{FDI} - v_L \hat{q}_S(q_N^{FDI}) + \frac{\hat{q}_S{}^2(q_N^{FDI})}{2} - \frac{q_N^{FDI^2}}{2})$, which is maximized at $q_N^{FDI} = \frac{v_L + \theta \bar{q_S}}{1+\theta}$. Thus, $\pi_N^{FDI'} = (m_H + m_L)\frac{(1-\theta)(v_L - \bar{q_S})^2}{2(1+\theta)}$. Then, $\hat{q}_S(q_N^{FDI}) = \frac{\bar{q}_S + \theta v_L}{1+\theta} < v_L$.

- If $\theta > \hat{\theta}$, for firm N to be better-off under separating equilibrium, we need $\pi_N^{FDI'} < \pi_N^{FDI*}|_{\theta > \hat{\theta}}$, or $(m_H + m_L)\frac{(1-\theta)(v_L - \bar{q_S})^2}{2(1+\theta)} < m_H[\frac{v_H^2}{2} - v_H v_L + v_L^2] \to m_H > m_L \frac{\frac{(1-\theta)(v_L - \bar{q_S})^2}{2(1+\theta)}}{\frac{v_H^2}{2} - v_H v_L + v_L^2 - \frac{(1-\theta)(v_L - \bar{q_S})^2}{2(1+\theta)}} = \tilde{m}_{H2}$.
- If $\theta \leq \hat{\theta}$, similarly, we need $\pi_N^{FDI'} < \pi_N^{FDI*}|_{\theta \leq \hat{\theta}}$, or $(m_H + m_L)\frac{(1-\theta)(v_L - \bar{q_S})^2}{2(1+\theta)} < m_H[-(1 - \theta)(v_H - v_L)\bar{q_S} + \frac{((1-\theta)v_H + \theta v_L)^2}{2}] \to m_H > m_L \frac{\frac{(1-\theta)(v_L - \bar{q_S})^2}{2(1+\theta)}}{-(1-\theta)(v_H - v_L)\bar{q_S} + \frac{((1-\theta)v_H + \theta v_L)^2}{2} - \frac{(1-\theta)(v_L - \bar{q_S})^2}{2(1+\theta)}} = \tilde{m}_{H2}$. *QED.*

Claim 5. *Assume $\theta > \hat{\theta}$. Then,*
(i) the separating SPNE of the game is an FDI equilibrium if $t+w \geq \Psi$ and $m_H > max(\tilde{m}_{H2}, \tilde{m}_{H3})$, where $\Psi = (v_H - v_L)(v_L - \bar{q}_S)$, $\tilde{m}_{H3} = m_L \frac{\frac{(v_L - \bar{q}_S)^2}{2} - t - w}{v_L^2 - v_H v_L - \frac{\bar{q}_S^2}{2} + v_H \bar{q}_S + t + w}$ if $t + w < \frac{(v_L - \bar{q}_S)^2}{2}$ and $\tilde{m}_{H3} = 0$ otherwise, and
(i) the separating SPNE of the game is an HP equilibrium if $t+w < \Psi$ and $m_H > max(\tilde{m}_{H1}, \tilde{m}_{H4})$, where $\tilde{m}_{H4} = m_L \frac{\frac{(1-\theta)(v_L - \bar{q_S})^2}{2(1+\theta)}}{v_L \bar{q}_S + \frac{v_H^2}{2} - v_H \bar{q}_S - t - w - \frac{(1-\theta)(v_L - \bar{q_S})^2}{2(1+\theta)}}$.

Proof. Let us compare firm N's profit under separating equilibrium of HP and FDI subgames when $\theta > \hat{\theta}$. It follows that FDI is better for firm N if $\pi_N^{FDI*}|_{\theta > \hat{\theta}} \geq \pi_N^{HP*} \to m_H[v_L^2 + \frac{v_H^2}{2} - v_H v_L] \geq m_H[v_L \bar{q_S} + \frac{v_H^2}{2} - v_H \bar{q_S} - w - t] \to t + w \geq (v_H - v_L)(v_L - \bar{q_S}) = \Psi$ which always holds if $w > \Psi$, or if $w \leq \Psi$ and $t > \bar{t_1} = \Psi - w$. In other cases, HP makes firm N better-off.

- For the separating SPNE of the game to be an FDI equilibrium, beside condition $t + w \geq \Psi$, we need firm N's profit if it deviates to sell to all consumers in HP subgame is lower than its profit in such an SPNE, $\pi_N^{HP'} < \pi_N^{FDI*}|_{\theta \geq \hat{\theta}} \to (m_H + m_L)(\frac{(v_L - \bar{q}_S)^2}{2} - t - w) < m_H[v_L^2 + \frac{v_H^2}{2} - v_H v_L]$, which is always true if $t + w \geq \frac{(v_L - \bar{q}_S)^2}{2}$. If $t + w < \frac{(v_L - \bar{q}_S)^2}{2}$, we need $m_H > m_L \frac{\frac{(v_L - \bar{q}_S)^2}{2} - t - w}{v_L^2 - v_H v_L - \frac{\bar{q}_S^2}{2} + v_H \bar{q}_S + t + w} \equiv \tilde{m}_{H3}$. Claim 4 provides sufficient condition.
- For the separating SPNE of the game is an HP equilibrium, beside condition $t + w < \Psi$, we need firm N's profit if it deviates to sell to all consumers in FDI subgame is lower than its profit in such an equilibrium, $\pi_N^{FDI'} < \pi_N^{HP*} \to (m_H + m_L)\frac{(1-\theta)(v_L - \bar{q_S})^2}{2(1+\theta)} < m_H[v_L \bar{q}_S + \frac{v_H^2}{2} - v_H \bar{q}_S - t - w] \to m_H > m_L \frac{\frac{(1-\theta)(v_L - \bar{q_S})^2}{2(1+\theta)}}{v_L \bar{q}_S + \frac{v_H^2}{2} - v_H \bar{q}_S - t - w - \frac{(1-\theta)(v_L - \bar{q_S})^2}{2(1+\theta)}} \equiv \tilde{m}_{H4}$. The sufficient condition is given by Claim 2. Note that, $\frac{(v_H - \bar{q}_S)^2}{2} > (v_H - v_L)(v_L - \bar{q}_S)$, so condition $m_H < \bar{m}_{H1} = +\infty$ in Claim 1 is always satisfied. *QED.*

Claim 6. *Assume $\theta \leq \hat{\theta}$. Then,*

(i) the separating SPNE of the game is an FDI equilibrium if $t \geq \bar{t}_2$ and $m_H > max(\tilde{m}_{H2}, \tilde{m}_{H5})$, where $\tilde{m}_{H5} = m_L \frac{\frac{(v_L-\bar{q}_S)^2}{2}-t-w}{-(v_H-v_L)\bar{q}_S(1-\theta)+\frac{((1-\theta)v_H+\theta v_L)^2}{2}-\frac{(v_L-\bar{q}_S)^2}{2}+t+w}$ if $t+w < \frac{(v_L-\bar{q}_S)^2}{2}$ and $\tilde{m}_{H5} = 0$ otherwise, and $\bar{t}_2 \equiv \theta(v_H - v_L)[v_H - \bar{q}_S - \theta\frac{v_H-v_L}{2}] - w$, and
(i) the separating SPNE of the game is an HP equilibrium if $t < \bar{t}_2$ and $m_H > max(\tilde{m}_{H1}, \tilde{m}_{H4})$.

Proof. Let us compare profit of firm N under separating equilibrium of FDI and HP subgames when $\theta \leq \hat{\theta}$. It follows that FDI is better for firm N if $\pi_N^{FDI*}|_{\theta\leq\hat{\theta}} \geq \pi_N^{HP*} \leftrightarrow m_H[-(v_H - v_L)\bar{q}_S(1-\theta) + \frac{((1-\theta)v_H+\theta v_L)^2}{2}] \geq m_H[v_L\bar{q}_S + \frac{v_H^2}{2} - v_H\bar{q}_S - w - t]$, or similarly, $t \geq \bar{t}_2 = \theta(v_H - v_L)[v_H - \bar{q}_S - \theta\frac{v_H-v_L}{2}] - w$. This condition always holds if $\bar{t}_2 \leq 0$, which is true when $w \geq \frac{(v_H-\bar{q}_S)^2}{2}$ (case a), or both $w < \frac{(v_H-\bar{q}_S)^2}{2}$ and $\theta \leq \frac{v_H-\bar{q}_S-\sqrt{(v_H-\bar{q}_S)^2-2w}}{v_H-v_L}$ hold (case b). If $w < \frac{(v_H-\bar{q}_S)^2}{2}$ and $\theta > \frac{v_H-\bar{q}_S-\sqrt{(v_H-\bar{q}_S)^2-2w}}{v_H-v_L}$, then FDI is better for firm N if $t > \bar{t}_2$ (case c). Furthermore, let us define $\theta^* = \frac{v_H-\bar{q}_S-\sqrt{(v_H-\bar{q}_S)^2-2(t+w)}}{v_H-v_L}$, $\theta^* \in [0,1)$, then case (b) and (c) can be summarized as if $\theta \leq \theta^*$ then firm N chooses FDI, and it chooses HP otherwise. This also captures case (a) by setting $\theta^* = 1$ if $w > \frac{(v_H-\bar{q}_S)^2}{2}$.[24]

- For the separating SPNE of the game to be an FDI equilibrium, beside condition $t \geq \bar{t}_2 \leftrightarrow \theta \leq \theta^*$, we need firm N's profit by deviating from this SPNE to sell to all consumers under HP will be lower, $\pi_N^{HP'} < \pi_N^{FDI*}|_{\theta<\hat{\theta}} \rightarrow (m_H + m_L)(\frac{(v_L-\bar{q}_S)^2}{2} - t - w) < m_H[(v_H - v_L)\bar{q}_S(1-\theta) + \frac{((1-\theta)v_H+\theta v_L)^2}{2}]$, which is always true if $t + w \geq \frac{(v_L-\bar{q}_S)^2}{2}$. If $t + w < \frac{(v_L-\bar{q}_S)^2}{2}$, we need $m_H > m_L \frac{\frac{(v_L-\bar{q}_S)^2}{2}-t-w}{-(v_H-v_L)\bar{q}_S(1-\theta)+\frac{((1-\theta)v_H+\theta v_L)^2}{2}-\frac{(v_L-\bar{q}_S)^2}{2}+t+w} \equiv \tilde{m}_{H5}$. Claims 4 provides sufficient condition.

- For the separating SPNE of the game to be an HP equilibrium, beside condition $\theta > \theta^*$, we need firm N's profit by deviating from this SPNE to sell to all consumers under FDI is lower than the profit it reaps in such an SPNE, $\pi_N^{FDI'} < \pi_N^{HP*} \rightarrow (m_H + m_L)\frac{(1-\theta)(v_L-\bar{q}_S)^2}{2(1+\theta)} < m_H[v_L\bar{q}_S + \frac{v_H^2}{2} - v_H\bar{q}_S - t - w] \rightarrow m_H > \tilde{m}_{H4}$ (see more in Claim 5). The sufficient condition is given by Claim 2. Note that, the condition of $m_H < \bar{m}_{H1}$ in Claim 1 is always satisfied in this case, since (i) if $t + w < \frac{(v_H-\bar{q}_S)^2}{2}$ then $\bar{m}_{H1} = +\infty$, and (ii) if $t + w \geq \frac{(v_H-\bar{q}_S)^2}{2} > \Psi$ then $\theta^* > \hat{\theta}$ and by defining $\theta^* = 1$, the separating SPNE is then an FDI equilibrium. *QED.*

With the help of Claims 1-6, the proof of Proposition 1 is completed by defining:

$$\tilde{m}_H = \begin{cases} max(\tilde{m}_{H2}, \tilde{m}_{H3}) & \text{if } \theta > \hat{\theta} \text{ and } t + w \geq \Psi \\ max(\tilde{m}_{H1}, \tilde{m}_{H4}) & \text{if } \theta > \hat{\theta} \text{ and } t + w < \Psi \\ max(\tilde{m}_{H2}, \tilde{m}_{H5}) & \text{if } \theta \leq \hat{\theta} \text{ and } t \geq \bar{t}_2 \\ max(\tilde{m}_{H2}, \tilde{m}_{H4}) & \text{if } \theta \leq \hat{\theta} \text{ and } t < \bar{t}_2 \end{cases}$$

[24] Without loss of generality, we assume that firm N chooses HP if $t \leq \bar{t}_2$, or if $\theta > \theta^*$, and it chooses FDI if $t > \bar{t}_2$ or if $\theta \leq \theta^*$.

Finally, since $\tilde{m}_{H2}$ and $\tilde{m}_{H4}$ are weakly decreasing in θ, $\tilde{m}_{H1}$ and $\tilde{m}_{H3}$ are independent of θ while $\tilde{m}_{H5}$ is weakly increasing in $\theta \in [0, \theta^*]$, if $m_H > \lim_{\theta \to \theta^*} \tilde{m}_H$ then the game has a separating equilibrium for all $\theta \in [0, 1)$.
QED.

Proof of Proposition 2.

- Consider the case of $t + w \geq \Psi$. For all θ in $(0, \hat{\theta})$, from the proof of Claim 6 above, $\theta^* = \frac{v_H - \bar{q}_S - \sqrt{(v_H - \bar{q}_S)^2 - 2(t+w)}}{v_H - v_L} \geq \hat{\theta} = \frac{v_H - \bar{q}_S - \sqrt{(v_H - \bar{q}_S)^2 - 2(v_H - v_L)(v_L - \bar{q}_S)}}{v_H - v_L}$ so that the separating SPNE of the game is an FDI equilibrium for all $\theta \in [0, \hat{\theta}]$. Furthermore, for all $\theta \in (\hat{\theta}, 1)$, following the proof of Claim 5 above, the separating SPNE of the game is an FDI equilibrium. Hence, we can re-define $\theta^* = 1$ to formalize the proof of Proposition 2.

- Consider the case of $t + w < \Psi$. In this case, since $\Psi \leq \frac{(v_H - \bar{q}_S)^2}{2}$, $\theta^* = \frac{v_H - \bar{q}_S - \sqrt{(v_H - \bar{q}_S)^2 - 2(t+w)}}{v_H - v_L}$ is increasing in t.

QED.

Proof of Proposition 3.
The proof comes directly from proof of Claim 3. *QED.*

Proof of Lemma 1.

The proof comes directly from proof of Claim 5, 6 and Proposition 2. *QED.*

Proof of Lemma 2.

When $\theta \leq \hat{\theta}$ then $WW(\theta) = m_H\big(q_N^{FDI} v_H - \frac{q_N^{FDI^2}}{2}\big) + m_L\big(q_S^{FDI} v_S - \frac{q_S^{FDI^2}}{2}\big)$, so that $\frac{\partial WW(\theta)}{\partial \theta} = -m_H \theta (v_H - v_L)^2 + m_L (v_L - \hat{q}_S(q'_N)) \frac{\partial \hat{q}_S(q'_N)}{\partial \theta}$, which is positive when $\theta = 0$. Furthermore, $\frac{\partial^2 WW(\theta)}{\partial \theta^2} = -m_H (v_H - v_L)^2 - m_L\big((\frac{\partial \hat{q}_S(q'_N)}{\partial \theta})^2 + (v_L - \hat{q}_S(q'_N)(v_H - v_L)\big) < 0$, hence $WW(\theta)$ is concave in θ for all $\theta \in [0, \hat{\theta}]$ and can be maximized at some $\tilde{\theta} \leq \hat{\theta}$, where $\theta = \tilde{\theta}$ makes $\frac{\partial WW(\theta)}{\partial \theta} = 0$. Note that when m_H is relatively high then $\tilde{\theta} \approx 0 < \hat{\theta}$. *QED.*

Proof of Proposition 4.

- If $\theta > \hat{\theta}$ then under separating equilibrium of FDI subgame, firm N chooses $q_N^{FDI*} = v_H$ while firm S chooses $q_S^{FDI*} = v_L$, so that $\pi_N(\theta)$, $\pi_S(\theta)$ and $CS(\theta)$ are all independent of θ.

- If $\theta \leq \hat{\theta}$ then in the separating equilibrium of FDI subgame (see also proof of Claim 3), it follows that $sign[\frac{\partial \pi_S(\theta)}{\partial \theta}] = sign[\frac{\partial CS(\theta)}{\partial \theta}] = sign[\frac{\partial q_S^{FDI}}{\partial \theta}] = v_H - \bar{q}_S - 2\theta(v_H - v_L) > 0$ since $\hat{\theta} < \frac{v_H - \bar{q}_S}{2(v_H - v_L)} \leftrightarrow 3(v_H - \bar{q}_S)^2 > 8(v_H - v_L)(v_L - \bar{q}_S)$ always holds; whereas $sign[\frac{\partial \pi_N^{FDI}}{\partial \theta}] = sign[\frac{\partial q_N^{FDI}}{\partial \theta}] = v_L - v_H < 0$. Note that, in the separating equilibrium of subgame i, $CS(\theta) = m_H (v_H - v_L) q_S^i$ holds.

- If θ increases from $\theta = \hat{\theta}$ to $\theta' > \hat{\theta}$ then firm N increases its quality level from $q_N < v_H$ to v_H while firm S increases quality level from $q_S = q_S(q_N|q_N < v_H) < v_L$ to v_L. Firm N's profit does not change. However, firm S profits from each consumer, $q_S v_L - \frac{q_S^2}{2}$, increases so that $\pi_S(\theta') > \pi_S(\hat{\theta})$ holds. Furthermore, per-consumer surplus, captured by $q_S(v_H - v_L)$ also increases following firm S's quality rise, thus $CS(\theta') > CS(\hat{\theta})$ holds.

QED.

Proof of Proposition 5.

- Since under FDI, $WS(\theta) = \pi_S(\theta) + CS(\theta)$, the proof concerning changes in $WS(\theta)$ comes directly from the proof of Proposition 4 for two components of it, $\pi_S(\theta)$ and $CS(\theta)$.
- Since under FDI, $WW(\theta) = q_S v_L - \frac{q_S^2}{2} + q_N v_H - \frac{q_N^2}{2}$, unambiguously $q_S = v_L$ and $q_N = v_H$ maximize $WW(\theta)$ so that $WW(\theta)|_{\theta \in (\hat{\theta},1)} > WW(\tilde{\theta})$ holds.

QED.

Proof of Proposition 6.

- If $\theta > \theta^*$ then the separating SPNE of the game is an HP equilibrium in which firm N chooses $q_N^{HP*} = v_H$ while firm S chooses $q_S^{HP*} = \bar{q}_S$, so that $\pi_N(\theta)$, $\pi_S(\theta)$ and $CS(\theta)$ are all independent of θ.
- If $\theta \leq \theta^*$ then the separating SPNE of the game is an FDI equilibrium, and firm N chooses $q_N^{FDI*} = q'_N$ while firm S chooses $q_S^{FDI*} = \hat{q}_S(q'_N)$. Hence, $sign[\frac{\partial \pi_S^{FDI}(\theta)}{\partial \theta}] = sign[\frac{\partial CS(\theta)}{\partial \theta}] = sign[\frac{\partial q_S^{FDI}}{\partial \theta}] = v_H - \bar{q}_S - 2\theta(v_H - v_L) > 0$ as $\theta^* = \hat{\theta} < \frac{v_H - \bar{q}_S}{2(v_H - v_L)}$ (see more in proof of Proposition 4), whereas $sign[\frac{\partial \pi_N^{FDI}(\theta)}{\partial \theta}] = sign[\frac{\partial q_N^{FDI}}{\partial \theta}] = v_L - v_H < 0$
- If θ increases from $\theta = \theta^*$ to $\theta' \geq \theta^*$, by Proposition 3 and Lemma 1, firm S chooses lower quality level thus $CS(\theta') < CS(\theta^*)$ and $\pi_S(\theta') < \pi_S(\theta^*)$ hold.

QED.

Proof of Proposition 7.

An increase in θ from θ^* to $\theta' > \theta^*$ switches the equilibrium of the game from FDI to HP, so that global welfare changes from $WW(\theta^*) = m_H(q''_N v_H - \frac{{q''_N}^2}{2}) + m_L(\hat{q}_S(q''_N)v_L - \frac{\hat{q}_S(q''_N)^2}{2})$ to $WW(\theta') = m_H(\frac{v_H^2}{2} - w) + m_L(v_L\bar{q}_S - \frac{\bar{q}_S^2}{2})$, where $q''_N = (1-\theta^*)v_H + \theta^* v_L$. Therefore, $WW(\theta') > WW(\theta^*) \leftrightarrow m_H(\frac{v_H^2}{2} - w) + m_L(v_L\bar{q}_S - \frac{\bar{q}_S^2}{2}) > m_H(q''_N v_H - \frac{{q''_N}^2}{2}) + m_L(\hat{q}_S(q''_N)v_L - \frac{\hat{q}_S(q''_N)^2}{2})$. This requires $w < \frac{\theta^{*2}(v_H - v_L)^2}{2}$ and $m_H > m_L \frac{\theta^*(q''_N - \bar{q}_S)(v_L - \frac{(2-\theta)\bar{q}_S + \theta q''_N}{2})}{\frac{\theta^{*2}(v_H - v_L)^2}{2} - w} \equiv \hat{m}_{H1}$.

Similarly, let $\tilde{q}_N$ be firm N's quality level when $\theta = \tilde{\theta}$, or $\tilde{q}_N = (1-\bar{\theta})v_H + \tilde{\theta}v_L$ then $WW(\tilde{\theta})$ is the maximum level of global welfare for all $\theta \in [0, \theta^*]$ by Lemma 2. Then, if $w < \frac{\tilde{\theta}^2(v_H - v_L)^2}{2}$,

$WW(\theta') > WW(\tilde{\theta}) \leftrightarrow m_H > m_L \frac{\tilde{\theta}(\tilde{q}_N - \bar{q}_S)(v_L - \frac{(2-\theta)\bar{q}_S + \theta\tilde{q}_N}{2})}{\frac{\tilde{\theta}^2(v_H - v_L)^2}{2} - w} \equiv \hat{m}_{H2}$. Since $WW(\tilde{\theta}) \geq WW(\theta^*)$, it follows that $\hat{m}_{H2} \geq \hat{m}_{H1}$ holds. Finally, by choosing parameterizations such that $\frac{\theta^{*2}(v_H - v_L)^2}{2} - w$ is small enough, $\hat{m}_{H1} > \lim_{\theta \to \theta^*} \tilde{m}_H$. *QED.*

References

[1] Aitken, B.J., and Harrison, A.E. 1999. "Do Domestic Firms Benefit from Direct Foreign Investment? Evidence from Venezuela." *The American Economic Review,* Vol. 89(3).

[2] Australian Chamber of Commerce and Industry. 2006. *China FTA - Need for Progress on Intellectual Property Rights.*

[3] Boccard, N., and Wauthy, X. 2005. "Enforcing Domestic Quality Dominance through Quotas." *Review of International Economics,* Vol. 13(2).

[4] Carluccio, J., and Fally, T. 2008. "Multinationals, Technological Incompatibilities, and Spillovers." *Working paper.*

[5] Chin, J.C., and Grossman, G.M. 1990. *Intellectual Property Rights and North-South Trade,* In: Jones, R.W., Krueger, A.O. (eds), The Political Economy of International Trade: Essays in Honor of Robert E. Baldwin. Blackwell, Cambridge, MA.

[6] Das, S.P., and Donnenfeld, S. 1987. "Trade Policy and its Impact on Quality of Imports: a Welfare Analysis." *Journal of International Economics,* Vol. 23.

[7] Das, S.P., and Donnenfeld, S. 1989. "Oligopolistic Competition and International Trade: Quantity and Quality Restrictions." *Journal of International Economics,* Vol. 27.

[8] Davis, S.J., Murphy, K.M, and Topel, R.H. 2004. "Entry, Pricing and Product Design in an Initially Monopolized Market." *Journal of Political Economy,* Vol. 112(1).

[9] Deardorff, A. 1992. "Effects of Global Patent Protection." *Economica,* Vol. 59(233).

[10] Diwan, I., and Rodrik, D. 1991. "Patents, Appropriate Technology, and North-South Trade." *Journal of International Economics,* Vol. 30.

[11] Djankov, S., and Hoekman, B. 2000. "Foreign Investment and Productivity Growth in Czech Enterprises." *World Bank Economic Review,* Vol. 14(1).

[12] Ernst & Young. 2005. "China's Automotive Sector - At the Crossroads." *EYG No. CT0003.*

[13] Falvey, R. 1979. "The Composition of Trade Within Import Restricted Trade Categories." *Journal of Political Economy,* Vol. 87.

[14] Freenstra, R.C. 2004. *Advanced International Trade: Theory and Evidence,* Princeton University Press.

[15] Gallagher, K.S. "Foreign Technology in China's Automobile Industry: Implications for Energy, Economic Development, and Environment." *China Environment Series,* Issue 6.

[16] Glass, A.J., and Saggi, K. 1998. "International Technology Transfer and The Technology Gap." *Journal of Development Economics,* Vol. 55.

[17] Glass, A.J., and Saggi, K. 2002. "Multinational Firms and Technology Transfer." *Scandinavian Journal of Economics,* Vol. 104(4).

[18] Gonzalez, J., and Viaene, J.M. 2005. "Trade Policy and Quality Leadership in Transition Economies." *European Economic Review,* Vol. 49.

[19] Grossman, G.M., and Lai, E. 2004. "International Protection of Intellectual Property." *American Economic Review,* Vol. 94(5).

[20] Haddad, M., and Harrison, A. 1993. "Are there positive spillovers from direct foreign investment?: Evidence from panel data for Morocco." *Journal of Development Economics,* Vol. 42.

[21] Helpman, E. 1993. "Imitation, and Intellectual Property Rights." *Econometrica,* Vol. 61(6).

[22] Keller, W. 2004. "International Technology Diffusion." *Journal of Economic Literature,* Vol. 42(3).

[23] Kim, J.E., and Lapan, H.E. 2008. "Heterogeneity of Southern Countries and Southern Intellectual Property Rights Policy." *Canadian Journal of Economics,* Vol. 41(3).

[24] Lai, E., and Qiu, L.D. 2005. "The North's Intellectual Property Rights Standard for the South?" *Journal of International Economics,* Vol. 59.

[25] Luo, J. 2005. "The Growth of Independent Chinese Automotive Companies." *International Motor Vehicle Program,* MIT.

[26] Mussa, M., and Rosen, S. 1978. "Monopoly and Product Quality" *Journal of Economic Theory,* Vol. 18.

[27] Naghavi, A. 2007. "Strategic Intellectual Property Rights Policy and North-South Technology Transfer." *Review of World Economics,* Vol. 143(1).

[28] Nguyen, X.T. 2010. “Multinational Firms, Technology Spillover, and Optimal Intellectual Property Rights.” *mimeo, University of New South Wales.*

[29] Pack, H., and Saggi, K. 2006. “Is There a Case for Industrial Policy? A Critical Survey.” *The World Bank Reserve Observer,* Vol. 21(2).

[30] Patibandla, M., Kapur, D., and Petersen, B. 1999. “A Byproduct of Import Substitution and Competitiveness out of International Orientation: A Brief Story of India’s Software Industry and Policy Implications.” *Working paper.*

[31] Praussello, F. 2005. ”Country Case Studies on Unequal Technology Transfer.” *Working paper.*

[32] Qiu, L.D. 2005. ”China’s Automotive Industry.” *Working paper.*

[33] Rhee, Y.W. 1990. “The Catalyst Model of Development: Lessons from Bangladesh’s Success with Garment Exports.” *World Development,* Vol. 18(2).

[34] Saggi, K. 2002. “Trade, Foreign Direct Investment, and International Technology Transfer: A Survey.” *The World Bank Research Observer,* Vol. 17(2).

[35] *The Quality Drag on China’s Car Industry,* Bloomberg Business Week, viewed 29 June 2007, <http://www.businessweek.com/globalbiz/content/jun2007/gb20070629_028900.htm>

[36] Thompson, E.R. 2003. “Technology Transfer to China by Hong Kong’s Cross-border Garment Firms.” *Developing Economies,* Vol. 41(1).

[37] Toshimitsu, T. 2005. “Tariffs, Quality Choice, and Cost Functions: a Foreign Monopoly Case.” *Review of International Economics,* Vol. 13(2).

[38] UNCTAD. 1992. *World Investment Report.* United Nations Publication, New York.

[39] UNCTAD. 1997. *World Investment Report.* United Nations Publication, New York.

[40] UNCTAD. 2000. *World Investment Report.* United Nations Publication, New York.

[41] *Understanding the WTO: The Agreements. Intellectual Property: Protection and Enforcement,* World Trade Organization, viewed 20 June 2010, <http://www.wto.org/english/thewto_e/whatis_e/tif_e/agrm7_e.htm>

[42] Waldman, M. 1996. “Durable Goods Pricing when Quality Matters.” *Journal of Business,* Vol. 69.

[43] Waldman, M. 1997. “Eliminating the Market for Secondhand Goods: An Alternative Explanation for Leasing.” *Journal of Law and Economics,* Vol. 40(1).

[44] Zigic, K. 1998. "Intellectual Property Rights Violations and Spillovers in North-South Trade." *European Economic Review,* Vol. 42.

[45] Zigic, K. 2000. "Strategic Trade Policy, Intellectual Property Rights Protection, and North-South Trade." *Journal of Development Economics,* Vol. 61.

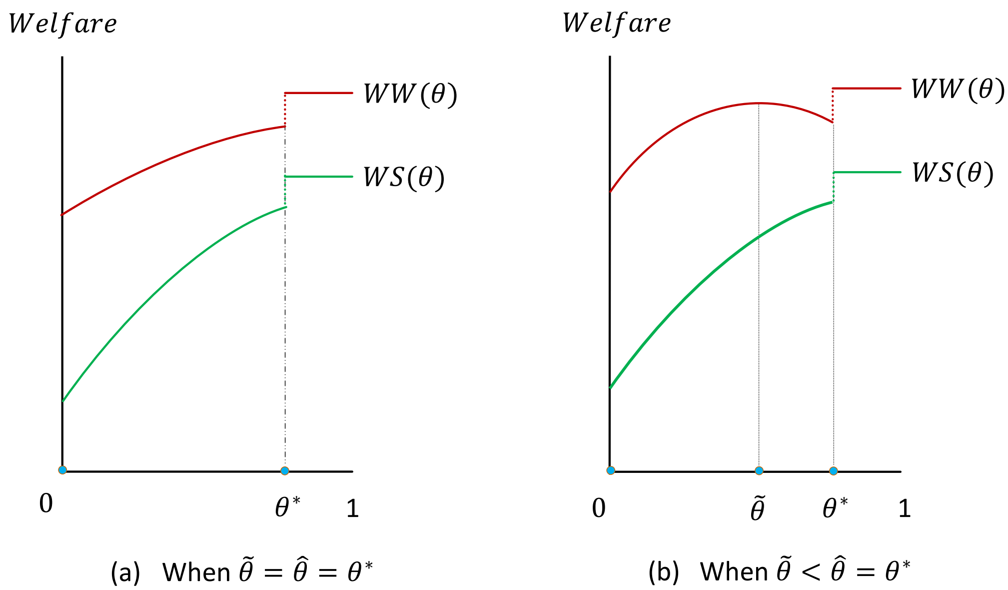

Figure 1: Impacts of IPR policy when FDI reduces Southern welfare