FDI in Post-Production Services and Product Market Competition*

Jota Ishikawa[†]	Hodaka Morita	Hiroshi Mukunoki
Hitotsubashi Univ.	Univ. of New South Wales	Gakushuin Univ.

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Abstract

Post-production services, such as sales, distribution, and maintenance, comprise a crucial element of business activity. A foreign firm faces a higher cost to perform such services than its domestic rival because of the lack of proximity to customers. We explore an international duopoly model in which a foreign firm can reduce its cost for post-production services by foreign direct investment (FDI), or alternatively can outsource such services to its domestic rival. Trade liberalization, if not accompanied by liberalization of service FDI, can hurt domestic consumers and decrease world welfare, but the negative welfare impacts can be mitigated and eventually turned into positive ones as service FDI is also liberalized. This finding yields important policy implications, given the reality that the progress of liberalization in service sectors is limited compared to the substantial progress already made in trade liberalization.

Key words: post-production services, trade liberalization, FDI, outsourcing, international oligopoly

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[†] *Corresponding author*: Faculty of Economics, Hitotsubashi University, Kunitachi, Tokyo 186-8601, Japan; Fax: +81-42-580-8882; E-mail: jota@econ.hit-u.ac.jp

1 Introduction

Business activity does not end with the production of the final product. After production, a variety of business activities such as marketing, sales and distribution, and the provision of maintenance and repair services should be effectively carried out to maximize the value of products that have been produced. This is a widely held view in the strategic management literature. Porter (1985), for example, pointed out that firms' primary activities can be divided into inbound logistics, operations, outbound logistics, marketing and sales, and service. In Porter's classification, *outbound logistics* means activities associated with collecting, storing, and physically distributing the product to buyers, *marketing and sales* means activities associated with providing a means by which buyers can purchase the product and inducing them to do so, and *service* means activities associated with providing service to enhance or maintain the value of the product.

In the present paper, *outbound logistics*, *marketing and sales*, and *service* are together referred to as "*post-production services*." A crucial strategic decision that every producer of final products needs to make is whether to perform post-production services by itself or outsource (some of) them to other firms. Since proximity to customers is a crucial element for post-production services to be carried out effectively, this decision is particularly important in the context of international trade. Foreign producers often outsource post-production services to their domestic rivals. For example, automobiles manufactured by foreign auto-makers are often sold and distributed by their local rivals.[1] Alternatively, foreign producers can establish local affiliates in the domestic market and perform post-production services by themselves (foreign direct investment (FDI) in post-production services).[2]

The objective of this paper is to analyze the provision of post-production services in the context of international trade and to explore its welfare consequences and policy implications.[3] To this end, we explore an international duopoly model in which two firms,

[1]In the Japanese market, examples include Volkswagen-Toyota, Ford-Mazda, Volvo-Subaru, and Peugeot-Suzuki, among others. The following examples are also found in Japan. (i) Several pharmaceutical products produced by Bayer, a German firm, are sold and distributed by its Japanese rivals, Meiji Seika and Kyorin Pharmaceutical. (ii) A Japanese liquor company, Suntory, sells wines, beers, whiskies, brandies, liqueurs, and mineral waters made by foreign companies. (iii) Evian, a mineral water made by French company Danone, is distributed in Japan by a Japanese beverage company, Calpis.

[2]For example, in the late 1980s a number of foreign auto-makers such as BMW, Chrysler, and Mercedes-Benz established their own distribution networks in Japan.

[3]Our approach is fundamentally different from the incomplete contracting approach which has been recently applied to the analysis of vertical structures in the context of international trade. For details,

one domestic and the other foreign, produce differentiated products in their own countries and compete in the domestic market. Post-production services must be performed before a product is consumed. The foreign firm has the option of outsourcing post-production services to its domestic rival by paying royalties or providing those services by itself in the domestic market. In the latter case, however, the variable cost for services is high because of the lack of proximity to the domestic market. This variable cost can be reduced if the foreign firm establishes its own service facilities in the domestic market by incurring a fixed cost for FDI. The connection between production and post-production services, uniquely captured by our model, yields novel welfare consequences and policy implications as outlined below.

Suppose that the tariff rate is initially high, and that the fixed cost for service FDI is also initially high so that the foreign firm chooses to outsource post-production services to its domestic rival. We find, contrary to the conventional result, that a tariff reduction may hurt consumers and reduce world welfare. As in the standard analyses, the direct effect of a tariff reduction is to benefit consumers and the foreign firm, and hurt the domestic firm. In our framework, however, the domestic firm can mitigate the negative effect of a tariff reduction by raising the price it charges the foreign firm for post-production services, and the higher service price hurts consumers. We demonstrate that, from the welfare standpoint, the latter indirect effect can overshadow the former direct effect so that the tariff reduction actually hurts consumers and reduces world welfare in equilibrium. Importantly, a reduction in the fixed cost for service FDI lowers the service price charged by the domestic firm, which in turn mitigates the negative welfare effect of tariff reduction and eventually turns it into a positive effect.

Multilateral negotiations under GATT/WTO have greatly facilitated the liberalization of the trade in goods, and many countries have committed to maintain low levels of tariff rates. However, with respect to the trade in services, although the General Agreements on Trade in Services (GATS) came into effect in 1995 as a result of the GATT Uruguay Round negotiations and has been contributing toward expanding trade in services, the progress is still limited. For instance, only 52 WTO members have made commitments to liberalizing distribution services under GATS (Roy, Marchetti, and Lim, 2006). The limited progress means that foreign firms may still have to incur substantial extra costs for service FDI because of regulatory impediments.[4] Melitz (2003), for ex-

see the second last paragraph of this section.

[4]In his recent study on restrictiveness of FDI, Golub (2003) adopted "obligatory screening and approval procedures" and "restrictions on foreign ownership" as two main restrictions, and found that FDI

ample, pointed out that an exporting firm must set up new distribution channels in the foreign country and conform to all the shipping rules specified by the foreign customs agency, and that, although some of these costs cannot be avoided, others are often manipulated by governments.[5,6] When restrictions on service FDI are high, foreign firms may have to rely on service outsourcing to perform post-production services in domestic markets. In fact, according to OECD (2001), the number of the non-equity form of new cross-border alliances in business services increased from 25 in 1989 to 1097 in 2000.

Our analysis uncovers a previously unnoticed importance of liberalization in the service sector. In our framework, the liberalization of the trade in services reduces the fixed cost of service FDI, and the liberalization of the trade in goods reduces the tariff. We demonstrate that the liberalization of the trade in goods, if not accompanied by the liberalization of service FDI, may hurt consumers and reduce world welfare, and that the negative welfare effect is mitigated and eventually turned into a positive one as the liberalization of service FDI makes progress. In other words, the liberalization of service FDI can convert a welfare-reducing trade liberalization into a welfare-enhancing trade liberalization. Interestingly, the liberalization of service FDI improves welfare even when it does not induce the foreign firm to actually undertake service FDI, because a reduction of the fixed cost of service FDI lowers the service price that the domestic firm can charge. We believe that these are important policy implications, given that post-production services consist of an important subclass of services,[7] and that foreign firms' difficulties in undertaking post-production services in the domestic market have been recently considered to be a serious non-tariff barrier.[8]

Cross-border transactions of services and FDI in services have been previously stud-

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restrictions on business and distribution services are higher than those on manufacturing.

[5]Melitz's argument is based on a number of interviews with managers in Colombian firms making export decisions conducted by Roberts and Tybout (1997).

[6]In the late 80's, Toysrus' retail establishment was delayed in Japan because of the Large-scale Retail Store Low. The United States considered that its application was arbitrary and regarded the low as a typical impediment against service FDI.

[7]Browning and Singelmann (1975), for example, classified services into distribution services, producer services, social services, and personal services, recognizing distribution services (transport, storage, retail, wholesale trade) as an important subclass of services.

[8]For example, in the U.S.-Japan Auto Negotiation in 1995, the U.S. government required the Japanese government to promote the dealership of imported cars by the domestic car producers. Foreign firms' profitability will surely increase if the price they have to pay to outsource post-production services in the local market is reduced. Our analysis, however, indicates that the liberalization of service FDI is equally or even more important not only for increasing foreign firms' profitability but also for benefiting domestic consumers and increasing world welfare.

ied in the trade literature.[9] Recently, several papers have considered market access and distribution, an important example of post-production services, in the context of international trade. Richardson (2004) has shown in a spatial-economy model that the domestic government has an incentive to open the access to retail distribution to foreign manufacturers when tariffs can be used, but it may limit the access when trade policy is not available. Francois and Wooton (2007) assume that sales of imported goods require the domestic distribution services that are supplied under imperfect competition. They have shown that trade volumes and the level of optimal tariff are positively related to the degree of competitiveness in the service sector. In these previous models, production and distribution of goods are assumed to be conducted in different industries. Qiu (2006) has developed a model to study firms' incentives to form cross-border strategic alliances and their choice of entry modes in foreign markets. In his two-country, multi-firm model, each firm's cost of distributing its products in the foreign country is assumed to become lower when the firm forms a strategic alliance with a firm in the foreign country. It should be noted that Qiu uses the term distribution costs to represent all costs incurred after production, which are costs for post-production services in our terminology.

Our paper is related to the previous studies mentioned above in the sense that we also investigate post-production services in the context of international trade. There are, however, some fundamental differences. In our model, the foreign firm determines whether it performs post-production services by itself or outsources them to its domestic rival. This decision is made under the strategic interactions between the foreign firm and the domestic firm, and their strategic interactions in the product market and the provision of post-production services are linked in our model. This linkage, which is uniquely explored in our analysis, in turn yields novel welfare and policy implications for the liberalization of both the trade in goods and service FDI. To our knowledge, our analysis is the first attempt to examine the linkage between FDI in post-production services and product market competition.

Also, our analysis is distinctively different from the incomplete contracting approach that has been recently applied to the analyses of vertical structures in the context of international trade; see Antrás, 2003, 2005; Antrás and Helpman, 2004; Grossman and Helpman, 2004; and Feenstra and Hanson, 2005.[10] Their analyses address the choice between vertical integration and the purchase of a specialized input through contractual

[9] See, for example, Djajić and Kierzkowski (1989), Markusen (1989), Francois (1990), Konan and Maskus (2006), and Wong, Wu, and Zhang (2006) for cross-border transactions of services, and Raff and von der Ruhr (2001) and Markusen, Rutherford, and Tarr (2005) for FDI in services.

[10] See also Spencer (2005) and Helpman (2006) for a recent survey of the literature.

outsourcing, where relationship-specific investments governed by incomplete contracts play a central role. In contrast, as mentioned above, we focus on the connection between production and post-production services in the context of international trade, and examine its welfare and policy implications. Given our focus, we do not address relation-specificity of investment and incompleteness of contracting.

The remainder of the paper is organized as follows: Section 2 develops an international duopoly model that captures the linkage between FDI in post-production services and product market competition, and derives the equilibrium of the model. Section 3 investigates the effects of the liberalization of the trade in goods, the liberalization of FDI for post-production services, and the connection between them. Section 4 elaborates on the policy implications of our findings and explores the robustness of the results. Section 5 summarizes the paper and offers concluding remarks, which include a discussion on the difference between post-production services and intermediate inputs in our framework.

2 The Model

Demands in the home country are characterized by a representative consumer who consumes non-numeráire goods as well as a numeráire good. The non-numeráire goods consist of goods D and F which are imperfect substitutes. The numeráire good is competitively produced and freely traded between countries. The indirect utility function is given by

$$V(p_D, p_F) = \overline{V} - a\,(p_D + p_F) + \frac{(p_F)^2}{2} + \frac{(p_D)^2}{2} - b p_D p_F + Y, \tag{1}$$

where p_D and p_F are the prices of good D and good F respectively, $\overline{V}$ is a positive constant, and Y is the income in the domestic country.[11] By using Roy's identity, the demand for each product i ($\in \{D, F\}$) is given by

$$x_i(p_i, p_j) = a - p_i + b p_j \quad (i, j \in \{D, F\},\ i \neq j) \tag{2}$$

where a (> 0) and $b \in [0, 1)$ respectively represent the market size and the substitutability of the two products. As b gets closer to one, the two products become more similar.

We consider an international duopoly model in which the domestic firm (firm D) and the foreign firm (firm F) engage in Bertrand competition in the domestic market. Firm D produces good D and firm F produces good F. The unit cost of producing goods is

[11] This indirect utility function is derived from a standard quasi-linear utility function given by $U(x_D, x_F, M) = \alpha\,(x_D + x_F) - \beta\{(x_D)^2 + (x_F)^2\}/2 - \gamma x_D x_F + M$ where x_D and x_F denote the consumption of good D and that of good F respectively, and M is the consumption of the numeráire good.

identical across firms and constant, and is denoted by c. An *ad valorem* tariff, t (≥ 0), is imposed on imports of good F.[12] Post-production services must be performed for goods to be consumed. We capture this by assuming that one unit of post-production services must be performed for one unit of goods to be consumed. Assume that firm D has already established its facilities to perform post-production services for good D in the domestic market, and its unit cost for post-production services is constant and given by c_S (> 0).

Also, firm D can perform post-production services for good F at the same unit cost c_S by incurring a fixed cost K_D, which includes costs for suitably adjusting its facilities and learning details on how to effectively perform services for firm F's product.[13] We assume that post-production services can be performed only by good producers (i.e., firms D and F) because of the economy of scope. The qualitative nature of our results is unchanged under an alternative model set-up in which a non-producer of the good can also perform post-production services for good F, but it must incur substantially higher fixed costs than firm D because it needs to learn the basics of the business from scratch. See Subsection 4.2 for robustness of our results under an alternative set-up in which (i) independent service organizations can also perform post-production services for good F without incurring high fixed costs, or (ii) more than one domestic firm exist and can perform post-production services for good F.

On the other hand, if firm F has not established service facilities in the domestic market, its unit service cost is $c_S + m$ ($m > 0$) which is higher than c_S because of the lack of proximity to domestic customers. For example, without maintenance and repair shops in the domestic market, firm F has to ship goods back and forth between two countries to perform maintenance and repair services, and this requires substantial costs for shipping and handling. Similarly, without a marketing and sales subsidiary in the domestic market, firm F's sales representatives have to make frequent business trips to the domestic country, requiring substantial costs for travel time, transportation and accommodation, and travel allowances. Firm F can reduce its unit service cost by establishing local facilities for performing post-production services in the domestic market. In particular, we assume that, if firm F undertakes FDI in post-production services by incurring a fixed investment cost K_F (> 0), its unit service cost is reduced to c_S. Note that the tariff on imports is still effective even if FDI in post-production

[12] See Subsection 4.2 for the case of specific tariffs.

[13] Although it seems natural to assume that firm D incurs the fixed cost K_D, the qualitative nature of our results remain mostly unchanged under an alternative assumption that firm F incurs the fixed cost K_D. See also Subsection 4.2.

services is made, which is in contrast to "tariff-jumping" FDI in production.

In sum, we consider the following three options for firm F to perform post-production services in the domestic market: (i) **No Local Facility**: Firm F performs post-production services at the unit cost $c_S + m$ without establishing its service facilities in the domestic market; (ii) **Service FDI**: Firm F reduces the unit service cost to c_S by incurring a fixed cost K_F to establish its service facilities; or (iii) **Service Outsourcing**: Firm F outsources post-production services to firm D, which incurs a fixed cost K_D and charges a service price (or royalty) of r (> 0) per unit of services.

To simplify mathematical expressions, we set $c_S = 0$.[14] We can express the profits of the two firms as

$$\pi_D(p_D, p_F) = (p_D - c)x_D(p_D, p_F) + \mu\left[r x_F(p_F, p_D) - K_D\right], \tag{3}$$

$$\pi_F(p_F, p_D) = \left[\frac{p_F}{1+t} - c - (1-\lambda)(1-\mu)m - \mu r\right] x_F(p_F, p_D) - \lambda K_F, \tag{4}$$

where $\mu = 1$ if firm F outsources post-production services to firm D and $\mu = 0$ otherwise, and $\lambda = 1$ if firm F makes service FDI and takes $\lambda = 0$ otherwise. Note that when $\lambda = 1$, $\mu = 0$ always holds.

The timing of the game is as follows.

[**Stage 1**]: Firm D determines whether to offer a service price of r (> 0), to which firm D must commit. If r is offered, firm F determines whether to accept the offer. We assume that, if firm F accepts the offer, it commits to outsourcing all post-production services for good F in the domestic market. Under this assumption, we can treat three options – no local facility, service FDI, and service outsourcing – as distinctive alternatives. If firm F rejects the offer, or firm D does not make an offer, firm F determines whether to make FDI in post-production services. See Figure 1 for a game tree that depicts the interaction between firms D and F at Stage 1.

[**Stage 2**]: Firms D and F simultaneously set prices of their own products, and then consumers make purchase decisions.

[Insert Figure 1 around here]

2.1 Product market competition

In this subsection, we derive the equilibria of Stage 2 subgames. The game has three Stage 2 subgames depending on decisions made at Stage 1: (i) **No Local Facility (NLF) subgame**: Firm F performs post-production services without establishing its service

[14] The assumption does not change the qualitative nature of our results.

facilities at Stage 1; (ii) **FDI subgame**: Firm F makes FDI in post-production services at Stage 1; (iii) **Outsourcing (OS) subgame**: Firm F outsources post-production services to firm D at Stage 1.

Throughout our analysis, we assume that the value of a is large enough and the tariff rate t is small enough so that each firm i $(= D,\ F)$ sells a strictly positive amount of good i in the domestic market in the equilibrium. In particular, we assume that the following conditions hold:

Assumption 1: $a > c$ and $t < \bar{t} \equiv \frac{(2+b)\{a-(1-b)c\}-(2-b^2)m}{(2-b^2)(c+m)}$.

Let us begin with the NLF subgame and the FDI subgame. In both subgames, $\mu = 0$ applies in equations (3) and (4). In the second stage, each firm maximizes its own profits. The first-order conditions are given by

$$\begin{aligned}\frac{\partial \pi_D(p_D, p_F)}{\partial p_D} &= x_D(p_D, p_F) + (p_D - c)\frac{\partial x_D(p_D, p_F)}{\partial p_D} = 0,\\ \frac{\partial \pi_F(p_D, p_F)}{\partial p_F} &= \frac{x_F(p_D, p_F)}{1+t} + \left[\frac{p_F}{1+t} - (1-\lambda)m - c\right]\frac{\partial x_F(p_D, p_F)}{\partial p_F} = 0.\end{aligned}$$

By solving these two equations, we can derive the equilibrium prices as:

$$\widetilde{p}_D\,(m, t; \lambda) = \frac{a+c}{2-b} + \frac{b\{ct + (1+t)\,(1-\lambda)m\}}{4-b^2}, \tag{5}$$

$$\widetilde{p}_F\,(m, t; \lambda) = \frac{a+c}{2-b} + \frac{2\{ct + (1+t)\,(1-\lambda)m\}}{4-b^2}. \tag{6}$$

Since the cost of supplying the domestic market is (weakly) higher for firm F than for firm D, we have $\widetilde{p}_F\,(m, t; \lambda) \geq \widetilde{p}_D\,(m, t; \lambda)$. The producer price of good F is given by $\widetilde{p}_F\,(m, t; \lambda)\,/(1+t)$. The equilibrium sales are given by

$$\widetilde{x}_D\,(m, t; \lambda) = \frac{a-(1-b)\,c}{2-b} + \frac{b\{ct + (1-\lambda)\,(1+t)\,m\}}{4-b^2}, \tag{7}$$

$$\widetilde{x}_F\,(m, t; \lambda) = \frac{a-(1-b)\,c}{2-b} - \frac{\left(2-b^2\right)\{ct + (1-\lambda)\,(1+t)\,m\}}{4-b^2}. \tag{8}$$

Note that we have $\widetilde{x}_D\,(m, t; \lambda) > 0$ and $\widetilde{x}_F\,(m, t; \lambda) > 0$ by Assumption 1.

Since $\lambda = 0$ in the NLF subgame, the equilibrium prices, sales, and profits in that subgame are respectively given by $p_D^{NLF} \equiv \widetilde{p}_D\,(m, t; 0)$, $p_F^{NLF} \equiv \widetilde{p}_F\,(m, t; 0)$, $x_D^{NLF} \equiv \widetilde{x}_D\,(m, t; 0)$, $x_F^{NLF} \equiv \widetilde{x}_F\,(m, t; 0)$, $\pi_D^{NLF} \equiv \pi_D(p_D^{NLF}, p_F^{NLF}) = (p_D^{NLF} - c)^2$, $\pi_F^{NLF} \equiv \pi_F(p_F^{NLF}, p_D^{NLF}) = \{p_F^{NLF} - (1+t)\,(c+m)\}^2/\,(1+t)$. Similarly, the equilibrium prices, sales, and profits in the FDI subgame are respectively given by $p_D^{FDI} \equiv \widetilde{p}_D\,(m, t; 1)$, $p_F^{FDI} \equiv \widetilde{p}_F\,(m, t; 1)$, $x_D^{FDI} \equiv \widetilde{x}_D\,(m, t; 1)$, $x_F^{FDI} \equiv \widetilde{x}_F\,(m, t; 1)$, $\pi_D^{FDI} \equiv \pi_D(p_D^{FDI}, p_F^{FDI}) = (p_D^{FDI} - c)^2$, $\pi_F^{FDI} \equiv \pi_F(p_F^{FDI}, p_D^{FDI}) = \{p_F^{FDI} - (1+t)\,c\}^2/\,(1+t) - K_F$.

Also, consumer surplus, domestic welfare, and world welfare in the equilibrium of these subgames are respectively given by $CS^k \equiv V(p_D^k, p_F^k) - Y$, $W^k \equiv CS^k + \pi_D^k + tp_F^k x_F^k/(1+t)$, and $WW^k \equiv W^k + \pi_F^k$, where $k = NLF$ or FDI.

Next turn to the OS subgame, where $\mu = 1$ and $\lambda = 0$ apply. In the remainder of this subsection, we consider the case in which the service price r is small enough for each firm i $(= D,\ F)$ to sell a strictly positive amount of good i in the domestic market in the equilibrium. In the second stage, each firm maximizes its profits with respect to its price given the service price, r, set by firm D in the first stage. The first-order conditions become

$$\begin{aligned}
\frac{\partial \pi_D}{\partial p_D} &= x_D(p_D, p_F) + (p_D - c)\frac{\partial x_D(p_D, p_F)}{\partial p_D} + r\frac{\partial x_F(p_F, p_D)}{\partial p_D} = 0, \\
\frac{\partial \pi_F}{\partial p_F} &= \frac{x_F(p_D, p_F)}{1+t} + \left[\frac{p_F}{1+t} - r - c\right]\frac{\partial x_F(p_D, p_F)}{\partial p_F} = 0.
\end{aligned}$$

By solving these equations, we find the equilibrium prices in the OS subgame as:

$$\widehat{p}_D(r,t) = \frac{a+c}{2-b} + \frac{(3+t)\,br}{4-b^2} \equiv p_D^{OS}, \tag{9}$$

$$\widehat{p}_F(r,t) = \frac{a+c}{2-b} + \frac{\{2(1+t)+b^2\}r + 2ct}{4-b^2} \equiv p_F^{OS}. \tag{10}$$

The equilibrium consumer surplus is given by $\widehat{CS}(r,t) = V(p_D^{OS}, p_F^{OS}) - Y \equiv CS^{OS}$, and it is decreasing in each good's price. Since both prices are increasing in r, a rise of the service price reduces the equilibrium consumer surplus with given t.

Lemma 1 *In the equilibrium of the Outsourcing subgame, a rise in the service price increases the prices of both goods and reduces the consumer surplus, holding the tariff rate fixed.*

Proof. Since $\partial p_j^{OS}/\partial r > 0$ $(j = \{D, F\})$ and $\partial V(p_D, p_F)/\partial p_j = -x_j < 0$, we have $\partial CS^{OS}/\partial r < 0$. ■

Also, we find that the equilibrium sales are

$$\widehat{x}_D(r,t) = \frac{a-(1-b)c}{2-b} - \frac{b\{(1-b^2)\,r - (c+r)\,t\}}{4-b^2} \equiv x_D^{OS}, \tag{11}$$

$$\widehat{x}_F(r,t) = \frac{a-(1-b)c}{2-b} - \frac{2(1-b^2)\,r + (2-b^2)(c+r)\,t}{4-b^2} \equiv x_F^{OS}. \tag{12}$$

Note that, given Assumption 1, $x_D^{OS} > 0$ and $x_F^{OS} > 0$ hold when r is small enough. The effect of an increase in r on x_F^{OS} is always negative whereas the effect on x_D^{OS} is ambiguous: an increase in r shifts demands from good F to good D, but it gives firm D an incentive to raise the price of good D. The first effect increases x_D^{OS}, while the second effect decreases it. Thus, the overall effect on x_D^{OS} is ambiguous.

The equilibrium profits of firms D and F are respectively given by

$$\widehat{\pi}_D(r,t) = (p_D^{OS}-c)^2 + r\{p_F^{OS} - b(p_D^{OS}-c) - (1+t)(c+r)\} - K_D \equiv \pi_D^{OS}, \quad (13)$$

$$\widehat{\pi}_F(r,t) = \frac{\{p_F^{OS} - (1+t)(c+r)\}^2}{(1+t)} \equiv \pi_F^{OS}. \quad (14)$$

Also, domestic welfare and world welfare are respectively given by $\widehat{W}(r,t) = CS^{OS} + \pi_D^{OS} + tp_F^{OS}x_F^{OS}/(1+t) \equiv W^{OS}$ and $\widehat{WW}(r,t) = W^{OS} + \pi_F^{OS} \equiv WW^{OS}$.

Lemma 2 *In the equilibrium of the Outsourcing subgame, a rise in the service price reduces firm F's profit and world welfare, holding the tariff rate fixed.*

Proof. By (14) and $\partial\{p_F^{OS}-(1+t)(c+r)\}/\partial r = -\{\left(2-b^2\right)t + 2\left(1-b^2\right)\}/(4-b^2) < 0$, we have $\partial\pi_F^{OS}/\partial r < 0$. We also have $\partial WW^{OS}/\partial r = -[(1-b^2)\{(2+b)^2(a-c+bc)+(4+5b^2)r\} + t(1-b)\{a(2+b)^2 + 2(2+2b+b^2)bc + 2(1+b)\left(4+b^2\right)r\} + (4-3b^2)(c+r)t^2]/(4-b^2)^2 < 0$. ■

An increase in r increases firm F's service cost and thereby decreases its profit. Although whether it increases or decreases firm D's profit and domestic welfare is ambiguous, it necessarily decreases world welfare since its damages to consumers and firm F always dominate the possible benefits of firm D as well as domestic welfare.

2.2 Equilibrium of the entire game

We now derive the equilibrium of the entire game. For expositional simplicity, we adopt the following tie-breaking rules: (i) If firm F is indifferent between accepting and rejecting a service price r offered by firm D at stage 1, firm F accepts it. (ii) If firm D is indifferent between offering and not offering r, firm D does not offer it. (iii) If firm F is indifferent between making and not making a service FDI, firm F makes it. Note that, since π_F^{FDI} is strictly decreasing in K_F while π_F^{NLF} is independent of K_F and $\pi_F^{FDI} > \pi_F^{NLF}$ holds when $K_F = 0$, there exists a unique value K_F' (> 0) such that $\pi_F^{FDI} \geq \pi_F^{NLF}$ if $K_F \leq K_F'$ and $\pi_F^{NLF} > \pi_F^{FDI}$ if $K_F > K_F'$.

Recall that firm F's profit in the Outsourcing subgame, $\widehat{\pi}_F(r,t)$, is strictly decreasing in the service price r. Also, if firm F does not accept r offered by firm D (or if firm D does not offer any service price), then firm F's subsequent equilibrium profit is

$\max[\pi_F^{NLF}, \pi_F^{FDI}]$, which is independent of r. This implies that firm F accepts service price r at Stage 1 if and only if $r \leq \bar{r}$ holds, where $\bar{r}$ (> 0) denotes the maximum acceptable service price. Note that $\bar{r}$ is uniquely determined by $\widehat{\pi}_F(\bar{r}, t) = \max[\pi_F^{NLF}, \pi_F^{FDI}]$. Assumption 1 implies $\max[\pi_F^{NLF}, \pi_F^{FDI}] > 0$, and hence $\widehat{\pi}_F(\bar{r}, t) > 0$. This in turn implies that each firm i ($= D$, F) sells a strictly positive amount of good i in the domestic market in the equilibrium of the Outsourcing subgame for all $r \in [0, \bar{r}]$.

We have the effect of an increase in r on firm D's equilibrium profit in the Outsourcing subgame, π_D^{OS}, as

$$\begin{aligned} \frac{\partial \pi_D^{OS}}{\partial r} &= 2(p_D^{OS} - c)\frac{\partial p_D^{OS}}{\partial r} + r\left[\frac{\partial p_F^{OS}}{\partial r} - b\frac{\partial p_D^{OS}}{\partial r} - (1+t)\right] \\ &\quad + \left[p_F^{OS} - b(p_D^{OS} - c) - (1+t)(c+r)\right]. \end{aligned} \tag{15}$$

Since an increase in r raises p_F^{OS} and thereby raises p_D^{OS}, it increases firm D's profits in the product market. The first term of (15) represents this strategic effect and it is positive. Although an increase in r increases firm D's per unit profit from performing post-production services for firm F, it also decreases the imports of good F. Hence, the change in firm D's profit from performing post-production services for firm F, represented in the sum of the second and the third terms, has an ambiguous sign.

In what follows, we focus our analysis on the range of parameterizations in which $\partial \pi_D^{OS}/\partial r > 0$ holds for all $r \leq \bar{r}$. Under this condition, if firm D offers its service price so that the offer is accepted by firm F, firm D offers the maximum acceptable price $r = \bar{r}$. This condition is satisfied when the market size, a, is sufficiently large, or the substitutability of products, b, is sufficiently high.[15]

We classify the equilibrium of the entire game as follows: (i) **No Local Facility (NLF) equilibrium**: Firm F performs post-production services without establishing its service facilities in the domestic market at Stage 1; (ii) **FDI equilibrium**: Firm F makes FDI in post-production services in the domestic market at Stage 1; (iii) **Outsourcing (OS) equilibrium**: Firm F outsources post-production services to firm D at Stage 1.

Proposition 1 characterizes the equilibrium, and Figure 2 provides a diagrammatic representation of the proposition.

Proposition 1 *The game has a unique equilibrium for any given parameterization. There exists a threshold K_D' such that the equilibrium is characterized by (i) and (ii) below.*

[15] See the Appendix for details. We have found that the qualitative nature of the results is mostly unchanged without imposing this condition. Without this condition, however, the analysis becomes substantially complex without adding new insights.

(i) Suppose $K_F \leq K'_F$. Then the equilibrium is an Outsourcing equilibrium if $K_D \leq K'_D$ and an FDI equilibrium if $K_D > K'_D$, where K'_D is strictly increasing in K_F for all $K_F \in (0, K'_F]$.
(ii) Suppose $K_F > K'_F$. Then the equilibrium is an Outsourcing equilibrium if $K_D \leq K'_D$ and a No Local Facility equilibrium if $K_D > K'_D$, where K'_D is independent of K_F for all $K_F > K'_F$.

Proof: See Appendix.

[Insert Figure 2 around here]

Proposition 1 and Figure 2 can be explained as follows: First consider the case of $K_F \leq K'_F$, which implies $\pi_F^{FDI} \geq \pi_F^{NLF}$. The maximum acceptable service price $\bar{r}$ is then determined by $\widehat{\pi}_F(\bar{r}, t) = \pi_F^{FDI}$, which gives

$$\bar{r} = \frac{\alpha - \sqrt{\alpha^2 - (4 - b^2)^2 (1 + t) K_F}}{(2 - b^2) t + 2 (1 - b^2)} \tag{16}$$

where $\alpha \equiv (2 + b) \{a - (1 - b) c\} - (2 - b^2) ct$. If $\hat{\pi}_D(\bar{r}, t) > \pi_D^{FDI}$, firm D offers $r = \bar{r}$ at Stage 1, and the equilibrium of the entire game is an Outsourcing equilibrium. On the other hand, if $\hat{\pi}_D(\bar{r}, t) \leq \pi_D^{FDI}$, firm D does not offer r at Stage 1, and the equilibrium is an FDI equilibrium. Given that $\widehat{\pi}_D(\bar{r}, t)$ is strictly decreasing in K_D while π_D^{FDI} is independent of K_D, there exists a threshold, denoted K'_D, such that $\hat{\pi}_D(\bar{r}, t) > \pi_D^{FDI}$ if $K_D < K'_D$, while $\hat{\pi}_D(\bar{r}, t) \leq \pi_D^{FDI}$ otherwise. We have that the threshold K'_D is strictly increasing in K_F for all $K_F \in (0, K'_F]$: as the fixed cost of service FDI, K_F, increases, the maximum acceptable service price $\bar{r}$ increases. This in turn increases $\hat{\pi}_D(\bar{r}, t)$, resulting in an increase in the threshold K'_D.

Next consider the case of $K_F > K'_F$. This implies $\pi_F^{FDI} < \pi_F^{NLF}$, and hence $\bar{r}$ is determined by $\widehat{\pi}_F(\bar{r}, t) = \pi_F^{NLF}$, which gives

$$\bar{r} = \frac{(2 - b^2)(1 + t) m}{(2 - b^2) t + 2 (1 - b^2)} \equiv \hat{r}(m, t). \tag{17}$$

Through an analogous procedure, we find that, if $K_D < K'_D$, $\widehat{\pi}_D(\bar{r}, t) > \pi_D^{NLF}$ holds and the equilibrium is an Outsourcing equilibrium, while, if $K_D \geq K'_D$, $\widehat{\pi}_D(\bar{r}, t) \leq \pi_D^{NLF}$ holds and the equilibrium is a No Local Facility equilibrium. In this case, $\bar{r}$ is independent of K_F (because π_F^{NLF} is independent of K_F), which implies that the threshold K'_D is independent of K_F. Note that the threshold K'_D, when it is viewed as a function of K_F, is discontinuous at $K_F = K'_F$ (see Figure 2). This is because the value of firm D's outside option jumps up from π_D^{FDI} to π_D^{NLF} while its gains from service outsourcing increase continuously as K_F increases (see Appendix for details).

The following Corollary is useful for the analysis in the next section.

Corollary 1 *For any given $K_D < K'_D|_{K_F=K'_F}$, there exists a value $K''_F \in (0, K'_F)$ such that the equilibrium is an Outsourcing equilibrium if $K_F \in (K''_F, K'_F)$ while it is an FDI equilibrium if $K_F \in (0, K''_F]$.*

3 Liberalization of goods trade and service FDI

This section investigates the effects of the liberalization of the trade in goods, liberalization of FDI for post-production services, and the connection between them. In our analysis, trade liberalization is represented by a reduction in the tariff rate, t, and liberalization of service FDI is represented by a reduction in the fixed cost of service FDI, K_F. Let $t_0 \in (0, \bar{t}]$ denote the tariff rate before trade liberalization, and K_F^0 (> 0) denote the fixed cost of service FDI before liberalization of service FDI. Assume that $K_F^0 > K'_F$ for all $t \in [0, t_0]$.[16] That is, the pre-liberalization level of K_F is so high that, if firm D does not offer service price r at Stage 1, firm F does not invest in service FDI in the subsequent equilibrium for any given $t \in [0, t_0]$.

As mentioned in the Introduction, the trade liberalization of goods has recently made substantial progress through multilateral negotiations under GATT/WTO, while the progress of liberalization in service sectors has been slow so far. Given this, we first investigate the effects of tariff reduction, holding K_F fixed at the pre-liberalization level K_F^0. We then investigate the effects of the liberalization of service FDI, showing that the liberalization of service FDI can convert a welfare-reducing trade liberalization into a welfare-enhancing trade liberalization. Also, in Subsection 3.3 we analyze the effects of tariff reduction when K_F is endogenously determined, and consider the effects of the liberalization of service FDI in this setup.

3.1 Outsourcing equilibrium as the pre-liberalization equilibrium

In this subsection, we consider the case of $K_D < K'_D|_{t=t_0}$, so that the pre-liberalization equilibrium is an Outsourcing equilibrium. We find that K'_D is strictly decreasing in

[16]We find that K'_F is strictly decreasing in t for all $t \in [0, \bar{t}]$ (see the proof of Proposition 1 in the Appendix). Given this, we assume $K_F^0 > K'_F|_{t=0}$.

t for all $t \in [0, \bar{t}]$ if $K_F > K'_F$.[17] Hence, $K_D < K'_D|_{t=t_0}$ implies that $K_D < K'_D$ for all $t \in [0, t_0]$. That is, holding K_F fixed at K_F^0, the equilibrium of the game is an Outsourcing equilibrium for all $t \in [0, t_0]$. In Figure 3, Point A represents the pre-liberalization equilibrium that we consider in this subsection, where the shifts of K'_D and K'_F depict effects of tariff reduction.[18] The case of $K_D > K'_D|_{t=t_0}$ (Point B in Figure 3) will be discussed in the next subsection.

[**Insert Figure 3 around here**]

First, we fix K_F at K_F^0 and investigate the effects of tariff reduction. Since the equilibrium of the game with $K_F = K_F^0$ is an Outsourcing equilibrium for all $t \in [0, t_0]$, the equilibrium prices of goods D and F are p_D^{OS} and p_F^{OS} respectively, and firm D charges $r = \bar{r} = \hat{r}(m, t)$ in the equilibrium. We find that

$$\frac{\partial \hat{r}(m,t)}{\partial t} = -\frac{\{(2-b^2)b^2 m}{\{(2-b^2)\,t + 2\,(1-b^2)\}^2} < 0$$

for all $t \in [0, t_0]$. That is, holding $K_F = K_F^0$ fixed, the trade liberalization of goods increases the equilibrium service price charged by firm D.

The logic behind this result can be explained as follows. Consider an Outsourcing subgame. Suppose good D's price is lowered, holding good F's price as fixed. Firm D's profit from performing post-production services for firm F then becomes lower, because firm F sells less due to good D's lower price. Because of this effect, firm D's incentive to increase its sales by lowering good D's price is weaker in the Outsourcing subgame than in the No Local Facility subgame. This implies that product market competition becomes weaker if firm F outsources post-production services by accepting a service price r offered by firm D if r is sufficiently high.[19]

Now suppose firm D offers $r = m$; that is, the service price r is equal to firm F's unit cost for performing post-production services without establishing local facilities. If firm F rejects this offer, its unit service cost is m since firm F does not invest in service FDI given $K_F = K_F^0 > K'_F$. Firm F is then strictly better off by accepting the offer $r = m$, because service outsourcing at $r \geq m$ weakens product market competition. Consequently, firm F accepts $r = \hat{r}(m, t) > m$ in the equilibrium, and this in turn implies

[17] We find that if $K_F > K'_F$, K'_D is decreasing in t for all $t \in [0, t_0]$ (see the proof of Proposition 1 in the Appendix). If $K_F < K'_F$, on the other hand, K'_D is either decreasing or increasing in t.

[18] Figure 3 depicts the case in which K'_D is decreasing in t for $K_F < K'_F$. The qualitative nature of the results would be unchanged if K'_D is increasing in t for $K_F < K'_F$.

[19] For product market competition to become weaker, $r \geq m$ is sufficient but not necessary. That is, even if $r < m$, product market competition can still become weaker when r is sufficiently close to m.

that the equilibrium price of good F, p_F^{OS}, is higher than the price firm F would charge in the equilibrium of the No Local Facility subgame, p_F^{NLF}. That is, we have $p_F^{OS} > p_F^{NLF}$ because service outsourcing at the service price $r = \hat{r}(m,t)$ weakens product market competition.

Let us now turn to the effect of a tariff reduction from t to $t-\Delta$ on the equilibrium service price. In general, the burden of *ad valorem* tariff increases with the price level. That is, given $p_F^{OS}/(1+t) > p_F^{NLF}/(1+t)$, a tariff reduction increases firm F's producer price, and consequently firm F's profit as well, more in the OS equilibrium than in the NLF equilibrium, holding the service price $r = \hat{r}(m,t)$ fixed. In other words, a tariff reduction benefits firm F more in the Outsourcing equilibrium than in the No Local Facility equilibrium. This increases the maximum acceptable service price, and firm D can increase the service price r from $r = \hat{r}(m,t)$ to $r = \hat{r}(m,t-\Delta)$ in order to absorb a part of firm F's gain from the tariff reduction.

We call this effect the *profit-absorbing motive* of a service price change, which results in $\partial\hat{r}(m,t)/\partial t < 0$. Note that $\hat{r}(m,t)$ is convex in t, so the degree of an increase in $\hat{r}(m,t)$ by a tariff reduction gets larger as the initial tariff rate gets smaller.

Concerning the effects of tariff reduction on equilibrium consumer prices p_D^{OS} and p_F^{OS}, we have

$$\begin{aligned}
\frac{\partial\, p_D^{OS}\big|_{r=\hat{r}(m,t)}}{\partial t} &= \frac{b\hat{r}(m,t)}{4-b^2} + \frac{(3+t)\,b}{4-b^2}\left(\frac{\partial\hat{r}(m,t)}{\partial t}\right), \\
\frac{\partial\, p_F^{OS}\big|_{r=\hat{r}(m,t)}}{\partial t} &= \frac{2\,(c+\hat{r}(m,t))}{4-b^2} + \frac{2\,(1+t)+b^2}{4-b^2}\left(\frac{\partial\hat{r}(m,t)}{\partial t}\right).
\end{aligned}$$

Since $\partial\hat{r}(m,t)/\partial t < 0$, the signs of the above equations are ambiguous. Although a tariff reduction directly reduces the commodity prices by reducing costs of firm F, it raises them through the indirect effect caused by an increase in the service price. If the latter effect dominates the former, a tariff reduction increases equilibrium consumer prices. This can indeed be the case, as shown by Lemma 3.

Lemma 3 *Holding K_F fixed at K_F^0, there exist critical values t' (>0), b' (>0), and ζ' (>0) such that $\partial p_D^{OS}/\partial t < 0$ holds if and only if $t < t'$, $b > b'$, and $c/m < \zeta'$. There also exist critical values $t''(< t')$, $b''(> b')$, and $\zeta''(< \zeta')$ such that $\partial p_D^{OS}/\partial t < 0$ and $\partial p_F^{OS}/\partial t < 0$ hold if and only if $t < t''$, $b > b''$, and $c/m < \zeta''$.*

Lemma 3 indicates that, if K_F is fixed at K_F^0, a tariff reduction may hurt consumers and reduce world welfare by increasing equilibrium consumer prices. Proposition 2 formalizes this by investigating how the trade liberalization of goods, if not accompanied by the liberalization of FDI for post-production services, affects consumers, world welfare, and firms' profitability. In what follows, let $CS(K_F, t)$, $WW(K_F, t)$, $\pi_D(K_F, t)$, and $\pi_F(K_F, t)$, respectively, denote consumer surplus, world welfare, firm D's profit, and firm F's profit in the equilibrium of the entire game. Note that, since both π_F^{NLF} and π_F^{FDI} are decreasing in t and $\pi_F(K_F, t) = \max[\pi_F^{NLF}, \pi_F^{FDI}]$ in equilibrium, $\partial \pi_F(K_F, t)/\partial t < 0$ always holds.

Proposition 2 *Holding K_F fixed at K_F^0, there exists a range of parameterizations in which a tariff reduction hurts consumers, decreases world welfare, and benefits firm D. More precisely, $\partial CS(K_F, t)/\partial t > 0$, $\partial WW(K_F, t)/\partial t > 0$, and $\partial \pi_D(K_F, t)/\partial t < 0$ hold if $t < t''$, $b > b''$, and $c/m < \zeta''$.*

Holding K_F fixed at K_F^0, a tariff reduction induces firm D to increase its service price driven by the *profit-absorbing motive*, and Lemma 3 tells us that this can in turn increase equilibrium consumer prices. This is the driving force of the negative welfare effects of the trade liberalization of goods when it is not accompanied by the liberalization of service FDI. In particular, Proposition 2 tells us that a tariff reduction necessarily hurts consumers, decreases world welfare, and benefits firm D, if it increases equilibrium prices of both goods D and F (i.e., if $t < t''$, $b > b''$, and $c/m < \zeta''$).[20] Note that this condition is sufficient but not necessary. The negative welfare effects may persist when a tariff reduction increases good D's price but decreases good F's price. That is, consumers are worse off when the negative effect of the tariff reduction due to an increase in good D's price outweighs its positive effects because of a decrease in good F's price.[21]

Next we consider the effects of the liberalization of service FDI, represented by a reduction in K_F from K_F^0, holding the tariff rate fixed. Since $K_D < K_D'$ for all $t \in [0, t_0]$, Corollary 1 tells us (see also Figures 2 and 3) that for any given $t \in [0, t_0]$, there exists a value $K_F'' \in [0, K_F')$ such that the equilibrium of the entire game is an Outsourcing equilibrium if $K_F > K_F''$ and an FDI equilibrium if $K_F \leq K_F''$.

Proposition 3 tells us that, holding the tariff rate fixed, liberalization of service FDI benefits consumers, increases world welfare, and hurts firm D, at least weakly. See Figure 4 for a diagrammatic representation of the proposition.

[20] In international oligopoly models, import tariffs have strategic effects that cause rent-shifting, and hence the welfare of domestic country, $W(K_F, t)$, can be either increasing or decreasing in t even if $\partial CS(K_F, t)/\partial t > 0$ holds. Since $\partial \pi_F(K_F, t)/\partial t < 0$ is always satisfied, however, $\partial W(K_F, t)/\partial t > 0$ holds whenever $\partial WW(K_F, t)/\partial t > 0$ holds.

[21] Also, even when a tariff reduction decreases the prices of both goods D and F, firm D's profit may still increase because of the higher service price it can charge.

Proposition 3 *For any given* $t \in [0, t_0]$, $CS(K_F, t)$, $WW(K_F, t)$, *and* $\pi_F(K_F, t)$ *are decreasing in* K_F *while* $\pi_D(K_F, t)$ *is increasing in* K_F *for all* $K_F \in (0, K_F^0]$, *with the following properties:*
(i) $\partial CS(K_F, t)/\partial K_F = 0$ *for all* $K_F < K_F''$, $\partial CS(K_F, t)/\partial K_F < 0$ *for all* $K_F \in (K_F'', K_F')$, *and* $\partial CS(K_F, t)/\partial K_F = 0$ *for all* $K_F > K_F'$.
(ii) $\partial WW(K_F, t)/\partial K_F < 0$ *for all* $K_F < K_F''$, $\partial WW(K_F, t)/\partial K_F < 0$ *for all* $K_F \in (K_F'', K_F')$, *and* $\partial WW(K_F, t)/\partial K_F = 0$ *for all* $K_F > K_F'$.
(iii) $\partial \pi_F(K_F, t)/\partial K_F < 0$ *for all* $K_F < K_F''$, $\partial \pi_F(K_F, t)/\partial K_F < 0$ *for all* $K_F \in (K_F'', K_F')$, *and* $\partial \pi_F(K_F, t)/\partial K_F = 0$ *for all* $K_F > K_F'$.
(iv) $\partial \pi_D(K_F, t)/\partial K_F = 0$ *for all* $K_F < K_F''$, $\partial \pi_D(K_F, t)/\partial K_F > 0$ *for all* $K_F \in (K_F'', K_F')$, *and* $\partial \pi_D(K_F, t)/\partial K_F = 0$ *for all* $K_F > K_F'$.

[Insert Figure 4 around here]

A reduction in K_F has pro-competitive effects when it reduces the equilibrium service price $\bar{r}$ charged by firm D because a reduction in the service price intensifies the competition between firms D and F in the product market. Recall that $\pi_F^{FDI} \geq \pi_F^{NLF}$ if and only if $K_F \leq K_F'$. If $K_F \in (K_F'', K_F']$, a reduction in K_F increases π_F^{FDI}, which in turn decreases the maximum acceptable service price $\bar{r}$ because $\bar{r}$ is determined by $\widehat{\pi}_F(\bar{r}, t) = \pi_F^{FDI}$ in this case. Hence a reduction in K_F benefits consumers and increases world welfare in the interval $(K_F'', K_F']$.[22] It is interesting to note that, in this interval, a reduction in K_F yields pro-competitive consequences even though the reduction in K_F does not induce firm F to actually invest in service FDI in the equilibrium. At $K_F = K_F''$, firm F invests in service FDI, and this increases the consumer surplus and world welfare in a discontinuous manner (see Figure 4). Beyond this point, further reduction in K_F in the interval $(0, K_F'')$ has no effects on firm D's profit and consumer surplus, though it increases world welfare by increasing firm F's profit.

We now explore the connection between trade liberalization of goods and liberalization of service FDI. Proposition 2 tells us that there exists a range of parameterizations in which $CS(K_F^0, t_1) < CS(K_F^0, t_0)$ and $WW(K_F^0, t_1) < WW(K_F^0, t_0)$ hold, where $0 \leq t_1 < t_0 \leq \bar{t}$. That is, holding K_F fixed at K_F^0, trade liberalization represented by the reduction in tariff rate from t_0 to t_1 can hurt consumers and reduce world welfare. Proposition 4 below tells us that the negative welfare effects of the tariff reduction from

[22] In the interval $(K_F', K_F^0]$, a reduction in K_F has no impacts, because $\bar{r}$ is determined by $\widehat{\pi}_F(\bar{r}, t) = \pi_F^{NLF}$, where a change in K_F has no effect on this equation.

t_0 to t_1 disappear and turn into positive ones when K_F is reduced to a sufficiently low level by the liberalization of service FDI.

Proposition 4 *Take any parameterization in which* $CS(K_F^0, t_1) < CS(K_F^0, t_0)$ *and* $WW(K_F^0, t_1) < WW(K_F^0, t_0)$ *hold, where* $0 \leq t_1 < t_0 \leq \bar{t}$. *Note that* K_F' *and* K_F'' *are evaluated at* $t = t_1$ *in (i) and (ii) below.*
(i) There exists a unique $\tilde{K}_F^{CS} \in [K_F'', K_F')$ *such that* $CS(K_F, t_1) > CS(K_F, t_0)$ *for all* $K_F \in (0, \tilde{K}_F^{CS})$*, where* $K_F'' < \tilde{K}_F^{CS}$ *holds under a range of parameterizations.*
(ii) There exists a unique $\tilde{K}_F^{WW} \in [K_F'', K_F')$ *such that* $WW(K_F, t_1) > WW(K_F, t_0)$ *for all* $K_F \in (0, \tilde{K}_F^{WW})$*, where* $K_F'' < \tilde{K}_F^{WW}$ *holds under a range of parameterizations.*

The logic behind Proposition 4 can be explained as follows: Let us consider what happens when liberalization of service FDI reduces K_F from $K_F = K_F^0$. The reduction does not affect the equilibrium service price and has no welfare effects, as long as $K_F > K_F'$ holds. Once K_F becomes smaller than K_F', further reduction in K_F reduces the maximum acceptable service price $\bar{r}$, resulting in a lower equilibrium service price. The lower service price intensifies the competition between firms D and F in the product market, mitigating the negative welfare effects of tariff reduction. Interestingly, the liberalization of service FDI can convert a welfare-reducing tariff reduction into a welfare-enhancing tariff reduction even if the reduction of K_F does not induce firm F to actually make service FDI. In particular, if K_F is reduced from $K_F = K_F^0$ to $K_F \in (K_F'', \min[\tilde{K}_F^{CS}, \tilde{K}_F^{WW}])$, then the tariff reduction from t_0 to t_1 benefits consumers and increase world welfare even though K_F is not low enough for firm F to make service FDI.

As Proposition 5 below tells us, when the liberalization of service FDI reduces K_F to a sufficiently low level so that firm F actually makes service FDI in the equilibrium, any tariff reduction has positive welfare effects.

Proposition 5 *Under an FDI equilibrium, a tariff reduction necessarily benefits consumers, hurts firm D, and increases world welfare. More precisely,* $\partial CS\left(K_F, t\right)/\partial t < 0$, $\partial \pi_D\left(K_F, t\right)/\partial t > 0$, *and* $\partial WW\left(K_F, t\right)/\partial t < 0$ *hold for all* $K_F < K_F''$.

3.2 No Local Facility equilibrium as the pre-liberalization equilibrium

This subsection discusses the case of $K_D > K_D'|_{t=t_0}$, so that the pre-liberalization equilibrium is a No Local Facility equilibrium. As in the previous section, consider a reduction in tariff from t_0 to t_1 ($0 \leq t_1 < t_0 \leq \bar{t}$), holding K_F fixed at K_F^0. There are two subcases. One subcase is $K_D > K'_D|_{t=t_1}$ ($> K'_D|_{t=t_0}$), where trade liberalization does not change the nature of the equilibrium. That is, the equilibrium of the game is a No Local Facility equilibrium not only before but also after the tariff reduction. In the No Local Facility equilibrium, firm F does not outsource post-production services to firm D, and hence the *profit-absorbing motive* of a service price change, which was identified in the previous subsection as the source of the negative welfare effects of trade liberalization, is not relevant here. This implies that trade liberalization has standard welfare effects of benefiting consumers and increasing world welfare in this subcase.

The other subcase is $K'_D|_{t=t_1} > K_D > K'_D|_{t=t_0}$, where trade liberalization changes the nature of the equilibrium from a No Local Facility equilibrium to an Outsourcing equilibrium (see Point B in Figure 3). Recall that outsourcing of post-production services weakens the competition between firms D and F in the product market. Because of this effect, we find that the tariff reduction from t_0 to t_1 can have negative welfare effects as depicted in Figure 5. As in Proposition 4, the negative welfare effects of trade liberalization disappear and turn into positive ones when trade liberalization is accompanied by the liberalization of service FDI.

[Insert Figure 5 around here]

3.3 Effects of trade liberalization with endogenous FDI costs

Thus far we have explored the effects of liberalization of goods trade and service FDI by treating the tariff rate and the fixed cost of service FDI as exogenous variables. As discussed in the Introduction, many countries have committed to maintain low levels of tariff rates under GATT/WTO multilateral agreements. Consequently, for many countries it is no longer possible to use tariffs as flexible policy instruments to enhance domestic welfare. In contrast, concerning service FDI, the limited progress of GATS means that countries can still manipulate the inflows of service FDI by raising the levels of regulatory impediments. In this subsection, we investigate the effects of trade liberalization (a reduction of tariff rate from t_0 to t_1) with endogenous FDI costs by assuming that the domestic government chooses K_F to maximize the domestic welfare under the exogenously given level of tariff rate t. We shall then consider the effects of the liberalization of service FDI, and demonstrate that the qualitative nature of our results remains unchanged in this setup.

Suppose that, before Stage 1, the domestic government chooses the level of K_F at

Stage 0, taking the tariff rate t as given. For any given $t \in (0, \bar{t}]$, there exists a unique level of K_F, denoted by $K_F^*(t)$, that the domestic government chooses to maximize domestic welfare in the equilibrium. Given the pre-liberalization level of tariff rate $t_0 \in (0, \bar{t}]$, the domestic government chooses $K_F = K_F^*(t_0)$ at Stage 0. Parallel to our analysis in Subsection 3.1, in what follows we consider the case in which the pre-liberalization equilibrium (that is, the equilibrium under $t = t^0$ and $K_F = K_F^*(t_0)$) is an Outsourcing equilibrium. The qualitative nature of our results are mostly unchanged under cases in which the pre-liberalization equilibrium is an FDI equilibrium or an NLF equilibrium.

Proposition 6 *There exists a range of parameterizations in which*
(i) the pre-liberalization equilibrium is an Outsourcing equilibrium, and
(ii) $CS(K_F^*(t_1), t_1) < CS(K_F^*(t_0), t_0)$ *and* $WW(K_F^*(t_1), t_1) < WW(K_F^*(t_0), t_0)$ *hold where* $0 \leq t_1 < t_0 \leq \bar{t}$.

Proposition 6 tells us that liberalization of goods trade can have negative welfare effects. Suppose that the tariff rate is reduced from t_0 to t_1. If K_F is fixed at $K_F^*(t_0)$, a result similar to Proposition 2 holds; that is, the tariff reduction can hurt consumers and decrease world welfare under a range of parameterizations. In response to the tariff reduction, the domestic government changes K_F from $K_F^*(t_0)$ to $K_F^*(t_1)$ to maximize domestic welfare. Proposition 3 tells us that, holding $t = t_1$ fixed, equilibrium consumer surplus is decreasing in K_F while firm D's equilibrium profit is increasing in K_F. We also find that the equilibrium tariff revenue can be either increasing or decreasing in (or a non-monotone function of) K_F. Hence the relationship between domestic welfare and K_F is ambiguous, and it depends on parameterizations.[23] We have found that the domestic government may increase K_F in response to the tariff reduction, or may decrease it but not to a low enough level that induces firm F to actually invest in service FDI. In such cases, the tariff reduction can hurt consumers and decrease world welfare.

Proposition 7 *Take any parameterization in which* $CS(K_F^*(t_1), t_1) < CS(K_F^*(t_0), t_0)$ *and* $WW(K_F^*(t_1), t_1) < WW(K_F^*(t_0), t_0)$ *hold, where* $0 \leq t_1 < t_0 \leq \bar{t}$. *Note that* K_F'' *is evaluated at* $t = t_1$ *in (i) and (ii) below.*
(i) There exists a unique $\hat{K}_F^{CS} \in [K_F'', K_F^*(t_1))$ *such that* $CS(K_F, t_1) > CS(K_F^*(t_0), t_0)$ *for all* $K_F \in (0, \hat{K}_F^{CS})$, *where* $K_F'' < \hat{K}_F^{CS}$ *holds under a range of parameterizations.*

[23] In international oligopoly models, any policy that increases foreign firms' operation costs generates strategic effects that cause rent-shifting, and hence such a policy tends to result in ambiguous welfare effects in each country.

(ii) There exists a unique $\hat{K}_F^{WW} \in [K''_F, K^*_F(t_1))$ *such that* $WW(K_F, t_1) > WW(K^*_F(t_0), t_0)$ *for all* $K_F \in (0, \hat{K}_F^{WW})$*, where* $K''_F < \hat{K}_F^{WW}$ *holds under a range of parameterizations.*

Proposition 7 is parallel to Proposition 4, telling us that the negative welfare effects of trade liberalization disappear and turn into positive ones when trade liberalization is accompanied by the liberalization of service FDI. A necessary condition for the tariff reduction to hurt consumers and decrease world welfare is $K^*_F(t_1) > K''_F$; that is, the domestic government sets the level of K_F at a relatively high level so that firm F does not invest in service FDI. Proposition 7 tells us that, by forcing the domestic government to reduce K_F, multilateral negotiations such as GATS can increase world welfare as well as consumer surplus (see Proposition 3), and convert a welfare-reducing trade liberalization into a welfare-enhancing trade liberalization.

4 Discussion

We have shown that the liberalization of trade in goods could hurt consumers, reduce world welfare, and benefit the domestic firm when the foreign firm outsources post-production services to the domestic rival firm, but that a reduction in the fixed cost of service FDI can mitigate and eventually eliminate these anti-competitive effects of trade liberalization. In this section, we first discuss the policy implications of our results, and then explore the robustness of our results under several alternative modelling choices.[24]

4.1 Policy implications

Through multilateral negotiations under GATT/WTO, countries have been lowering the barriers for the trade in goods. Growing attention is now being paid to the market access of foreign firms in the service sector. The GATT Uruguay Round negotiations succeeded in establishing the framework of liberalizing cross-country transactions of services, that is, the GATS. The actual degree of liberalization, however, has been relatively small. For instance, only 52 WTO members have made commitments to liberalizing distribution services under GATS (Roy, Marchetti, and Lim, 2006). Under the limited progress of liberalization in the service sector, many foreign firms still face significantly high costs for service FDI, which prevent them from establishing local service facilities to perform post-production services by themselves in the local market.

[24]Detailed analyses of the robustness of our results are available upon request.

In our theoretical framework, the current state of the world corresponds to a situation in which the tariff rate t is reduced to a reasonably low level but the fixed cost for service FDI, K_F, is still high. Our comparative statics results then suggest that further progress of trade liberalization under GATT/WTO may hurt consumers and decrease world welfare, if it is not accompanied by the liberalization of service FDI. Our analysis uncovers a previously unnoticed importance of liberalization of service FDI in its connection to trade liberalization. That is, the liberalization of service FDI is important not only because it reduces per-unit costs of post-production services but also because it recovers the gains from the trade liberalization of goods for both consumers and world welfare. We have also found that the qualitative nature of the results remains unchanged under an alternative setup in which, without the liberalization of service FDI, K_F is endogenously determined by the domestic government. Therefore, making progress on the liberalization of service FDI under GATS is crucial to secure positive welfare consequences of trade liberalization under GATT/WTO. Since the anti-competitive effects of trade liberalization are more likely as the tariff becomes lower (see Proposition 2), the liberalization of service FDI becomes more important as trade liberalization proceeds.

Recently, many regional trade agreements (RTAs) have established codes for the liberalization in the service sector in addition to those for the liberalization of the trade in goods. In these RTAs, some countries have undertaken further commitments on the liberalization of FDI in post-production services on top of the existing GATS commitments. For instance, in its RTA with Australia, Thailand allows Australian firms 100% foreign equity ownership for distribution of their products, even though it limits foreign equity ownership up to 49% in its GATS distribution commitments.[25] Singapore made broader commitments on the retailing of certain goods in its RTAs with the US, Australia, and Korea. Our analysis indicates that RTAs with deeper commitments towards the liberalization of service FDI are more likely to make trade liberalization pro-competitive, suggesting that the recent proliferation of RTAs may be superior to multilateral liberalization under GATT/WTO.

Our model also yields a new policy implication regarding foreign producers' accessibility to service outsourcing in the local market. Suppose that the values of K_F and K_D are initially high so that the model exhibits a No Local Facility equilibrium, and that

[25] Oman has also undertaken similar commitments in its RTA with the US. Many countries which had no GATS commitments in distribution services, such as Bahrain, Chile, Colombia, Costa Rica, Dominican Republic, El Salvador, Guatemala, Honduras, Morocco, and Nicaragua have undertaken commitments in distribution services in their RTAs with the US. See Roy, Marchetti, and Lim (2006) for details.

the domestic government implements a policy to reduce K_D, firm D's fixed cost for performing post-production services for firm F. A sufficient reduction of K_D switches the equilibrium to an Outsourcing equilibrium, in which firm D charges a service price that is higher than m, product-market competition becomes weaker, and consumer surplus and world welfare both become lower than in the No Local Facility equilibrium. Our model therefore offers a warning to the government on the possibility that such a policy may result in negative welfare consequences unless it is accompanied by the liberalization of service FDI.

We end this subsection by commenting on horizontal FDI. Since horizontal FDI in production to serve the local market 'jumps' tariffs, it has the same effect as a tariff elimination. In our model, the tariff elimination may hurt consumers and reduce world welfare if it is not accompanied by the liberalization of service FDI. Our findings therefore indicate that, to secure its positive welfare consequences, the liberalization of FDI in production should be accompanied by the liberalization of service FDI.

4.2 Robustness

Bargaining power: The assumption that firm D makes a take-it-or-leave-it offer gives firm D all the bargaining power to set the service price. The qualitative nature of our results would remain unchanged under more general bargaining procedures in which the two firms share the surplus from service outsourcing, as long as firm D has sufficiently strong bargaining power. Recall that, in the Outsourcing equilibrium, firm D offers the maximum acceptable service price $r = \bar{r}$ at which firm F is indifferent between outsourcing the post-production services and performing the services by itself. If $\bar{r}$ is sufficiently high, a tariff reduction can increase the equilibrium service price through the logic presented in Subsection 3.1 (see the third to fifth paragraph of the subsection), and this effect is the driving force of our main comparative results presented in Propositions 2 to 5. If the two firms share the surplus through bargaining, the equilibrium service price, $\hat{r}$, is less than $\bar{r}$ and decreasing in firm F's bargaining power. However, as long as firm D's bargaining power is sufficiently strong, $\hat{r}$ takes a sufficiently high value so that a tariff reduction still increases the equilibrium service price. Then, our main results hold under a more general bargaining set-up in a range of parameterizations.

More than one domestic firms: We have analyzed the strategic interaction between firms D and F by assuming that only one firm can produce the final good in the domestic country. One can consider an alternative set-up in which N (≥ 2) symmetric domestic firms, indexed by $D1$, $D2$, ..., DN, produce differentiated products. In the presence of more than one domestic firm, the qualitative nature of our main results remains unchanged if firm F negotiates prices for service outsourcing with one domestic firm at a time in a sequential fashion. In particular, suppose that firm F first negotiates with firm $D1$ on service prices, and, if firm F decides not to outsource services to firm $D1$, then firm F performs services by itself (No Local Facility or Service FDI) or negotiates with firm $D2$, and so on.[26] In the product-market competition stage, $N + 1$ firms compete in a Bertrand fashion under differentiated oligopoly. We find that the alternative model has a unique pure-strategy equilibrium, which is a No Local Facility equilibrium, an FDI equilibrium, or an Outsourcing equilibrium, depending on parameterizations. In the Outsourcing equilibrium, the equilibrium service price $\hat{r}$ can increase as tariff is reduced, and our main comparative statics results hold under a range of parameterizations.

Alternatively, suppose that domestic firms simultaneously offer service prices, and firm F accepts one offer or rejects all offers. There exists no pure strategy equilibrium in this case since domestic firms incur K_D in providing services (see Sharkey and Sibley, 1993). Each firm chooses the probability of offering service prices in a mixed strategy equilibrium, and the case in which only one firm offers the maximum acceptable service price $r = \bar{r}$ remains an equilibrium with a positive probability. Also, if domestic firms have different per-unit costs for performing post-production services for firm F, there exists a pure-strategy equilibrium in which a domestic firm offers $r = \bar{r}$ when the domestic firm's cost is substantially lower than other domestic firms' costs.

Independent service organizations: Our model assumes that post-production services can be performed only by goods producers (firms D and F) because of economy of scope. Alternatively, suppose that several independent service organizations (ISOs) can also perform post-production services for firm F at constant marginal cost k (≥ 0), and for simplicity assume that their fixed costs are zero. In this alternative set-up, firm F has an option of outsourcing services to an ISO at the per-unit service price of k. The logical structure of this alternative set-up is identical to the one of the base model if $k = m$, and they are similar as long as $k > 0$, implying that the qualitative nature of our results remains unchanged in this alternative set-up as long as $k > 0$. Also, the free

[26] The sequential set-up can be regarded as approximating the following scenario, which we feel is fairly realistic: When a foreign firm attempts to outsource post-production services to one of its domestic rivals, the foreign firm needs to identify a candidate firm by incurring search costs, and negotiate the terms of service outsourcing with the candidate. If the negotiation is unsuccessful, the firm will identify another candidate to negotiate with.

entry of ISOs does not change the results.

Two-part tariff for service outsourcing: We have focused on per-unit royalties for service outsourcing by assuming that firm D offers a per-unit service price r to perform post-production services for firm F. The qualitative nature of our results would remain unchanged under an alternative set-up in which firm D can offer a two-part tariff (R, r) $(R \geq 0,\ r \geq 0)$, where R denotes a fixed fee and r denotes a per-unit royalty. In the Outsourcing equilibrium, firm D chooses (R, r) to maximize its profit $\widehat{\pi}_D(r,t)+R$ subject to $\widehat{\pi}_F(r,t) - R = \max[\pi_F^{NLF}, \pi_F^{FDI}]$. That is, firm D chooses (R, r) so that firm F is indifferent between outsourcing services and performing them by itself. We have found that $R = 0$ and $r = \bar{r}$ holds under a range of parameterizations.[27] That is, given that product market competition becomes weaker as the royalty rate r increases, there is a range of parameterizations in which firm D offers the maximum acceptable royalty rate $r = \bar{r}$ and the zero fixed fee even when a two-part tariff is allowed. Also, even if $r = \bar{r}$ does not hold and $r < \bar{r}$ and $R > 0$ holds in the equilibrium, a decrease in t can still increase r and the qualitative nature of our results is unchanged under a range of parameterizations.[28]

Cournot competition: Consider an alternative set-up in which firms compete against each other by choosing quantities. Suppose that, in an Outsourcing subgame, firm D increases the quantity of good D, holding the quantity of good F fixed. This does not affect firm D's profit for performing post-production services for firm F since the quantity of good F is fixed. That is, unlike Bertrand competition, Cournot competition does not capture the idea that, although firm D can increase the sales of its own product by adopting a more aggressive strategy, such a strategy also reduces its profit from performing services for its rival firm. This in turn implies that, under Cournot competition, service outsourcing does not weaken product market competition. Since this effect is the driving force of our main comparative statics results, our findings do not hold under Cournot competition.

Specific tariff: We have considered *ad valorem* tariffs, given their prevalence in the real world. In the case of specific tariffs, it can be shown that the equilibrium service price becomes independent of the tariff rate with linear demands. With non-linear demand functions, however, it can be shown that the qualitative nature of our results remains

[27] If the market size represented by a is large enough, then $\partial\{\widehat{\pi}_D(\bar{r},t) + \widehat{\pi}_F(\bar{r},t)\}/\partial r > 0$ holds, which in turn implies that $R = 0$ and $r = \bar{r}$ hold in the Outsourcing equilibrium.

[28] Firm D always offers $r > 0$ because under Bertrand competition with differentiated products, $\partial\{\widehat{\pi}_D(r,t) + \widehat{\pi}_F(r,t)\}/\partial r > 0$ necessarily holds at $r = 0$.

unchanged in the case of specific tariffs.

The fixed cost for service outsourcing: We have assumed that firm D incurs a fixed cost for service outsourcing, K_D. If firm F incurs K_D instead, its profit in the Outsourcing equilibrium (π_F^{OS}) is decreasing in K_D and hence the maximum acceptable service price, $\overline{r}$, is also decreasing in K_D. Although this changes the quantitative details of the results, their qualitative nature remains unchanged. That is, product market competition becomes weaker in the Outsourcing equilibrium when $\bar{r}$ is sufficiently high, and this in turn leads to results analogous to Propositions 2 to 5 in a range of parameterizations.

Non-tariff barriers: We can interpret t as a proxy for non-tariff barriers rather than a tariff. Then a reduction in t results in the saving of real costs, which works in favor of world welfare. We have found that $WW(K_F^0, t_1) < WW(K_F^0, t_0)$ (where $0 \leq t_1 < t_0 \leq \bar{t}$) can hold even in this case under a range of parameterizations, and hence Propositions 4 and 5 hold under the alternative interpretation of t. Also, domestic welfare can still decrease when K_F is reduced, and hence Propositions 6 and 7 hold even though the domestic country does not earn tariff revenue in this case.

5 Conclusion

Post-production services such as sales, distribution, and maintenance consist of an important subclass of services. Although the liberalization of the trade in goods has made substantial progress through multilateral negotiations under GATT/WTO, the progress of the liberalization in the service sector has been limited so far. In this paper, we have uncovered a previously unnoticed importance of liberalization in the service sector by exploring an international duopoly model that captures the linkage between product market competition and provision of post-production services. That is, we have found that the trade liberalization of goods may have negative welfare effects if it is not accompanied by the liberalization of service FDI.

Trade liberalization reduces trade costs, and this intensifies competition between a foreign firm and a domestic firm in the product market. At the same time, when the foreign firm outsources post-production services, trade liberalization induces the domestic firm to charge a higher service price to absorb a part of the foreign firm's incremental profit due to lower trade costs. We have demonstrated that, if the foreign firm's fixed cost of service FDI is relatively high, the latter negative welfare effect overshadows the former positive one so that trade liberalization hurts consumers and reduces world welfare in a range of parameterizations. Importantly, this negative welfare effect of trade liberalization is mitigated and eventually turned into a positive one as service FDI is also liberalized. This is because a reduction in the fixed cost of service FDI decreases the price of service outsourcing that the foreign firm would accept. We have found that the qualitative nature of the results remains unchanged under an alternative setup in which, without the liberalization of service FDI, K_F is endogenously determined by the domestic government.

Our analysis has therefore indicated that the liberalization of service FDI is important not only because it reduces per-unit costs of post-production services but also because it recovers gains from trade liberalization in goods for both consumers and world welfare. Making progress on the liberalization of service FDI under GATS is crucial to secure positive welfare consequences of trade liberalization under GATT/WTO.

We offer two final remarks to conclude the paper. First, we comment on the difference between post-production services and intermediate inputs in our framework. In our international duopoly model, the foreign firm has an option of outsourcing post-production services to its domestic rival or performing the services by itself in the domestic market. It is possible to consider a model with an analogous logical structure in which post-production services are replaced by intermediate inputs. For example, one can consider a foreign firm that does not have the facilities to produce an intermediate input, and can suppose that the foreign firm determines whether it procures the intermediate input from its domestic rival or produces the input by building its own production facilities.

Since intermediate inputs are not services but goods, service FDI has no direct effects on the foreign firm's make-or-buy decision. In contrast, the liberalization of service FDI plays a critical role in our framework. That is, in order to perform post-production services effectively, the foreign firm needs to undertake service FDI and establish its own service facilities in the domestic market because of the importance of proximity to customers. In our analysis, the connection between production and post-production services has yielded a novel policy implication that trade liberalization should be accompanied by the liberalization of service FDI to secure its positive welfare effects. The recent progress of trade liberalization is not yet accompanied by the sufficient progress of liberalization of service FDI, and this reality has motivated us to study the connection between production and post-production services in international contexts.[29]

[29] Also, since the liberalization of the trade in goods affects the intermediate-goods market as well as the final-goods market, its policy implications may be different between the model with intermediate inputs and the model with post-production services. To the best of our knowledge, the model of intermediate inputs as mentioned above has not been previously explored (see Chen, Ishikawa, and Yu (2004) for a related analysis) and its investigation is left to future research.

Second, given that imperfect competition in the product market is an important element of our analysis, one might argue that strengthening product market competition could be a substitute for liberalizing service FDI. Suppose that the domestic government has stimulated competition in the product market by inducing firms' entry, and consequently there are N (≥ 2) domestic firms. As we discussed in Subsection 4.2, the liberalization of service FDI can still be critical in recovering gains from the trade liberalization of goods, as long as the price for service outsourcing is determined by one-to-one negotiations. Also, although the domestic government could induce the entry of some independent service organizations, the liberalization of service FDI can still be critical as discussed in Subsection 4.2.

Appendix

Conditions for $\partial\hat{\pi}_D(r,t)/\partial t > 0$ for $r \in [0, \bar{r}]$

By (13),

$$\frac{\partial\widehat{\pi}_D(r,t)}{\partial r} = \frac{\left[\begin{array}{c} a\,(2+b)\left\{(1+b)\left(4-2b+b^2\right)+2bt\right\} \\ -\left\{\left(1-b^2\right)(2+b)\left(4-2b+b^2\right)+2t\,(1-b)\left(4+6b+b^2\right)+2b^2t^2\right\}c \\ -2\beta\,(b,t)\,r \end{array}\right]}{\left(4-b^2\right)^2}$$

where $\beta\,(b,t) = 8(1-b^2)\,(1+t) + b^2(1-b^2-t^2)$. When b is large and $t > 0$, $\beta\,(b,t) < 0$ and then $\partial\widehat{\pi}_D(r,t)/\partial r > 0$ always holds. When $\beta\,(b,t) > 0$, $\partial\widehat{\pi}_D(r,t)/\partial r$ is concave in r. When it is evaluated at $r = \widehat{r}(m,t)$, we have

$$\left.\frac{\partial\widehat{\pi}_D(r,t)}{\partial r}\right|_{r=\widehat{r}(m,t)} = \frac{\left[\begin{array}{c} a\,(2+b)\left\{(1+b)\left(4-2b+b^2\right)+2bt\right\} \\ -\left\{\left(1-b^2\right)(2+b)\left(4-2b+b^2\right)+2t\,(1-b)\left(4+6b+b^2\right)+2b^2t^2\right\}c \end{array}\right]}{\left(4-b^2\right)^2} - \frac{2m\left(2-b^2\right)(1+t)\,\beta\,(b,t)}{\left(4-b^2\right)^2\left\{\left(2-b^2\right)t+2\left(1-b^2\right)\right\}}$$

and it is positive if a is large enough, and c and m are small enough to satisfy $[a(2+b)\{(1+b)\left(4-2b+b^2\right)+2bt\} - \{(1-b^2)(2+b)(4-2b+b^2)+2t(1-b)(4+6b+b^2)+2b^2t^2\}c]\{(2-b^2)t+2(1-b^2)\}/2(2-b^2)(1+t)\beta\,(b,t) > m$. Since $\widehat{r}'(K_F,t)$ is increasing in K_F with $\widehat{r}'(K_F',t) = \widehat{r}(m,t)$, $\widehat{r}'(K_F,t) < \widehat{r}(m,t)$ is satisfied and so $\partial\widehat{\pi}_D(r,t)/\partial r > 0$ also holds for $K_F \in [0, K_F')$. Thus, $\partial\widehat{\pi}_D(r,t)/\partial r|_{r=\widehat{r}'(K_F,t)} > 0$ is also satisfied as long as $\partial\widehat{\pi}_D(r,t)/\partial r|_{r=\widehat{r}(m,t)} > 0$ holds.

Proof of Proposition 1

By comparing π_F^{FDI} with π_F^{NLF}, we have

$$\pi_F^{FDI}-\pi_F^{NLF} \gtreqless 0 \Longleftrightarrow \frac{\left(2-b^2\right)\left[2\left(2+b\right)\left\{a-\left(1+b\right)c\right\}-\left(2-b^2\right)\left\{2ct+\left(1+t\right)m\right\}\right]m}{\left(4-b^2\right)^2} \equiv K_F' \gtreqless K_F$$

where K_F' is the cut-off value of the fixed cost of service FDI. We can verify that K_F' is strictly decreasing in t.

Under $K_F \leq K_F'$, $\pi_F^{FDI} \geq \pi_F^{NLF}$ holds and firm D offers r if $\pi_D^{OS} > \pi_D^{FDI}$ holds. By comparing π_D^{OS} with π_D^{FDI}, we have

$$\pi_D^{OS}-\pi_D^{FDI} \gtreqless 0 \Longleftrightarrow \frac{\left\{\alpha-\sqrt{\alpha^2-\left(4-b^2\right)^2\left(1+t\right)K_F}\right\}Z_1}{\left(4-b^2\right)^2\left\{\left(2-b^2\right)t+2\left(1-b^2\right)\right\}^2} \equiv \widetilde{K}_D' \gtreqless K_D \qquad \text{(A1)}$$

where $Z_1 \equiv b\left(1-b^2\right)\left(2+b\right)\left(4-3b+2b^2\right)\left\{a-\left(1+b\right)c\right\}+b\left(1+b\right)\left\{a\left(2+b\right)\left(8-6b+2b^2-b^3\right)-\left(1-b\right)^2\left(16+2b+b^3\right)c\right\}t+b\left\{a\left(2+b\right)\left(4+b-2b^2\right)-c\left(1-b\right)\left(8-7b^2+2b-2b^3\right)\right\}t^2+\left(2-b^2\right)b^2ct^3+\left\{8-7b^2-b^4+8(1-b)^2t-b^2t^2\right\}\sqrt{\alpha^2-\left(4-b^2\right)^2\left(1+t\right)K_F}$. Note that K_D' represents firm D's gains from service outsourcing gross of the fixed cost of service outsourcing. Since $\widehat{\pi}_D(r,t)$ is increasing in r, $\widehat{\pi}_D(r,t)+K_D=\pi_D^{FDI}$ holds evaluated at $r=0$, and $\overline{r}>0$ holds, $K_D'=\widehat{\pi}_D(\overline{r},t)-\pi_D^{FDI}+K_D$ is always positive (i.e., $Z_1>0$). Note that $\widetilde{K}_D'$ is either increasing or decreasing in t.

Under $K_F > K_F'$, $\pi_F^{NLF} > \pi_F^{FDI}$ holds and firm D offers r if $\pi_D^{OS} > \pi_D^{NLF}$ holds. By comparing π_D^{OS} with π_D^{NLF}, we have

$$\pi_D^{OS}-\pi_D^{NLF} \gtreqless 0 \Longleftrightarrow \frac{\left(1+t\right)\left(1+b\right)mZ_2}{\left(4-b^2\right)\left\{\left(2-b^2\right)t+2\left(1-b^2\right)\right\}^2} = \widehat{K}_D' \gtreqless K_D$$

where $Z_2 \equiv \left\{\left(2-b^2\right)t+2\left(1-b^2\right)\right\}\left[\left(2+b\right)\left(2-2b+b^2\right)\left\{a-\left(1-b\right)c\right\}-4\left(1-b\right)ct\right]-\left(1-b\right)\left(1+t\right)\left\{4\left(2-b^2\right)\left(1+t\right)-b^4\right\}m$. Since $\widehat{\pi}_D(r,t)$ is increasing in r, $\widehat{\pi}_D(r,t)+K_D > \pi_D^{NLF}$ holds evaluated at $r=m$, and $\overline{r}=\widehat{r}(m,t)>m$ holds, $K_D'=\widehat{\pi}_D(\overline{r},t)-\pi_D^{NLF}+K_D$ is always positive (i.e., $Z_2>0$). Note that $\widetilde{K}_D'\Big|_{K_F=K_F'} > K_D'$ holds because $\pi_D^{OS}-\pi_D^{NLF} < \left(\pi_D^{OS}-\pi_D^{FDI}\right)\Big|_{K_F=K_F'}$ is satisfied. By differentiating $\widehat{K}_D'$ with respect to t, we have $\partial\widehat{K}_D'/\partial t = -\left(1+b\right)m[4t^2\left(1-b\right)\left(2-b^2\right)\left\{6\left(1-b^2\right)+\left(2-b^2\right)t\right\}\left(c+m\right)+tZ_3+2\left(1-b\right)Z_4]/[\left(4-b^2\right)\left\{\left(2-b^2\right)t+2\left(1-b^2\right)\right\}^3]$ where $Z_3 \equiv ab^2\left(2+b\right)\left(2-b^2\right)\left(2-2b+b^2\right)+\left(1-b\right)\left(4-4b^2-b^3\right)\left(12-12b^2+4b^3-b^4\right)c+2\left(1-b\right)\left(24-48b^2+18b^4+b^6\right)m$ and $Z_4 \equiv ab^2\left(2+b\right)\left(1+b\right)\left(2-2b+b^2\right)+\left(1-b^2\right)\left(8-12b^2+2b^3-b^5\right)c+\left(8-20b^2+8b^4+b^6\right)m$. Since Z_3 and Z_4 are increasing in a and $a>c+m$ must hold, $Z_3 > Z_3|_{a=c+m} = (48-48b-88b^2+96b^3+36b^4-44b^5+4b^6-b^8)c+\left(48-48b-88b^2+92b^3+32b^4-32b^5+2b^6-3b^7\right)m >$

0 and $Z_4 > Z_4|_{a=c+m} = (1+b)\left(8-8b-8b^2+12b^3-2b^4+b^6\right)c+(8-16b^2+2b^3+6b^4+b^5+2b^6)m > 0$ are satisfied. Hence, $\partial \widehat{K}'_D/\partial t < 0$ holds for all $t \in [0, \bar{t}]$.

Putting them all together, we have

$$K'_D = \begin{cases} \widetilde{K}'_D & \text{if} \quad K_F \leq K'_F \\ \widehat{K}'_D & \text{if} \quad K_F > K'_F \end{cases} .$$

(i) If $K_F \geq K'_F$ and $K_D < K'_D$ hold so that $\pi_F^{FDI} \leq \pi_F^{NLF}$ and $\pi_D^{OS} > \pi_D^{NLF}$ are satisfied, firm D offers service outsourcing and firm F accepts the offer. In this case, the equilibrium is an OS equilibrium where the service price is set at $r = \widehat{r}(m,t)$ and it is uniquely determined given m and t. Once the service price is determined, there is a unique equilibrium in the product market. (ii) If $K_F < K'_F$ and $K_D < K''_D$ hold so that $\pi_F^{FDI} > \pi_F^{NLF}$ and $\pi_D^{OS} > \pi_D^{FDI}$ are satisfied, firm D offers service outsourcing by setting the service price at $r = \bar{r}$ and firm F accepts the offer. In this case, the equilibrium is an OS equilibrium where the service price and the equilibrium prices of products are uniquely determined. (iii) If $K_F < K'_F$ and $K_D \geq K'_D$ hold so that $\pi_F^{FDI} > \pi_F^{NLF}$ and $\pi_D^{FDI} \geq \pi_D^{OS}$ are satisfied, firm D does not offer a service price and firm F makes service FDI. In this case, the equilibrium is an FDI equilibrium. (iv) Otherwise, $\pi_F^{FDI} \leq \pi_F^{NLF}$ and $\pi_D^{OS} \leq \pi_D^{NLF}$ hold and the equilibrium is an NLF equilibrium since firm D does not offer a service price and firm F does not make service FDI. In all cases, the equilibrium service price, the equilibrium prices of products, and the other endogenous variables are uniquely determined for any given parameterization. ■

The discontinuity of K'_D at $K_F = K'_F$

Suppose $K_F = K'_F$ so that $\pi_F^{FDI} = \pi_F^{NLF}$ holds. Then, if firm D does not offer a service price r at stage 1, firm F makes service FDI, and hence firm D's subsequent equilibrium profit is π_D^{FDI}. Now suppose K_F increases from $K_F = K'_F$ to $K_F = K'_F + \epsilon$ ($\epsilon > 0$) so that $\pi_F^{FDI} < \pi_F^{NLF}$ holds. Then, if firm D does not offer a service price r, firm F does not make service FDI, and hence firm D's subsequent equilibrium profit is π_D^{NLF}. Comparing firm D's profits in these two cases, we have $\pi_D^{FDI} < \pi_D^{NLF}$. That is, service FDI reduces firm F's per unit service cost, and this intensifies the competition between the two firms, lowering firm D's profit. Note that, since π_F^{NLF} is independent of K_F, the maximum acceptable service price $\bar{r}$, determined by $\widehat{\pi}_F(\bar{r}, t) = \max[\pi_F^{NLF}, \pi_F^{FDI}]$, is also independent of K_F for all $K_F \geq K'_F$. Then, since K'_D is determined by $\widehat{\pi}_D(\bar{r}, t)|_{K_D = K'_D} = \pi_D^{FDI}$ if $K_F = K'_F$ and $\widehat{\pi}_D(\bar{r}, t)|_{K_D = K'_D} = \pi_D^{NLF}$ if $K_F > K'_F$ where $\widehat{\pi}_D(\bar{r}, t)$ is continuous and strictly decreasing in K_D, $\pi_D^{FDI} < \pi_D^{NLF}$ implies that $K'_D|_{K_F = K'_F} > K'_D|_{K_F = K'_F + \epsilon}$

when ϵ approaches to zero. This results in the discontinuity.

Proof of Corollary 1

Suppose $0 < K_D < K_D'$ and $K_F \geq K_F'$ are satisfied given t. By Proposition 1, the equilibrium is an OS equilibrium. Since we restrict our attention to the case where $\partial\widehat{\pi}_D(r,t)/\partial r > 0$ is satisfied, and $\partial\widehat{r}'(K_F,t)/\partial K_F > 0$ holds by (16), $\partial\pi_D/\partial K_F > 0$ holds for $0 < K_F < K_F'$. Besides that, since $\pi_F^{FDI} = \pi_F^{NLF}$ holds at $K_F = K_F'$, we have $\widehat{r}(m,t) = \widehat{r}'(K_F,t)$ at $K_F = K_F'$, and thereby $\pi_D^{OS} = \widehat{\pi}_D(\widehat{r}(m,t),t) = \widehat{\pi}_D(\widehat{r}'(K_F',t),t)$ is satisfied. Since we have $\pi_D^{NLF} > \pi_D^{FDI}$, $\pi_D^{OS} - \pi_D^{FDI} > \pi_D^{OS} - \pi_D^{NLF}$ holds at $K_F = K_F'$ which means $K_D' < K_D''|_{K_F=K_F'}$. Since K_D'' is increasing in K_F by (A1) and $K_D''|_{K_F=0} = 0$, given $K_D < K_D''|_{K_F=K_F'}$, there exists K_F'' such that $K_D < K_D''$ for $K_F'' < K_F < K_F'$ and $K_D'' < K_D$ for $0 \leq K_F \leq K_F''$. ■

Proof of Lemma 3

By (9), (10), and (17), given $K_F \geq K_F'$ and $K_D < K_D'$ and so $\overline{r} = \widehat{r}(m,t)$,

$$\frac{\partial\, p_D^{OS}|_{r=\widehat{r}(m,t)}}{\partial t} = \frac{b\begin{bmatrix} \{(2-b^2)\,t + 2\,(1-b^2)\}^2 c \\ +\{2-5b^2+4\,(1-b^2)\,t+(2-b^2)\,t^2\}(2-b^2)m \end{bmatrix}}{(4-b^2)\,\{(2-b^2)\,t+2\,(1-b^2)\}^2},$$

$$\frac{\partial\, p_F^{OS}|_{r=\widehat{r}(m,t)}}{\partial t} = \frac{\begin{bmatrix} 2\{(2-b^2)\,t + 2\,(1-b^2)\}^2 c \\ +\{(4-6b^2-b^4)+8\,(1-b^2)\,t+2\,(2-b^2)\,t^2\}\,(2-b^2)\,m \end{bmatrix}}{(4-b^2)\,\{(2-b^2)\,t+2\,(1-b^2)\}^2}.$$

By these equations, we have

$$\frac{\partial\, p_D^{OS}|_{r=\widehat{r}(m,t)}}{\partial t} \lesseqgtr 0 \iff -\frac{(2-b^2)\{2-5b^2+4\,(1-b^2)\,t+(2-b^2)\,t^2\}}{\{(2-b^2)\,t+2\,(1-b^2)\}^2} = \zeta' \gtreqless \frac{c}{m},$$

$$\frac{\partial\, p_F^{OS}|_{r=\widehat{r}(m,t)}}{\partial t} \lesseqgtr 0 \iff -\frac{(2-b^2)\{(4-6b^2-b^4)+8\,(1-b^2)\,t+2\,(2-b^2)\,t^2\}}{2\{(2-b^2)\,t+2\,(1-b^2)\}^2} = \zeta'' \gtreqless \frac{c}{m}.$$

It can be verified that $\partial\zeta'/\partial b > 0$, $\partial\zeta''/\partial b > 0$, $\partial\zeta'/\partial t < 0$, and $\partial\zeta''/\partial t < 0$, and thereby the sign of $\partial p_i^{OS}/\partial t$ is more likely to be negative when b is large and t is small, and c/m is relatively small. Beside that, since

$$\zeta' - \zeta'' = \frac{b^2\,(2-b^2)\,(4-b^2)}{2\{(2-b^2)\,t+2\,(1-b^2)\}^2} > 0,$$

a decrease in t is less likely to increase p_F^{OS} than p_D^{OS}. Since $\zeta'|_{t=0} > 0 \iff b > b' \equiv \sqrt{10}/5$, $\zeta''|_{t=0} > 0 \iff b > b'' \equiv \sqrt{\sqrt{13}-3}$ $(> \sqrt{10}/5)$, $\zeta'|_{b=1} > 0 \iff t < t' \equiv \sqrt{3}$, and $\zeta''|_{b=1} > 0 \Longleftrightarrow t < t'' \equiv \sqrt{6}/2\ (< \sqrt{3})$, p_D^{OS} increases with a tariff reduction if and only if $t < t'$, $b > b'$, and $c/m < \zeta'$ hold, and the prices of both goods increase with a tariff reduction if and only if $t < t''$, $b > b''$, and $c/m < \zeta''$ hold. ■

Proof of Proposition 2

First note that consumer surplus is decreasing in both p_D and p_F. By (13), $\partial\pi_D^{OS}/\partial p_D = 2(p_D^{OS} - c) - br = 2\,(2+b)\,\{a - (1-b)\,c\} + b\{2\,(1+t) + b^2\}r > 0$ and $\partial\pi_D^{OS}/\partial p_F = r > 0$ hold. Since we focus on the case where $\partial\hat{\pi}_D(r,t)/\partial t > 0$ holds and $\partial\overline{r}/\partial t = \partial\widehat{r}(m,t)/\partial t < 0$ is satisfied at $K_F = K_F^0$, $\partial\pi_D(K_F,t)/\partial t < 0$ holds whenever both $\partial p_D/\partial t < 0$ and $\partial p_D/\partial t < 0$ hold. Beside that, since tariff revenue is a transfer from firm F to the domestic country, and a decrease in consumer surplus always outweighs firms' gains from increases in goods' prices, the world welfare is also decreasing in p_D and p_F.

By Lemma 3, if $t < t''$, $b > b''$, and $c/m < \zeta''$ are satisfied, $\partial p_D/\partial t < \partial p_F/\partial t < 0$ holds and thereby $\partial CS(K_F,t)/\partial t > 0$, $\partial CS(K_F,t)/\partial t > 0$, and $\partial\pi_D(K_F,t)/\partial t < 0$ necessarily hold. Besides that, Lemma 3 suggests that $\partial p_D/\partial t < 0$ holds if and only if $t < t'$, $b > b'$, and $c/m < \zeta'$ are satisfied, and $\partial p_D/\partial t < \partial p_F/\partial t < 0$ holds only if $t < t'$, $b > b'$, and $c/m < \zeta'$ are satisfied. Since $\partial CS(K_F,t)/\partial t > 0$ and $\partial WW(K_F,t)/\partial t > 0$ can hold only if $\partial p_D/\partial t < 0$ is satisfied, they hold only if $t < t'$, $b > b'$, and $c/m < \zeta'$ are satisfied. As for $\partial\pi_D(K_F,t)/\partial t$, it can be negative even if $t < t'$, $b > b'$, and $c/m < \zeta'$ are not satisfied and $\partial p_F/\partial t > \partial p_D/\partial t > 0$ holds, since an increase in the service price by a tariff reduction directly increases the profits of firm D. ■

Proof of Proposition 3

When $K_F \leq K_F''$ holds, the equilibrium is an FDI equilibrium where the prices of goods, consumer surplus, and the profits of firm D are independent of K_F. An increase in K_F reduces world welfare, because K_F is incurred by firm F under the FDI equilibrium. Hence, $\partial CS(K_F,t)/\partial K_F = 0$, $\partial WW(K_F,t)/\partial K_F = \partial\pi_F(K_F,t)/\partial K_F < 0$ and $\partial\pi_D(K_F,t)/\partial K_F = 0$ hold for all $K_F < K_F''$. When $K_F \in (K_F'', K_F')$ holds, the equilibrium is an OS equilibrium where the service price is set at $r = \widehat{r}'\,(K_F,t)$ and it is increasing in K_F. Given t, an increase in r necessarily raises the prices of both goods, and so $\partial CS(K_F,t)/\partial K_F < 0$, $\partial WW(K_F,t)/\partial K_F < 0$, $\partial\pi_F(K_F,t)/\partial K_F < 0$, and $\partial\pi_D(K_F,t)/\partial K_F > 0$ hold for all $K_F \in (K_F'', K_F')$ where the last inequality is due to $\partial\widehat{\pi}_D(r,t)/\partial r > 0$. When $K_F > K_F'$ holds, the equilibrium is an OS equilibrium where the service price is set at $r = \widehat{r}(m,t)$ and it is independent of K_F.

Hence, $\partial CS(K_F,t)/\partial K_F = 0$, $\partial WW(K_F,t)/\partial K_F = 0$, $\partial \pi_F(K_F,t)/\partial K_F = 0$, and $\partial \pi_D(K_F,t)/\partial K_F = 0$ hold for all $K_F > K'_F$.

By comparing the equilibrium prices between an FDI equilibrium and an OS equilibrium, we have $\widehat{p}_D(r,t) - p_D^{FDI} = (3+t)\,br/(4-b^2) > 0$, $\widehat{p}_F(r,t) - p_F^{FDI} = [\{2(1+t) + b^2\}r + 2ct]/(4-b^2) > 0$. In addition, $\widehat{r}(K_F,t) \leq \widehat{r}(m,t)$ holds for $K_F \in (K''_F, K'_F]$ with equality at $K_F = K'_F$. Hence, for given t and any K_{F1}, K_{F2}, and K_{F3} such that $0 < K_{F3} < K''_F < K_{F2} < K'_F < K_{F1} < K^0_F$, $CS(K_{F3},t) > CS(K_{F2},t) > CS(K_{F1},t)$, $WW(K_{F3},t) > WW(K_{F2},t) > WW(K_{F2},t)$, $\pi_F(K_{F3},t) > \pi_F(K_{F2},t) > \pi_F(K_{F2},t)$, and $\pi_D(K_{F3},t) < \pi_D(K_{F2},t) < \pi_D(K_{F1},t)$ hold. In sum, for any given $t \in [0,\bar{t}]$, $CS(K_F,t)$, $WW(K_F,t)$, and $\pi_F(K_F,t)$ are decreasing in K_F while $\pi_D(K_F,t)$ is increasing in K_F for all $K_F \in (0, K^0_F]$. ■

Proof of Proposition 4

Firstly, we should note that $p_i^{OS} > p_i^{FDI}$ $(i \in \{D,F\})$ always holds and thereby $CS^{FDI} > CS^{OS}$ is also satisfied given t. As for the world welfare, $WW^{FDI} - WW^{OS} = (CS^{FDI} - CS^{OS}) + (TR^{FDI} - TR^{OS}) + (\pi_D^{FDI} - \pi_D^{OS}) + (\pi_F^{FDI} - \pi_F^{OS}) = (CS^{FDI} - CS^{OS}) + (TR^{FDI} - TR^{OS})$ holds at $K_F = K'_F$ and given t. The last equality is because both $\pi_D^{FDI} = \pi_D^{OS}$ and $\pi_F^{FDI} = \pi_F^{OS}$ hold at $K_F = K''_F$. We have $\partial\{(CS^{FDI} - CS^{OS}) + (TR^{FDI} - TR^{OS})\}/\partial a = [r\{(1+b)(2+b) + 2\left(2+2b-b^2\right)t + \left(2+b-b^2\right)t^2\}]/\{(2-b)^2(2+b)(t+1)\} > 0$. By using this and $a > c+r$, the following inequality holds: $(CS^{FDI} - CS^{OS}) + (TR^{FDI} - TR^{OS}) > (CS^{FDI} - CS^{OS})\big|_{a=c+r} + (TR^{FDI} - TR^{OS})\big|_{a=c+r} = r(Z_3 + Z_4 r)/\{2(1+t)(4-b^2)^2\} > 0$ where $Z_3 = 2(1+b)(2+b)^2bc + 2(4+8b+5b^2+b^4)ct + 2(8+4b-b^3)ct^2 + 2(4-b^2)t^3c > 0$ and $Z_4 = (1+b)(4+12b-3b^2+5b^3) + (12+24b+b^2-4b^3+3b^4)t + (12+8b-b^2-2b^3)t^2 + (4-b^2)t^3 > 0$. As a result, $WW^{FDI} > WW^{OS}$ is satisfied at $K_F = K'_F$ and given t.

Secondly, we should examine the cut-off values of the fixed investment cost of service FDI before and after the trade liberalization. Since both K'_F and K''_F depend on t, we denote them by $K'_F(t)$ and $K''_F(t)$ respectively for expositional convenience from here on. While K'_F is decreasing in t and $\overline{K}'_F := \max[K'(t_0), K'_F(t_1)] = K'_F(t_1)$ always holds (see the proof of Proposition 1), it is ambiguous whether $K''_F(t_1)$ is larger or smaller than $K''_F(t_0)$ since $\pi_D^{OS} - \pi_D^{FDI}$ can be either increasing or decreasing in t.

Now we explore the existence of the unique cut-off values $\tilde{K}_F^{CS}$ and $\tilde{K}_F^{WW}$ such that $CS(K_F,t_1) > CS(K_F,t_0)$ holds if $K_F < \tilde{K}_F^{CS}$ and $WW(K_F,t_1) > WW(K_F,t_0)$ holds if $K_F < \tilde{K}_F^{WW}$. When $K_F \leq \underline{K}''_F := \min[K''_F(t_0), K''_F(t_1)]$ holds, the equilibrium becomes an FDI equilibrium at both $t = t_0$ and $t = t_1$. Since we have $K''_F(t) > 0$ given

$K_D > 0$, we can always find some K_F such that this inequality holds irrespective of the parameter values. As long as $K_F \leq \underline{K}''_F$, $CS(K_F, t_1) > CS(K_F, t_0)$ and $WW(K_F, t_1) > WW(K_F, t_0)$ always hold (see Proposition 5). Thus, the cut-off values must satisfy $\tilde{K}_F^{CS} \geq \underline{K}''_F$ and $\tilde{K}_F^{WW} \geq \underline{K}''_F$.

Next consider the case where $\underline{K}''_F < K_F < \overline{K}''_F := \max[K''_F(t_0), K''_F(t_1)]$. There are two cases: (i) $K''_F(t_1) < K''_F(t_0)$ and (ii) $K''_F(t_0) < K''_F(t_1)$. (i) Suppose $K''_F(t_1) < K''_F(t_0)$ holds. If K_F increases from $K_F = K''_F(t_1)$ to $K_F = K''_F(t_1) + \varepsilon$ ($\leq K''_F(t_0)$) where ε is an infinitesimal value ($\varepsilon > 0$), the equilibrium at $t = t_1$ changes from an FDI equilibrium to an OS equilibrium, and the change necessarily lowers consumer surplus and world welfare for given t. Note that under an OS equilibrium with $K_F < K'_F$, any increase in K_F reduces consumer surplus as well as world welfare (see Proposition 3). There are two sub-cases: (a) If $CS(K''_F(t_1) + \varepsilon, t_1) < CS(K''_F(t_1) + \varepsilon, t_0)$ holds, the cut off value is determined by $\tilde{K}_F^{CS} = K''_F(t_1)$. Similarly, we have $\tilde{K}_F^{WW} = K''_F(t_1)$ if $WW(K''_F(t_1) + \varepsilon, t_1) < WW(K''_F(t_1) + \varepsilon, t_0)$ holds, (b) if $CS(K''_F(t_1) + \varepsilon, t_1) \geq CS(K''_F(t_1) + \varepsilon, t_0)$ and $CS(K''_F(t_0), t_1) < CS(K''_F(t_0), t_0)$ hold, on the other hand, there exists $\tilde{K}_F^{CS} \in (K''_F(t_1), K''_F(t_0))$ such that $CS(\tilde{K}_F^{CS}, t_1) = CS(\tilde{K}_F^{CS}, t_0)$ holds. Similarly, there exists $\tilde{K}_F^{WW} \in (K''_F(t_1), K''_F(t_0))$ such that $WW(\tilde{K}_F^{WW}, t_1) = WW(\tilde{K}_F^{WW}, t_0)$ holds if $WW(K''_F(t_1) + \varepsilon, t_1) \geq WW(K''_F(t_1) + \varepsilon, t_0)$ and $WW(K''_F(t_0), t_1) < WW(K''_F(t_0), t_0)$ are satisfied. (c) Otherwise, neither $\tilde{K}_F^{CS}$ nor $\tilde{K}_F^{WW}$ exists in $K_F \in (K''_F(t_1), K''_F(t_0))$. (ii) Suppose $K''_F(t_1) > K''_F(t_0)$ holds. Since $CS(K_F, t_1) > CS(K_F, t_0)$ and $WW(K_F, t_1) > WW(K_F, t_0)$ necessarily hold for $K_F \in (K''_F(t_0), K''_F(t_1))$, neither $\tilde{K}_F^{CS}$ nor $\tilde{K}_F^{WW}$ exists in $K_F \in (K''_F(t_0), K''_F(t_1))$. By (i) and (ii), we can confirm that $\tilde{K}_F^{CS} \geq K''_F(t_1)$ and $\tilde{K}_F^{WW} \geq K''_F(t_1)$ must hold.

We have seen that $\tilde{K}_F^{CS}$ does not exist in $K_F \in [0, \overline{K}''_F)$ if both $CS(\underline{K}''_F, t_1) > CS(\underline{K}''_F, t_0)$ and $CS(\overline{K}''_F, t_1) > CS(\overline{K}''_F, t_0)$ hold. Then, let us consider the case for $\overline{K}''_F \leq K_F$. Suppose K_F increases from $K_F = \overline{K}''_F$ to $K_F = \overline{K}''_F + \varepsilon$ ($\leq K'_F(t_0)$). Then the equilibrium is an OS equilibrium whether $t = t_0$ or $t = t_1$. (i) Suppose $\overline{K}''_F = K''_F(t_0)$ holds. Since $CS(K''_F(t_0), t_0) > CS(K''_F(t_0) + \varepsilon, t_0)$ and $CS(K''_F(t_0), t_1) \approx CS(K''_F(t_0) + \varepsilon, t_1)$ are satisfied for small ε, $CS(\overline{K}''_F + \varepsilon, t_1) > CS(\overline{K}''_F + \varepsilon, t_0)$ necessarily holds. Thus, $\tilde{K}_F^{CS} > \overline{K}''_F$ holds in this case. By the same reason, $\tilde{K}_F^{WW} > \overline{K}''_F$ must hold in this case. (ii) Suppose $\overline{K}''_F = K''_F(t_1)$ holds. In this case, $CS(\overline{K}''_F + \varepsilon, t_1) < CS(\overline{K}''_F + \varepsilon, t_0)$ can be satisfied since $CS(K''_F(t_0), t_1) > CS(K''_F(t_0) + \varepsilon, t_1)$ and $CS(K''_F(t_0), t_0) \approx CS(K''_F(t_0) + \varepsilon, t_0)$. If it is satisfied, then we obtain $\tilde{K}_F^{CS} = \overline{K}''_F$. By the same reason, $\tilde{K}_F^{WW} = \overline{K}''_F$ if $WW(\overline{K}''_F + \varepsilon, t_1) < WW(\overline{K}''_F + \varepsilon, t_0)$ is satisfied. Otherwise, $\tilde{K}_F^{CS} > \overline{K}''_F$ and $\tilde{K}_F^{WW} > \overline{K}''_F$ must hold.

Given $CS(\overline{K}''_F+\varepsilon,t_1) > CS(\overline{K}''_F+\varepsilon,t_0)$, a further increase in K_F from $K_F = \overline{K}''_F+\varepsilon$ continuously reduces both $CS(K_F,t_0)$ and $CS(K_F,t_1)$ for $K_F \in (\overline{K}''_F, K'_F(t_0)]$, and reduces only $CS(K_F,t_1)$ and does not affect $CS(K_F,t_0)$ for $K_F \in (K'_F(t_0), K'_F(t_1)]$. Because we have considered the parameterizations in which $CS(K^0_F,t_1) < CS(K^0_F,t_0)$ hold, there necessarily exists $\tilde{K}^{CS}_F$ in the range $\overline{K}''_F < K_F < \min[K'_F(t_1), K^0_F]$. Note that $\tilde{K}^{CS}_F$ cannot exceed $K'_F(t_1)$ since both $CS(K_F,t_1)$ and $CS(K_F,t_0)$ are independent of K_F in this range. By the same procedure, we can obtain $\tilde{K}^{WW}_F \in (\overline{K}''_F, \min[K'_F(t_1), K^0_F])$ if $WW(\overline{K}''_F+\varepsilon,t_1) > WW(\overline{K}''_F+\varepsilon,t_0)$ holds.

Thus, given $CS(K^0_F,t_1) < CS(K^0_F,t_0)$ and $WW(K^0_F,t_1) < WW(K^0_F,t_0)$ hold for $0 \le t_1 < t_0 \le \bar{t}$, we can always find a unique $\tilde{K}^{CS}_F \in [K''_F(t_1), K'_F(t_1))$ such that $CS(K_F,t_1) > CS(K_F,t_0)$ for all $K_F \in (0, \tilde{K}^{CS}_F)$ and a unique $\tilde{K}^{WW}_F \in [K''_F(t_1), K'_F(t_1))$ such that $WW(K_F,t_1) > WW(K_F,t_0)$ for all $K_F \in (0, \tilde{K}^{WW}_F)$.

To prove $K''_F(t_1) < \tilde{K}^{CS}_F$ and $K''_F(t_1) < \tilde{K}^{WW}_F$ can hold under a range of parameterizations, we provide a numerical example. Parameters are set at $a = 5$, $b = 0.9$, $c = 0.5$, $m = 1.5$, $K_D = 0.01$, and $K^0_F = 5$. We consider trade liberalization in which the import tariff is reduced from $t_0 = 0.8$ to $t_1 = 0$. The parameterization is consistent with $\partial\widehat{\pi}_D(r,t)/\partial r > 0$ for $r \in [0,\overline{r}]$ and positive sales of the two firms in any equilibrium. Under these parameterizations, we have $K'_F(t_0) = 4.3055 < K'_F(t_1) = 4.7229$. Since $K^0_F = 5 > \max[K'_F(t_0), K'_F(t_1)]$ holds, we have $K'_D|_{t=t_0} = 15.375 < K'_D|_{t=t_1} = 30.279$. Given $K_D = 0.01 < \min[K'_D|_{t=t_0}, K'_D|_{t=t_1}]$, the pre-liberalization equilibrium is an OS equilibrium with $K_F > K'_F$. It is calculated that $K''_F(t_1) = 0.01324 < K''_F(t_0) = 0.01915$.

We can calculate that (i) $CS(K_F,t_1) - CS(K_F,t_0) = -7.934 < 0$ holds, (ii) $CS(K_F,t_1) = CS(K_F,t_0)$ holds at $K_F = 0.92121$ $(< K'_F(t_0))$, (iii) $CS(K_F,t_1) - CS(K_F,t_0) = 5.5131\sqrt{206.07 - 10.176K_F} - 5.156\sqrt{192.63 - 18.317K_F} - (5.9482 + 3.2686K_F) > 0$ holds for $K_F \in (K''_F(t_1), 0.92121)$, (iv) $CS(K_F,t_1) - CS(K_F,t_0) = 0.52044(\sqrt{206.07 - 10.176K_F} - 14.355)^2 + 20.455\sqrt{206.07 - 10.176K_F} - 292.0 > 0$ holds for $K_F \in (K''_F(t_1), K''_F(t_0)]$, (v) $CS(K_F,t_1) - CS(K_F,t_0) = 1.624$ holds for $K_F \in [0, K''_F(t_0)]$. Thus, we have $\tilde{K}^{CS}_F = 0.92121$ which satisfies $\tilde{K}^{CS}_F > K''_F(t_1)$.

Similarly, we can calculate that (i) $WW(K^0_F,t_1) - WW(K^0_F,t_0) = -1.1207 < 0$, (ii) $WW(K_F,t_1) = WW(K_F,t_0)$ at $K_F = 1.1896$ $(< K'_F(t_0))$, (iii) $WW(K_F,t_1) - WW(K_F,t_0) = -3.9653\sqrt{192.63 - 18.317K_F} + 16.987\sqrt{206.07 - 10.176K_F} - 188.64 + 3.2689K_F > 0$ for $K_F \in (K''_F(t_0), 1.1896)$, (iv) $WW(K_F,t_1) - WW(K_F,t_0) = -243.77 + 6.296K_F + 16.987\sqrt{206.07 - 10.176K_F} > 0$ holds for $K_F \in (K''_F(t_1), K''_F(t_0)]$, and (v) $WW(K_F,t_1) - WW(K_F,t_0) = 0.17598$ holds for $K_F \in [0, K''_F(t_1)]$. Thus, we have $\tilde{K}^{WW}_F = 1.1896$ which satisfies $\tilde{K}^{WW}_F > K''_F(t_1)$. ■

Proof of Proposition 5

By differentiating CS^{FDI} with respect to t, we have $dCS^{FDI}/dt = -c[(2+b)^2 \{a - (1-b)c\} - (4-3b^2)ct]/(4-b^2)^2$, and it is positive by Assumption 1. Similarly, by differentiating π_D^{FDI}, and WW^{FDI} with respect to t, we obtain $d\pi_D^{FDI}/dt = 2bc[(2+b)\{a - (1-b)c\} + bct]/(4-b^2)^2 > 0$ and $dWW^{FDI}/dt = -c[(1-b)(2+b)^2 \{a-(1-b)c\} + (4-3b^2)ct]/(4-b^2)^2 < 0$. ∎

Proof of Proposition 6

To prove the proposition, the basic parameters are set at the same values used in the proof of Proposition 5: $a = 5$, $b = 0.9$, $c = 0.5$, $m = 1.5$. In addition, we set $\overline{V} = 100$ and $K_D = 1$. The value of $\overline{V}$ does not affect the ranking of each surplus nor the optimum level of K_F. We consider trade liberalization in which the import tariff is reduced from $t_0 = 0.5$ to $t_1 = 0.4$. Under the parameterizations, we have $K_F'(t_0) = 4.3055 < K_F'(t_1) = 4.7229$. For $K_F > K_F'(t)$, $K_D = 1 < K_D'|_{t=t_0} = 17.734 < K_D'|_{t=t_1} = 18.915$ holds and thereby the equilibrium is an OS equilibrium. For $K_F \leq K_F'$, by solving $\pi_D^{OS} = \pi_D^{FDI}$ for K_F, we have $K_F''(t_1) = 0.18697 < K_F''(t_0) = 0.19246$. Hence, the equilibrium is an OS equilibrium if $K_F''(t) < K_F \leq K_F'(t)$ and an FDI equilibrium if $0 \leq K_F \leq K_F''(t)$.

Given t, the domestic government maximizes $W(K_F, t)$ with respect to K_F. Suppose $t = t_0$. We have $W(K_F, t_0) = 7.2581 + 3.2373K_F + 5.170\,9\sqrt{197.61 - 15.264K_F}$ for $K_F \in (K_F''(t_0), K_F'(t_0)]$. We can verify that $W(K_F, t_0)$ is an inverse U-shaped curve in K_F for this range, which takes the maximum at $\hat{K}_F^0 = 3.2108$. Thus, the maximized level of the domestic welfare under $K_F \in (K_F''(t_0), K_F'(t_0)]$ becomes $W(\hat{K}_F^0, t_0) = 80.686$. In other cases, the domestic welfare is independent of K_F and it is given by $W(K_F, t_0) = 76.805$ $(< W(\hat{K}_F^0, t_0))$ for $K_F \in (K_F'(t_0), +\infty)$ and $W(K_F, t_0) = 79.947$ $(< W(\hat{K}_F^0, t_0))$ for $K_F \in [0, K_F''(t_0)]$. Accordingly, $W(K_F, t_0)$ is maximized at $K_F = \hat{K}_F^0$ and thereby $K_F^*(t_0) = \hat{K}_F^0$.

Similarly, suppose $t = t_1$. We have $W(K_F, t_1) = -4.2261 + 3.3998K_F + 5.8901$ $\sqrt{199.29 - 14.247K_F}$ for $K_F \in (K_F''(t_1), K_F'(t_1)]$, which is an inverse U-shaped curve in K_F for this range. It takes the maximum at $\hat{K}_F^1 = 3.2964$ and the maximized level of the domestic welfare under $K_F \in (K_F''(t_1), K_F'(t_1)]$ becomes $W(\hat{K}_F^1, t_1) = 79.678$. In other cases, the domestic welfare is independent of K_F and it is given by $W(K_F, t_1) = 79.553$ $(< W(\hat{K}_F^1, t_1))$ for $K_F \in (K_F'(t_1), +\infty)$ and $W(K_F, t_1) = 78.926$ $(< W(\hat{K}_F^1, t_1))$ for $K_F \in [0, K_F''(t_1)]$. Accordingly, $W(K_F, t_1)$ is maximized at $K_F = \hat{K}_F^1$ and thereby $K_F^*(t_1) = \hat{K}_F^1$. Note that $K_F^*(t_1) > K_F^*(t_0)$ means the tariff reduction increases, rather than decreases, the optimum level of K_F in this case.

By substituting $K_F = K_F^*(t_0)$ and $K_F = K_F^*(t_1)$ into $CS(K_F, t)$ and $WW(K_F, t)$, we have $CS(K_F^*(t_1), t_1) - CS(K_F^*(t_0), t_0) = -0.50163 < 0$ and $WW(K_F^*(t_1), t_1) - WW(K_F^*(t_0), t_0) = -0.051217 < 0$. ■

Proof of Proposition 7

Suppose $CS(K_F^*(t_1), t_1) < CS(K_F^*(t_0), t_0)$ and $WW(K_F^*(t_1), t_1) < WW(K_F^*(t_0), t_0)$ are satisfied. These inequalities hold only if the equilibrium under $K_F = K_F^*(t_1)$ is an Outsourcing equilibrium. Since $\partial CS(K_F, t_1)/\partial K_F \leq 0$ and $\partial WW(K_F, t_1)/\partial K_F \leq 0$ hold (see Proposition 3), we have $CS(K_F, t_1) < CS(K_F^*(t_0), t_0)$ and $WW(K_F, t_1) < WW(K_F^*(t_0), t_0)$ for all $K_F \geq K_F^*(t_1)$. For $K_F \in [0, K_F''(t_1)]$, the post-liberalization equilibrium becomes an FDI equilibrium and thereby $CS(K_F, t_1) > CS(K_F^*(t_0), t_0)$ and $WW(K_F, t_1) > WW(K_F^*(t_0), t_0)$ necessarily hold. If K_F increases from $K_F = K_F''(t_1)$ to $K_F = K_F''(t_1) + \varepsilon$ and $CS(K_F''(t_1) + \varepsilon, t_1) < CS(K_F^*(t_0), t_0)$ holds where ε is an infinitesimal value ($\varepsilon > 0$), we have $\hat{K}_F^{CS} = K_F''(t_1)$. If $CS(K_F''(t_1) + \varepsilon, t_1) \geq CS(K_F^*(t_0), t_0)$ holds, on the other hand, there exists $\hat{K}_F^{CS} \in (K_F''(t_1), K_F^*(t_1))$ such that $CS(K_F, t_1) = CS(K_F^*(t_0), t_0)$ holds at $K_F = \hat{K}_F^{CS}$ and $CS(K_F, t_1) > CS(K_F^*(t_0), t_0)$ holds for all $K_F \in (K_F''(t_1), \hat{K}_F^{CS})$. By the same procedure, we have $\hat{K}_F^{WW} = K_F''(t_1)$ if $WW(K_F''(t_1) + \varepsilon, t_1) < WW(K_F^*(t_0), t_0)$ holds and $\hat{K}_F^{WW} \in (K_F''(t_1), K_F^*(t_1))$ otherwise.

To prove $K_F''(t_1) < \hat{K}_F^{CS}$ and $K_F''(t_1) < \hat{K}_F^{WW}$ can hold under a range of parameterizations, we use the same parameterizations as those used in the proof of Proposition 6. We have $CS(K_F.t_1) - CS(K_F^*(t_0), t_0) = 0.16843(\sqrt{199.29 - 14.247K_F} - 14.117)^2 + 10.957 \sqrt{199.29 - 14.247K_F} - 136.26$ and $WW(K_F, t_1) - WW(K_F^*(t_0), t_0) = 2.3997K_F + 5.8902 \sqrt{-14.247K_F + 199.29} - 80.660$. We have $\hat{K}_F^{CS} = 3.2131 > K_F''(t_1) = 0.18697$ where $CS(K_F, t_1) = CS(K_F^*(t_0), t_0)$ holds at $K_F = \hat{K}_F^{CS}$and $CS(K_F.t_1) > CS(K_F^*(t_0), t_0)$ holds for all $K_F \in [0, \hat{K}_F^{CS})$. Similarly, we have $\hat{K}_F^{WW} = 3.2446 > K_F''(t_1)$ where $WW(K_F, t_1) = WW(K_F^*(t_0), t_0)$ holds at $K_F = \hat{K}_F^{WW}$ and $WW(K_F, t_1) > WW(K_F^*(t_0), t_0)$ holds for all $K_F \in [0, \hat{K}_F^{WW})$. ■

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Figure 1

Choice of Service Mode

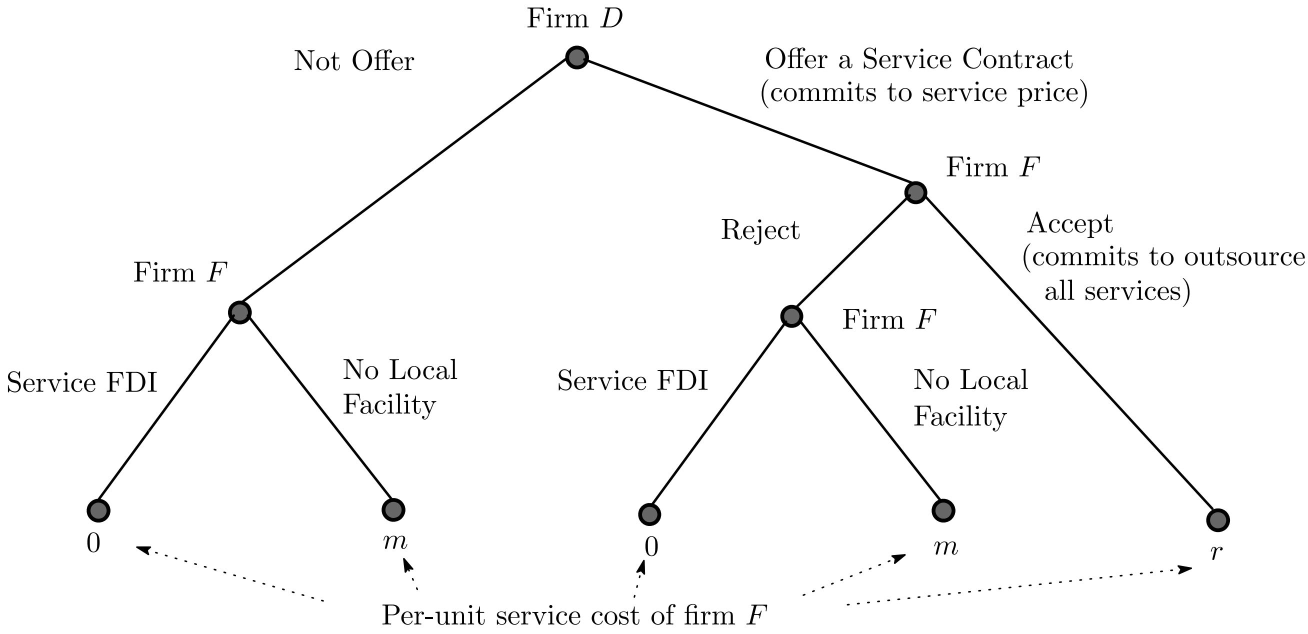


Figure 2

Equilibrium Service Sheme

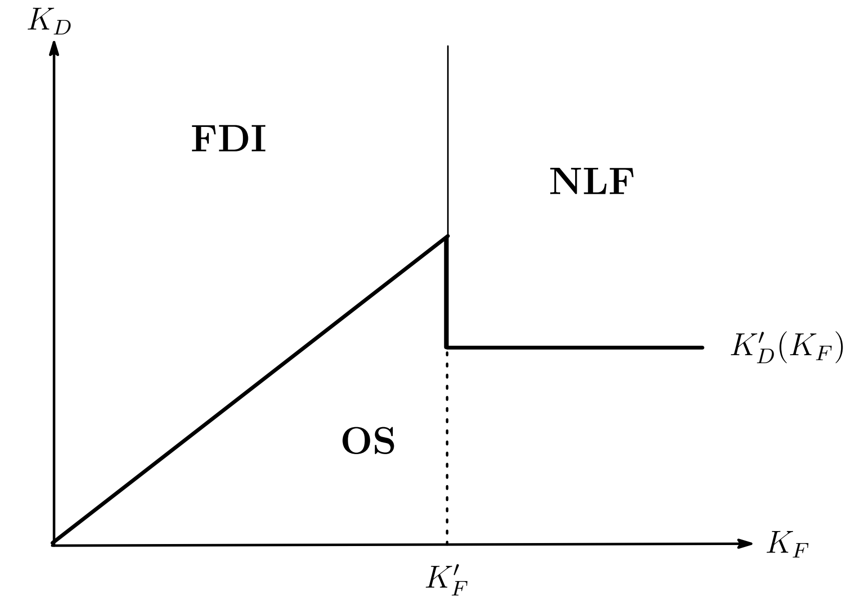


Figure 3

Tariff Reduction and Equilibrium Service Sheme

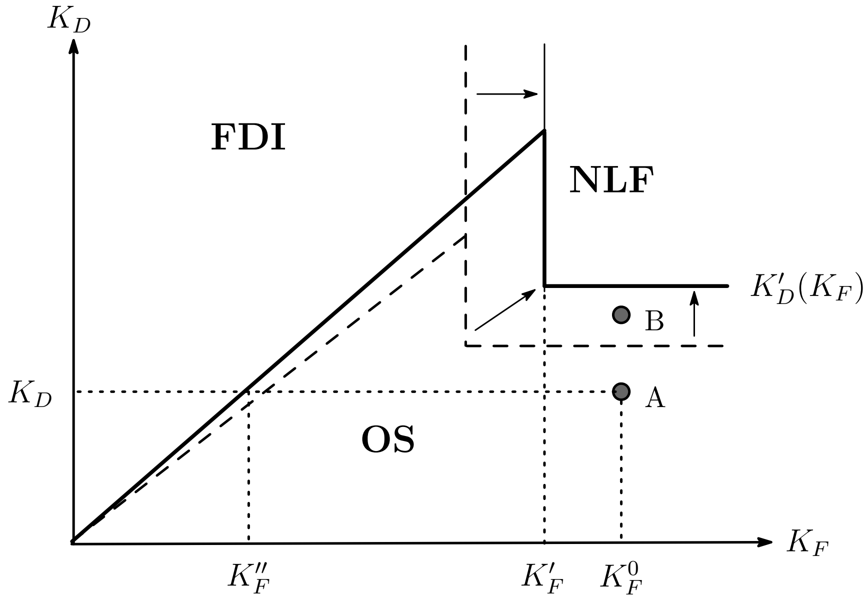


Figure 4

Effects of Liberalization in Service FDI with $K_D < K'_D$

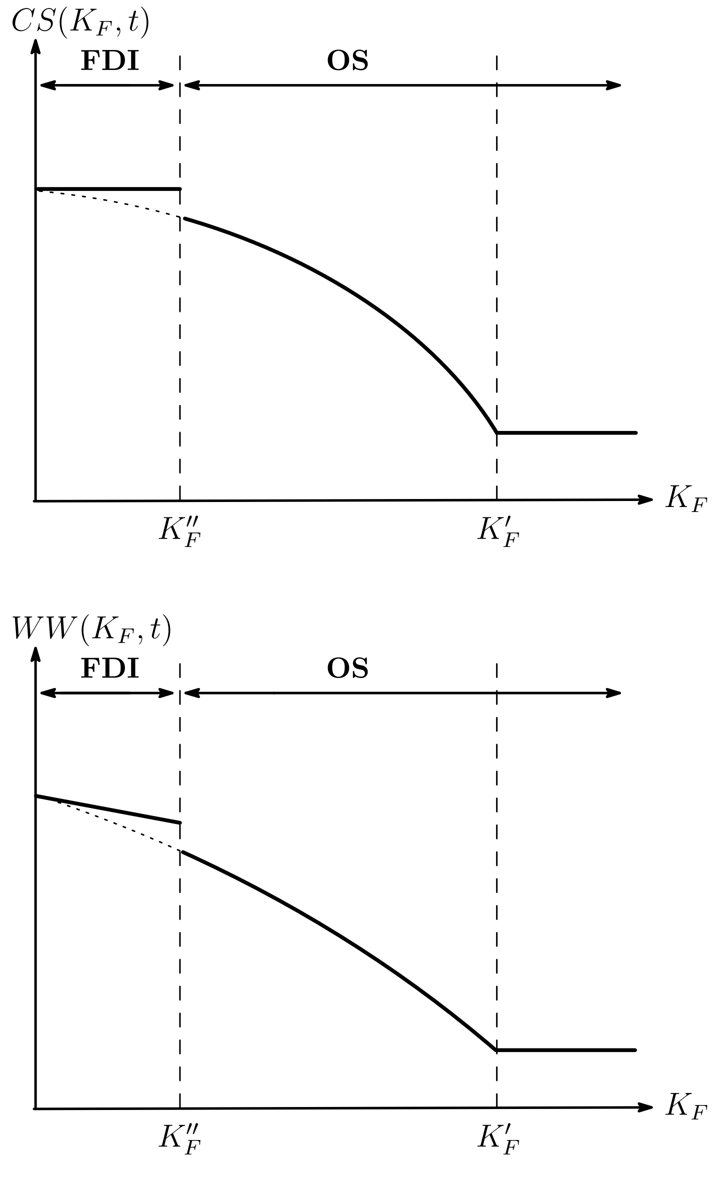
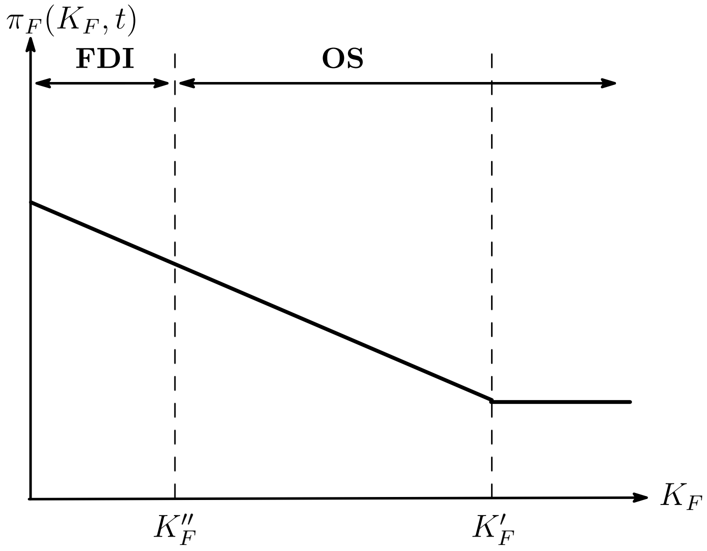


Figure 4 (continued)



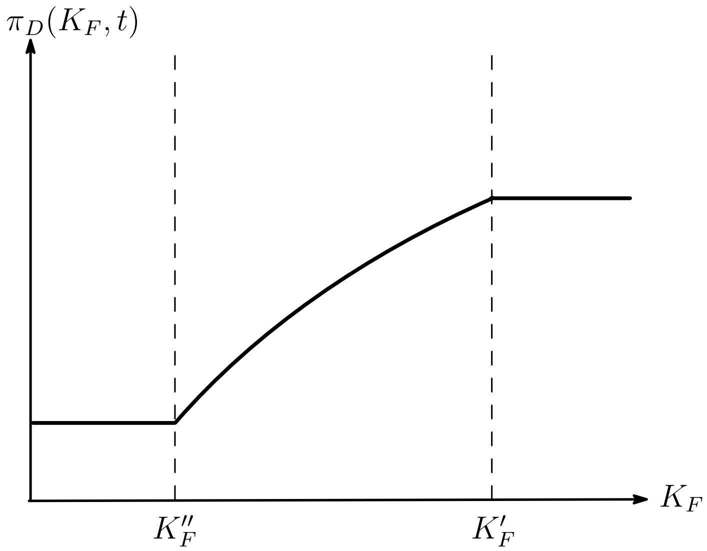


Figure 5

Anti-Competitive Scheme Switch by Trade Liberalization