# Trade Liberalization and FDI in Repair Services under International Oligopoly*

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**Abstract**

By a duopoly model, this paper examines interaction between trade liberalization in goods and foreign direct investment (FDI) in repair services. Consumers buy goods of which a certain fraction becomes broken and useless, and they can repair broken units by purchasing repair services. When the fixed cost of FDI in repair services is high, lower import tariff enhances the domestic firm's entry into the service market for imports, and the entry reduces trade, benefits the domestic firm, and hurts the foreign firm and domestic consumers. A service provision of an independent service organization may reduce imports more. The result suggests that promoting service FDI is important to guarantee the conventional effects of trade liberalization.

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# 1 Introduction

International trade between nations usually contains durable goods, such as automobiles, consumer electronics, furniture, machine tools, bags, shoes, and so on. For those goods, maintenance services or repair services are essential to keep them fresh and to use them continuously. Since these services requires communication and a proximity between suppliers and consumers, foreign exporters must establish overseas affiliates to provide the services to local consumers. In other words, these services require a foreign direct investments (FDI).[1] For instance, Eschenbach and Hoekman (2005) reports that distribution and repair services account for about 10% to 20% of the stock of inward service FDI in the Central and Eastern European countries and the South East European countries.

Due to the set-up costs of FDI, however, foreign exporters may refrain from making service FDIs. As a result, maintenance and repair services of imported goods by the original foreign producers may become limited. Under the circumstance, the rival producers sometimes provide the repair services by utilizing the economies of scope. For instance, Nidec Sankyo Service Engineering Corp., which is a domestic subsidiary of the Japanese company, Nidec Sankyo Corp., provides repair and maintenance services for competitors' machine tools including foreign made one. Daikin Air Conditioning Technology Co., Ltd. in the People Republic of China, which is a foreign subsidiary of a Japanese air-conditioning company, Daikin Industry, Ltd., provide maintenance and repair services for competitors' products as well as its own products. There are also the cases where the domestic independent service organizations (ISOs) provide repair services.

Although trade and FDI in services become increasingly important, the international trade theory has mainly focuses on trade and FDI in commodities, and theoretical analyses that consider trade in services are not so large. For example, Djajić and Kierzkowski (1989) introduce a labor-intensive service sector in Hecksher-Ohlin model and show that

[1] Recently, service trade becomes a significant fraction of international transcations. The World Trade Organization (WTO) reports that exports in services account for 19.3% of the total world exports in 2004 (See WTO, *International Trade Statistics 2005*). Since trade in services covers a broad range of international transactions, the GATS classifies them into four modes: (i) cross-border supply (mode 1), (ii) consumption abroad (mode 2), (iii) commercial presence (mode 3), and (iv) presence of natural persons (mode 4). The service in question in this paper is one of the mode 3 services. Since trade in services which is provided locally through foreign affiliates are not included in the WTO trade statistics, the actual value of service trade would be much more larger. Fukao and Ito (2003) estimates the size of the Japanese trade in services conducted through foreign affiliates.

the volume and direction of trade is influenced by whether services are traded internationally. Markusen (1989) and Francois (1990) show in a monopolistic competition model that producer services increase returns from specialization and liberalization in the service sectors increases gains from trade. Francois and Wooton (2001) incorporate a oligopolistic transport sector into a standard trade model and show that firms in the sector grab a certain fraction of benefits from trade liberalization in goods and so increase in trade flows and consumers' and exporters' gains from trade liberalization become smaller. Francois and Wooton (2005) assume the sales of imported goods require the domestic distribution services that are supplied under imperfect competition, and show that trade volumes and the level of optimal tariff are positively related to the degree of competitiveness in the service sector. Wong, Wu and Zhang (2006) adopt the "ideal variety" approach of intra-industry trade and show that service trade liberalization between two identical economies may or may not be welfare-enhancing depending on the degree of pre-trade domestic service liberalization. Papers on service FDI are also few. In a monopolistic-competition model of intermediate producer services, Raff and von der Ruhr (2001) investigate the determinants of FDI in producer services, and Markusen, Rutherford and Tarr (2005) examine the effects of service FDI on the market for domestic skilled labour. None of them, however, investigate the effects of trade policies in goods with endogenous FDI in services.

By focusing on a repair service, this paper investigates the interaction between trade liberalization in goods and FDI in services, which is overlooked in the existing literature. We use an international duopoly model where the domestic firm and the foreign firm compete in the domestic market and the provider of repair services for imports are endogenously determined. Specifically, we consider the situation in which a certain fraction of purchased goods become useless.[2] We assume the domestic firm already has the service facilities and the domestically produced good come with full warranty repair services. Hence, any broken units of the domestic good are always repaired. For the imported good, however, the broken units remain unrepaired unless service facilities for

[2]Hence, our model is related to literatures on durable-goods theory (though our model does not consider time passages directly). Among them, Driskill and Horowitz (1996) and Goering and Pippenger (2000) examine effects of trade policy under an international durable-good oligopoly, but maintenace services are not considered in these papers. Mann (1992), Chen and Ross (1993,1998,1999), Ekzubga and Mills (2001), Morita and Waldman (2004) consider maintenace or repair markets, but all of them consider a closed economy.

repairing the good are established. The provision of repair service for imports incurs both a fixed set-up cost and a variable operation cost. The foreign original producer can provide repair services in the domestic country by a service FDI. In addition, the domestic competitor that produces a similar product can also provide the repair services for imported good.

The result shows that trade liberalization in goods represented by lowering import tariff may reduce imports, benefit the domestic firm, and hurt the foreign firm when the changes in market structure of repair services are taken into account. This paradoxical result does not arise from unprovision nor underprovision of the repair services for imports. As will be shown, trade liberalization induces the domestic firm's entry into the service markets, and she always fixes all broken units of the competitor's product in equilibrium. Hence, the domestic firm's repairs for imports per se benefit consumers. However, the consumer benefit from repairs is weakened by the decreased amount of imports. This is because the domestic firm captures all the rents from repairs and the repairs decrease, rather than increase, the 'perceived demands' for the primary good the foreign firm faces. The effect reduces the foreign firm's operation profits. In addition, the domestic firm decreases sales of its own product to expand the size of the repair market and so the price of the domestically produced good increases. Since the loss from the weakened competition in the product market outweighs the gains from the increased availability of the foreign good, consumer becomes worse off with repairs. We will also show as an extension that even if the domestic service provider is an ISO, its entry reduces imports and the foreign firm's profits as long as it monopolizes the repair market for imports.

When the foreign firm provides repair services by making a service FDI, on the other hand, she increases exports since she can now capture the whole rents associated with its productf. Hence, both the working units of the foreign good and the degree of competition in the product market increases and so consumers become better off with repairs. We show, however, that trade liberalization in goods does not necessarily enhance the service FDI. In order to guarantee conventional consumer benefits and improve the economic efficiency of the world, FDIs in repair services should be liberalized in tandem with trade liberalization in goods.

Our result supports the recent efforts of service trade liberalization. For instance, the Uruguay Round negotiations of General Agreement on Tariffs and Trade (GATT) suc-

ceeded in establishing the framework of service trade liberalization, that is, the General Agreements on Trade in Services (GATS). The actual degree of liberalization, however, has been relatively small. In our model, service trade liberalization means an attempt to reduce impediments to service FDI. As the conventional theory of FDI suggests, some cultural barriers or the lack of information make it difficult to operate in foreign countries. These obstacles seem remarkable in service FDI, since services transactions, such as after-sales services, require proximity and communication between seller and buyer. Service FDI can be also deterred by the host country's regulations. For instance, People's Republic of China has prohibited provisions of after-sales service including repairs by foreign firms, before its accession to the WTO. Even if repair services are allowed, a repair service provider may not secure skilled workers by the regulation on the posting of workers across borders.

The remainder of the paper is organized as follows. In section 2, we explain the model and the timing of the game. In section 3, equilibrium in product markets and a repair market are derived. In section 4, firms' entry decisions into the service market is examined, and the effects of tariff reduction and service trade liberalization are explored. In section 5, we introduces ISOs as potential entrants. In section 6, we summarize and conclude the paper. Proofs of lemmas and propositions are given in the appendix.

## 2 Model

We analyze a three-stage duopoly model. The basic framework is based on Chen and Ross (1998), but we extend their closed-economy monopoly model to an international duopoly model with horizontal product differentiation. The two firms are the domestic firm (firm $D$) that produce good $D$ within the domestic country and the foreign firm (firm $F$) that produces good $F$ within the foreign country. After consumers purchase goods, some of them are broken and useless. We denote the probability of each good works correctly as $q \in (0, 1)$. Hence, the failure rate is $(1 - q)$.

We assume firm $D$ commits to provide a full warranty for its own product, and so consumer can repair all broken units with no fee. The repairs of good $F$, however, must be paid for and the service can be provided by either the original producer or the rival producer. Repaired units and unbroken units are perfect substitutes for consumers.

We consider the three-stage game. At stage 1, the two firms simultaneously make

entry decision into the repair-service market for good $F$. Note that the entry of firm $F$ into the service market takes the form of a service FDI. If the firm $i \in \{D, F\}$ enters, it has to incur a fixed set-up cost $K_i$ that is sunk. These fixed costs contain the cost of establishing facilities, that of learning know-how of repairing the competitor's product (if firm $D$ repairs), and the conventional costs of FDI (if firm $F$ repairs) which reflects the presumption that it is more difficult for firms to start local business in foreign countries. We assume $K_D \leq K_F$.

At stage 2, the two firms produce goods and supply them to the domestic market, and the domestic consumers buy the goods. The utility function of a representative consumer is given by $U(d_D, d_F, Z) = V(d_D, d_F) + Z$ where $d_i$ and $Z$ respectively represent the amount of good $i$ that works correctly and the consumption of a numeraire good. The function $V(d_D, d_F)$ is given by a standard quadratic form as $V(d_D, d_F) = a\,(d_D + d_F) - (d_D^2 + d_F^2)/2 - b d_D d_F$. We define $V_D(d_D, d_F) \equiv \partial V(d_D, d_F)/\partial d_D$ and $V_F(d_D, d_F) \equiv \partial V(d_D, d_F)/\partial d_F$ and assume both firms have the identical marginal cost of producing goods denoted by $c$. The domestic government levies a tariff on imports of the foreign good which is non-negative and denoted by $t$. The operating profits of firm $D$ and those of firm $F$ from sales of their primary goods are respectively given by $\Pi_D = [p_D - \{c + (1-q)\,m_L\}]x_D$ and $\Pi_F = [p_F - (c+t)]x_F$ where $p_i$ is the price of good $i$. Since firm $D$ must repair all broken units of good $D$, its expected marginal cost of production is given by $c + (1-q)\,m_L$. We concentrate on the case where consumers always buy both goods.

At stage 3, consumers repair broken units. As is mentioned, broken units of good $D$ are subject to free repair services by firm $D$. For good $F$, if any service facilities are established at stage 1, consumers can fix broken units of good $F$ by purchasing repair services. If both firms enter the repair market for good $F$, they set their repair prices simultaneously. We assume that there exist economies of scope between repairs and the production of goods, so each firm has a cost advantage over its rival in repairs of its own product. Specifically, the marginal cost of repairing its own product is $m_L$ is lower than that of repairing its rival product is $m_H$. Those costs are assumed to be no higher than the production cost, that is, $m_L < m_H \leq c$. The advantage is also large enough to

exclude entries of ISOs.[3]

The operating profits from repair services for good $F$ are respectively given by $\pi_D = (r - m_H)x_{DR}$ and $\pi_F = (r - m_L)x_{FR}$ where $r$ is the repair price and $x_{iR}$ is the amount of fixed units that are repaired by firm $i$. Note that $x_R \equiv \sum x_{iR} \leq (1-q)\, x_F$ and so $d_F = qx_F + x_R \leq x_F$.

# 3 Repair services and product market competition

In this section, we derive the product market and the repair market equilibria given each firm's decisions at stage 1. There are four possibilities: (i) the domestic firm's service monopoly (the DSM case), (ii) the foreign firm's service monopoly by the foreign direct investment in services (the FDI case), (iii) the service duopoly by the domestic firm and the foreign firm, and (iv) no repair services are provided for imports (the NR case). As will be seen below, the equilibrium in case (iii) generates the same equilibrium payoffs as case (ii) for producers and consumers.

## 3.1 Repair services

First, we consider the case where either or both firms established repair service facilities for good $F$. We use the backward induction to derive the sub-game perfect equilibrium.

At stage 3, the consumer maximizes $V(x_D, qx_F + x_R) - rx_R$ with respect to $x_R$ to determine the demand for repairs of good $F$. If $V_F(x_D, qx_F + x_R) \geq r$ when it is evaluated at $x_R = (1-q)\, x_F$, the demand for repairs is inelastic and given by $x_R = (1-q)\, x_F$. Alternatively, if $V_F(x_D, qx_F + x_R) < r$ at $x_R = (1-q)\, x_F$, only a part of the broken units is fixed and the demand for repair is given by $r = V_F(x_D, qx_F + x_R)$. Rearranging the equation gives

$$x_R\,(x_D, x_F) = a - r - qx_F - bx_D. \tag{1}$$

There are three possibilities as the structure of the repair market for imported goods: (i) the DSM case (ii) the FDI case, and (iii) both firm provide the services. In case (i) and (ii), the producer sets $r$ to maximize $\pi_i$ subject to $x_R \leq (1-q)\, x_F$. In case

[3] Our main result would not change when the producers of goods can exploit the profits of ISOs by selling parts and other intermediates that are indispensable to provide repair services. However, some striking results are obtained if ISOs are completely free from the producers' influences. See Section 5 for details.

(iii), repair-price competition by the two firms results in the equilibrium repair price as $r = m_H > m_F$, and $x_{DR} = 0$ and $x_{FR} = x_R$. As Chen and Ross (1998) suggest, we can confirm that all broken units are repaired in equilibrium.

**Lemma 1** *When repair services for imports are provided, all broken units are fixed in equilibrium.*

Intuitive explanation is as follows. Since a working unit and a broken unit are perfect substitutes for consumers, repairing one units of broken foreign goods are the same thing as buying one extra units of new foreign goods. By firm $F$'s optimization at stage 2, the expected marginal revenue and the marginal cost of selling new goods, $c + t$, coincide at $x_F$. Since we assume repaired units are never broken, the marginal revenue from repairing broken units exceeds marginal revenue from selling new units, and so it always exceeds $c + t$ for $0 \leq x_R \leq (1 - q)\, x_F$. Because $m_L < m_H \leq c + t$, the marginal revenue of repairs always exceeds the marginal cost and the service monopolist sets the repair price which is low enough to make consumers repair all the broken units. Under service duopoly, the race to the bottom of repair price competition makes the equilibrium price much lower, and so all broken units are fixed as well.

At stage 2, the consumer anticipates that repair price $r$ are set to satisfy $x_R = (1 - q)\, x_F$ at stage 3, and so she maximizes $V(x_D, qx_F + (1 - q)\, x_F) + Z$ subject to $I \geq p_D x_D + \{p_F + r\,(1 - q)\}x_F$ where $I$ represents the income of the representative consumer. The first-order condition yields the inverse demand function of each good given by

$$p_D = V_D(x_D, x_F) = a - x_D - bx_F, \tag{2}$$

$$p_F + (1 - q)\, r = V_F(x_D, x_F) = a - x_F - bx_D. \tag{3}$$

The left-hand side of (3) represents the 'full price' that the consumer must pay to consume $x_F$ units of good $F$. In what follows, we derive the equilibrium of the product market given the structure of the repair market.

### 3.1.1 Service monopoly by the domestic producer (DSM)

When firm $D$ monopolizes the repair market for good $F$, it will repair all broken units ($x_R = (1 - q)x_F$) and set the maximum price given $V_F(x_D, qx_F + x_R) \geq r$ at stage 3. Hence, the repair price is given by $r = V_F(x_D, x_F)$. Hence, the inverse demand

for imports becomes $p_F = qV_F(x_D, x_F)$ by (3). In Figure 1, the demand for imports with monopoly repairs is depicted by the solid line, where the dotted line represents the full demand for good $D$, $p_F + (1-q)\,r = V_F(x_D, x_F)$. Given $x_D$, consumers pay $p_F = qV_F(x_D, x_F)$ in the product market and $(1-q)\,r = (1-q)\,V_F(x_D, x_F)$ in the repair market to consumer $x_F$ amount of good $F$.

**[Figure 1 around here]**

By monopolizing the repair service, firm $D$ earns $(1-q)\,V_F$ of revenues per unit of imports, and firm $F$ earns $qV_F$ of those. Then, firm $D$ sets $x_D$ to maximize $\Pi_D + \pi_D = [p_D - \{c + (1-q)\,m_L\}]x_D + (r - m_H)\,(1-q)\,x_F = [V_D(x_D, x_F) - \{c + (1-q)\,m_L\}]x_D + \{V_F(x_D, x_F) - m_H\}\,(1-q)\,x_F$, and firm $F$ sets $x_F$ to maximize $\Pi_F = \{qV_F(x_D, qx_F) - (c+t)\}x_F$.

By the first-order condition, the optimal $x_D$ satisfies $V_D(x_D, x_F) + \{\partial V_D(x_D, x_F)/\partial x_D\}$ $x_D + (1-q)\{\partial V_F(x_D, x_F)/\partial x_D\}x_F = c + (1-q)\,(m_L + m_H)$. The first and the second term of the left-hand side of the equation is the marginal revenue of selling its own good, and the third-term represents the decline in revenue since increase in $x_D$ lowers the repair price. The right-hand side represents the expected marginal cost. On the other hand, firm $F$ sets $x_F$ so that the expected marginal revenue of selling goods is equal to the marginal cost, that is, $q[V_F(x_D, x_F) + \{\partial V_F(x_D, x_F)/\partial x_F\}x_F] = c + t$. Even though all broken units of good $F$ are fixed, the repairs are done by the competitor and so firm $F$ cannot capture the overall profits from selling $x_F$. Hence, a fraction of profits remains 'broken' for firm $F$ in this situation.

Solving the first-order conditions yield the equilibrium sales as

$$x_D^{DSM} = \frac{2\{a - c - (1-q)\,m_L\}q - ab\left(2 - q^2\right) + (2-q)\,b\,(c+t)}{\{4 - (2-q)\,b^2\}q}, \tag{4}$$

$$x_F^{DSM} = \frac{\{a\,(2-b) + bc\}q + bq\,(1-q)\,m_L - 2\,(c+t)}{\{4 - (2-q)\,b^2\}q}. \tag{5}$$

To guarantee $x_D^{DSM} > 0$ and $x_F^{DSM} > 0$, we assume the following inequalities are satisfied:

$$\begin{aligned} a &> \underline{a} = c + (1-q)\,m_L, \\ \frac{a\,(2-b)\,q}{(2-qb)} &\equiv \overline{c} > c, \quad \frac{a\,(2-b)\,q - (2-qb)\,c + bq\,(1-q)\,m_L}{2} \equiv \overline{t} > t. \end{aligned} \tag{6}$$

Namely, production cost, repair cost, and tariff rate are assumed to be not so high. The equilibrium operating profits (that is, the profits gross of fixed set-up cost of service

facilities) are given by

$$\begin{aligned}\Pi_D^{DSM} + \pi_D^{DSM} &= \left(x_D^{DSM}\right)^2 + (1-q)\left(x_F^{DSM}\right)^2 \\ &\quad + \left(\frac{c+t}{q} - m_H\right)(1-q)\, x_F^{DSM} + (1-q)\, b\left(x_D^{DSM}\right)\left(x_F^{DSM}\right), \quad (7) \\ \Pi_F^{DSM} &= q\left(x_F^{DSM}\right)^2 \quad (8)\end{aligned}$$

where firm $D$'s net profits are given by $\Pi_D^{DSM} + \pi_D^{DSM} - K_D$. The first-term of (7) represents firm $D$'s profits from selling its own good. The equilibrium can be interpreted as if firm $F$ sells $qx_F$ and firm $D$ sells $(1-q)x_F$ with different costs. Hence, the second term and the third term respectively represents the 'dividend effect' and the 'cost-reducing effect' of providing a repair service. In addition, since firm $D$ takes into account that an increase in $x_D$ reduces profits from repair services by decreasing the size of the repair market and the repair price, the firm has an incentive to set $x_D$ below the level that is optimal when the firm does not providing the repair service. The situation can be considered as if the producer and the repairer of its competitor's product colluded to increase their joint profits. This 'self-collusion effect' is reflected in the fourth term of (7).

The equilibrium consumer surplus and the tariff revenue are respectively given by

$$\begin{aligned}CS^{DSM} &= \frac{(x_D^{DSM})^2 + (x_F^{DSM})^2}{2} + b(x_D^{DSM})(x_F^{DSM}) \quad (9) \\ TR^{DSM} &= tx_F^{DSM}. \quad (10)\end{aligned}$$

The domestic welfare becomes $W_D^{DSM} = CS^{DSM} + TR^{DSM} + \Pi_D^{DSM} + \pi_D^{DSM} - K_D$.

### 3.1.2 Service provision by the original producer (FDI)

When only firm $F$ provides repair services for good $F$, it sets $r = V_F(x_D, x_F)$ in the repair market at stage 3 and so the demand for imports becomes $p_F = qV_F(x_D, x_F)$. At stage 2, firm $D$ sets $x_D$ to maximize $\Pi_D = [V_D(x_D, x_F) - \{c + (1-q)\, m_L\}]x_D$ and firm $F$ sets $x_F$ to maximize $\Pi_F + \pi_F = [p_F + (1-q)\, r - \{c + t + (1-q)\, m_L\}]x_F = [V_F(x_D, x_F) - \{c + t + (1-q)\, m_L\}]x_F$. Now firm $F$ can capture all the rents concerning good $F$ and earn the per unit revenue of $V_F(x_D, x_F)$ by suppling $x_F$, which is depicted by the dotted line in Figure 1.

The first-order conditions yields the equilibrium sales as

$$x_D^{FDI} = \frac{(2-b)\{a-c-(1-q)m_L\}+bt}{4-b^2}, \tag{11}$$

$$x_F^{FDI} = \frac{(2-b)\{a-c-(1-q)m_L\}-2t}{4-b^2}. \tag{12}$$

We can verify that $x_D^{FDI} > 0$ and $x_F^{FDI} > 0$ as long as (6) is satisfied. The equilibrium operating profits are given by

$$\Pi_D^{FDI} = \left(x_D^{FDI}\right)^2, \quad \Pi_F^{FDI} + \pi_F^{FDI} = \left(x_F^{FDI}\right)^2. \tag{13}$$

The foreign firm's net profits are given by $\Pi_F^{FDI} + \pi_F^{FDI} - K_F$. The equilibrium consumer surplus, the tariff revenue, and the domestic welfare are respectively given by

$$CS^{FDI} = \frac{(x_D^{FDI})^2 + (x_F^{FDI})^2}{2} + b(x_D^{FDI})(x_F^{FDI}), \tag{14}$$

$$TR^{FDI} = tx_F^{FDI}. \tag{15}$$

The domestic welfare is given by $W_D^{FDI} = CS^{FDI} + TR^{FDI} + \Pi_D^{FDI}$.

Alternatively, when both firm $D$ and firm $F$ establish the service facilities for good $F$, firm $F$ sets $r = m_H$. Hence, $p_F = V_F(x_D, x_F) - (1-q)m_D$. Firm $F$'s optimization problem is setting $x_F$ to maximize $\Pi_F + \pi_F = [p_F + (1-q)m_D - \{c+t+(1-q)m_F\}]x_F = [V_F(x_D, x_F) - \{c+t+(1-q)m_F\}]x_F$. Since the objective function is the same as the foreign monopoly case, the equilibrium sales of each firm are given by (11) and (12) and the consumer surplus and the tariff revenue also become the same. In the repair market, the repair price decreases and it per se benefits consumer and hurts firm $F$. Firm $F$, however, is able to compensate for the loss by raising the product price. Thus, firm $D$'s entry when firm $F$ already supplies the repair service has no effect on the overall operating profits nor the consumer surplus. As long as service facilities must be established before they sell the products, it does not affect the entry decisions of the two firms at stage 1.[4]

### 3.2 No repair services for good $F$ (NR)

The remaining case is that neither firm $D$ nor firm $F$ establishes service facilities for good $F$ at stage 1. In this case, broken units of good $F$ become scraps and so $d_F = qx_F$.

[4] If the entry decisions are done after firms sold products, the equilibrium can be different. In particular, if set-up costs are not sunk, the repair price can be a tool to deter entry and the strategic interaction between the two firms becomed more complicated.

In stage 2, the consumer maximize $V(x_D, qx_F)$ $+Z$ subject to $I \geq p_D x_D + p_F x_F$. The first-order condition yields demands for each product given by

$$p_D = V_D(x_D, qx_F) = a - x_D - bqx_F, \tag{16}$$

$$p_F = qV_F(x_D, qx_F) = q\left(a - qx_F - bx_D\right). \tag{17}$$

Since a fraction of the foreign goods becomes useless, the demand for the foreign good depends on the 'expected' marginal utility represented by $qV_F(x_D, qx_F)$. We have $\partial\{qV_F(x_D, x_F)\}/\partial x_F = -q < \partial\{qV_F(x_D, qx_F)/\partial x_F = -q^2$, so the inverse demand curve for imports without repairs is flatter than that with monopoly repairs, which is depicted by the solid line in Figure 2. When broken units remains unrepaired, consumers anticipate that the actual amount of the foreign good they consume is smaller than the amount they purchase. Hence, the degree of an decrease in their marginal utilities by an increase in $x_F$ becomes smaller than the decrease with repairs and so the slope of the demand curve is flatter.

**[Figure 2 around here]**

Given the inverse demand functions, firm $D$ and firm $F$ maximize $\Pi_D = [V_D(x_D, qx_F) - \{c + (1-q)\, m_L\}]x_D$ and $\Pi_F = \{qV_F(x_D, qx_F) - (c+t)\}x_F$ with respect to $x_D$ and $x_F$ respectively. The first-order condition becomes $V_D(x_D, qx_F) + \partial V_D(x_D, qx_F)/\partial x_D = c$ and $q\{V_F(x_D, qx_F) + \partial V_F(x_D, qx_F)/\partial x_{F\}} = c + t$. The equilibrium sales are given by

$$\begin{aligned} x_D^{NR} &= x_D^{DSM} + \frac{2b\,(1-q)}{\{4-(2-q)\,b^2\}} x_F^{NR} \\ &= \frac{\{a\,(2-b) - 2c\}q - 2q\,(1-q)\,m_L + b\,(c+t)}{(4-b^2)\,q}, \end{aligned} \tag{18}$$

$$\begin{aligned} x_F^{NR} &= \frac{\{4-(2-q)\,b^2\}}{(4-b^2)\,q} x_F^{DSM} \\ &= \frac{\{a\,(2-b) + bc\}q + bq\,(1-q)\,m_L - 2\,(c+t)}{(4-b^2)\,q}. \end{aligned} \tag{19}$$

Note that $x_D^{NR} > 0$, $x_F^{NR} > 0$ as long as (6) is satisfied. We have $\partial x_D^{NR}/\partial t > 0$ and $\partial x_D^{NR}/\partial t < 0$. In equilibrium, the profits of each firm are given by

$$\Pi_D^{NR} = \left(x_D^{NR}\right)^2, \quad \Pi_F^{NR} = \left(qx_F^{NR}\right)^2. \tag{20}$$

The consumer surplus, and the tariff revenue are respectively given by

$$CS^{NR} = \frac{(x_D^{NR})^2 + (qx_F^{NR})^2}{2} + b(x_D^{NR})(qx_F^{NR}), \tag{21}$$

$$TR^{NR} = tx_F^{NR}. \tag{22}$$

The domestic welfare becomes $W_D^{NR} = CS^{NR} + TR^{NR} + \Pi_D^{NR}$.

### 3.3 Comparison

Before investigating the two firms' entry decisions into the service market, we first compare the three equilibria. Firstly, we compare the effects of trade liberalization in each regime, which is represented by the reduction of $t$. We have the following proposition.

**Proposition 1** *Given the structure of the repair market, a tariff reduction always benefits firm $F$ and consumers. A tariff reduction may benefit firm $D$ in the DSM case, though it always hurts firm $D$ in the NR case and the FDI case.*

Hence, trade liberalization has the conventional effects when the foreign original producer provides repair services or there are no repair services. When the domestic producer provides the repair services, the liberalization can either increase or decrease its profits. For firm $D$, trade liberalization has two opposite effects when it monopolizes the repair market. On one hand, it decreases $x_D^{DSM}$ and so profits from selling its own product decline, but it increases $x_F^{DSM}$ and raises profits from repairing services on the other hand. Thus, the domestic firm can either be better off or worse off by trade liberalization, depending on the magnitudes of the two effects. It is likely to become better off when $c$ is large relative to $m_H$, and $b$, and $q$ are small (see the proof of Proposition 1 given in the appendix). Consumers and firm $F$ benefit from the trade liberalization in all regimes. Since the tariff has a rent-shifting effect under international oligopoly, trade liberalization can either increases or decreases the domestic welfare.

Next, we compare sales, profits, and consumer surplus in three equilibria when evaluated at the same tariff rate. As for the equilibrium sales, we have the following proposition.

**Proposition 2** *Given $t$, $x_F^{DSM} < x_F^{NR}$, $qx_F^{NR} < \min[x_F^{DSM}, x_F^{FDI}]$, and $\max[x_D^{DSM}, x_D^{FDI}] < x_D^{NR}$, .*

**Proof.** By (4), it is clear that $x_D^{DSM} < x_D^{NR}$ and $x_F^{DSM} < x_F^{NR}$ is satisfied. By (18), (19), (11) and (12). $x_D^{NR} - x_D^{FDI} = (1-q)\, b\, (c - qm_L + t) / \{\left(4 - b^2\right) q\} > 0$, $x_F^{DSM} - qx_F^{NR} = (1-q)\, qb^2 x_F^{NR} / \{4 - (2-q)\, b^2\} > 0$, and $x_F^{FDI} - qx_F^{NR} = 2\,(1-q)\,(c - qm_F + t) / \{\left(4 - b^2\right) q\} > 0$. ■

The amount of imports is lower with firm $D$'s repairs than that without repairs. As is discussed in Section 3.2, the price sensitivity of import demand without repairs is larger than that with repairs. The difference induces firm $F$ to make relatively larger exports without repairs. Although a risk of being broken-down also reduces the market size of good $F$, only the former effect matters for firm $F$ when firm $D$ monopolizes repair services and so the benefits from a market-size increase are wholly captured by the competitor. In other words, no repairs and repairs by the rival firm are the same for firm $F$, in that she cannot capture possible profits associate with broken units, $(1-q)x_F$. They are different, however, for consumers and so the demand for the primary goods are reduced with repairs though the overall demand that includes demand for repairs is increased. When firm $F$ provides repair services, on the other hand, whether they increase or decrease imports are ambiguous. As for sales by the domestic firm, they are lower with repairs than those without repairs, because repairs increase the amount of working units of good $F$.

As for each firm's profits, the following rankings are obtained.

**Proposition 3** *Given $t$, $\Pi_D^{FDI} < \Pi_D^{NR} < \Pi_D^{DSM} + \pi_D^{DSM}$ and $\Pi_F^{DSM} < \Pi_F^{NR} < \Pi_F^{FDI} + \pi_F^{FDI}$.*

The operating profits of each firm are highest if it monopolizes the repair service, and lowest if its competitor monopolizes the service. Since the equilibrium payoffs under a service duopoly are the same as those under firm $F$'s service monopoly, firm $F$ gains and firm $D$ lose in operating profits when both firms set up service facilities.

As for the consumer surplus, it is largest under the FDI case. Between the two remaining regimes, consumer surplus under the NR case is larger than that under the DSM case.

**Proposition 4** *Given $t$, $CS^{DSM} < CS^{NR} < CS^{FDI}$.*

Compared to the NR case, service FDI by firm $F$ increases the working units of good $F$ and has a pro-competitive effect in the product market. The service monopoly by firm $D$, on the other hand, increases the working units of good $F$ but deters competition in the product market. This is because firm $D$ can now earn profits in the product $F$ market through repair services and thereby she accommodates imports by reducing supplies of good $D$. This self-collusion effect increases price of good $D$ and it offsets the benefits

from the increased availability of the foreign working units. Hence, consumers become better off with firm $F$'s repairs but they become worse off with firm $D$'s repairs..

# 4 Entry into the service market

We now describe the equilibrium at stage 1. Firm $D$'s gains in operating profits from monopolizing the service market is given by

$$\Delta\Pi_D \equiv \Pi_D^{DSM} + \pi_D^{DSM} - \Pi_D^{NR}. \tag{23}$$

Note that $\Delta\Pi_D = 0$ with $t = \bar{t}$. When firm $D$ does not establish service facilities, firm $F$'s gains in operating profits from monopolizing the service market is

$$\Delta\Pi'_F \equiv \Pi_F^{FDI} + \pi_F^{FDI} - \Pi_F^{NR}. \tag{24}$$

If firm $D$ monopolized repair services, the firm $F$'s operating profits are declined to $\Pi_F^{DSM}$ if she does not enter. Then, firm $F$'s gains from entry become

$$\Delta\Pi''_F \equiv \Pi_F^{FDI} + \pi_F^{FDI} - \Pi_F^{DSM}. \tag{25}$$

Since $\Pi_F^{DSM} < \Pi_F^{NR}$, $\Delta\Pi'_F < \Delta\Pi''_F$. It can be confirmed that $\Delta\Pi_D$, $\Delta\Pi'_F$, and $\Delta\Pi''_F$ have the following properties.

**Lemma 2** *(i)* $\partial(\Delta\Pi_D)/\partial t < 0$. *(ii)* $\partial(\Delta\Pi'_F)/\partial t$ *and/or* $\partial(\Delta\Pi''_F)/\partial t$ *are inverse U-shaped curves in* $t \in [0, \bar{t})$ *if* $m_F$ *is large and* $c$ *is small enough. Otherwise,* $\partial(\Delta\Pi'_F)/\partial t \leq 0$ *and/or* $\partial(\Delta\Pi''_F)/\partial t \leq 0$.

The lemma indicates that when firm $F$ does not enter the service market, the firm $D$'s gains from entry become larger as trade liberalization proceeds. The firm $F$'s gains from entry, on the other hand, may or may not increase with a tariff reduction. Since the price sensitivity of demand for good $F$ is larger without repairs than that with repairs. Hence, the degree of the increase in $x_F$ by the tariff reduction is larger without service FDI. Although trade liberalization also increases the size of the repair market as well as gains from repair services, the reduced gains by the smaller increase in exports may dominate it so that trade liberalization may undermine firm $F$'s entry. The case is likely to occur when the tariff is small, the cost of production is small, and the cost of repair is high.

Now we derive the possible equilibria. Firstly, we consider firm $D$'s strategy and its relation to the tariff rate. Remember that under the service duopoly, firm $D$ cannot earn positive profits in the service market and the equilibrium profits of firm $F$ are the same as those under the service monopoly by the firm. Hence, firm $D$ enters the service market if and only if firm $F$ does not enter. When $K_D < \Delta\Pi_D|_{t=0}$, there exists a unique cut-off value of $t$, $\widehat{t}_D$, that satisfies

$$\Delta\Pi_D \begin{cases} > K_D & \text{for} \quad t \in [0, \widehat{t}_D) \\ = K_D & \text{for} \quad t = \widehat{t}_D \\ < K_D & \text{for} \quad t \in (\widehat{t}_D, \overline{t}) \end{cases} . \tag{26}$$

When $\Delta\Pi_D|_{t=0} \leq K_D$ we set $\widehat{t}_D = 0$. Hence, firm $D$'s strategy is entering if firm $F$ does not choose entering and $t \in [0, \widehat{t}_D)$, and not entering otherwise.

Next, let

$$\Delta\Pi_F = \begin{cases} \Delta\Pi''_F & \text{for} \quad t \in [0, \widehat{t}_D) \\ \Delta\Pi'_F & \text{for} \quad t \in [\widehat{t}_D, \overline{t}) \end{cases}$$

denote the firm $F$'s gains in operating profits from providing repair services given firm $D$'s actions. Let us also denote $t_F^{\max} = \text{argmax}_{t \in [0.\overline{t})} \Delta\Pi_F$. If $\Delta\Pi_F$ is decreasing in $t$, $t_F^{\max} = 0$, and if $\Delta\Pi_F$ is inverse U-shaped in $t$, $t_F^{\max} \in (0, \overline{t})$. When $t_F^{\max}$ is positive and $K_F < \Delta\Pi_D|_{t=t_F^{\max}}$, there exists $\widehat{t}_F^L < \widehat{t}_F^H$ such that

$$\Delta\Pi_F \begin{cases} > K_F & \text{for} \quad t \in (\widehat{t}_F^L, \widehat{t}_F^H) \\ = K_F & \text{for} \quad t = \widehat{t}_F^L \text{ or } t = \widehat{t}_F^H \\ < K_F & \text{for} \quad t \in [0, \widehat{t}_F^L) \text{ or } t \in (\widehat{t}_F^H, \overline{t}) \end{cases} . \tag{27}$$

When $t_F^{\max} = 0$ and $K_F < \Delta\Pi_F|_{t=t_F^{\max}}$, we set $\widehat{t}_F^L = 0$ and when $\Delta\Pi_F|_{t=t_F^{\max}} \leq K_F$ we set $\widehat{t}_F^L = \widehat{t}_F^H = 0$. By this manipulation, we can use (27) in any states to derive equilibrium. Specifically, firm $F$'s strategy is entering if $t \in (\widehat{t}_F^L, \widehat{t}_F^H)$ and is not entering otherwise. There are three possible Nash equilibria of the entry game.

**Proposition 5** *In equilibrium, (i) the domestic firm monopolizes the service market if either* $\widehat{t}_F^H \leq t < \widehat{t}_D$ *or* $0 \leq t < \min[\widehat{t}_D, \widehat{t}_F^L]$ *is satisfied, (ii) the foreign firm monopolizes the service market if* $\widehat{t}_F^L < t < \widehat{t}_F^H$ *is satisfied, (iii) neither of the two firms enters the service market if either* $\max[\widehat{t}_F^H, \widehat{t}_F^H] \leq t$ *or* $\widehat{t}_D \leq t < \widehat{t}_F^L$ *is satisfied.*

Given $K_D$, the possible equilibrium outcomes in the $(t, K_F)$ space are depicted in Figure 3.[5] No repair services becomes the equilibrium outcome when $t$ and $K_F$ are high (shown as the region 'NR' in the figure). When $t$ is not so high, a service monopoly by firm $D$ can be the equilibrium outcome and it is more likely when $K_F$ is high (the region 'DSM'). Otherwise, a service FDI by firm $F$ is the equilibrium outcome (the region 'FDI').

**[Figure 3 around here]**

Now we examine the effects of trade liberalization in commodities represented by a decline in $t$ and trade liberalization in services represented by a decline in $K_F$, given that they can change the equilibrium market structure of the service sector. For instance, suppose $K_F = \widehat{K}_F$ in Figure 3. In this case, $\widehat{t}_F^L = 0 < \widehat{t}_F^H < \widehat{t}_D < \overline{t}$ and a successive decline in $t$ from $\overline{t}$ to zero changes the equilibrium outcomes from no services (NR) to firm $D$'s service monopoly (DSM), and then from firm $D$'s service monopoly to service FDI by firm $F$. In figure 4, we present a numerical example of this case. We set parameters as $a = 20$, $b = 0.5$, $c = 5$, $q = 0.5$, $m_H = 2$, $m_F = 1$, $K_D = 10$, $K_F = 26$. Under these parameter values, the cut-off values of tariffs become $\widehat{t}_F^L = 0$, $\widehat{t}_F^H = 0.58302$, $\widehat{t}_D = 1.775$, and $\overline{t} = 3.1875$.

**[Figure 4 around here]**

As is shown in the figure, when the initial tariff is high enough ($t \in (\widehat{t}_D, \overline{t})$) and so initially repair services are not provided, trade liberalization from $t$ to $t' \in (\widehat{t}_F^H, \widehat{t}_D]$ induces the entry into the repair market by firm $D$. Although the standard trade liberalization effect increases imports, consumer surplus, and firm $F$'s profit, the change in the market structure has the opposite effects as is proved by Propositions 2, 3 and 4. Thus, a trade liberalization in appearance may works as a import protection in practice when the degree of tariff decline is small and so the entry effect of firm $D$ is relatively important. Since firm $D$ gains from the entry, and the trade liberalization effect may increase firm $D$'s profit for $t \in (\widehat{t}_F^H, \widehat{t}_D]$ (see Proposition 1), trade liberalization can benefit firm $D$. In addition, since $\Delta\Pi_D - K_D = 0$, $CS^{DSM} < CS^{NR}$ and $x_F^{DSM} < x_F^{NR}$, and $\Pi_F^{DSM} < \Pi_F^{NR}$ at $t = \widehat{t}_D$, the entry effect reduces the domestic welfare as well as the world welfare. We have the following proposition.

[5] To include all possible cases in the figure, the case in which both $\Delta\Pi_F'$ and $\Delta\Pi_F''$ are inverse U-shaped curves is employed.

**Proposition 6** *A tariff reduction may reduce imports, benefit the domestic firm, and hurt consumers and the foreign firm when the degree of tariff reduction is small and the reduction induces entry of the domestic firm into the service market. It may also worsen the domestic welfare and world welfare.*

To avoid the 'pitfall' of trade liberalization, the foreign firm's service FDI should be promoted. In some case, a large tariff reduction encourages the service FDI as is the above example. In general, however, it is ambiguous whether trade liberalization in goods promotes or hampers the service FDI. The latter is the case when $m_F$ is large and $c$ is small so that $\Delta\Pi_F$ is an inverse U-shaped curve, and $K_F$ is relatively high to satisfy $\Delta\Pi_F|_{t=0} < K_F$. In this case, $\widehat{t}_F^L$ is positive and a trade liberalization from above and near $\widehat{t}_F^L$ may discourage service FDI and encourage the rival's entry or no service provisions. To avoid such a situation, $K_F$ should be lowered to make service FDI more attractive for firm $F$. In particular, sufficient liberalization in the service FDI guarantees the conventional effects of trade liberalization as the following corollary states.

**Corollary 1** *When $K_F < \min_{t\in[0,\overline{t})} \Delta\Pi_F$, the foreign firm always makes a service FDI.*

## 5 Repair services by an independent service organization

So far, we have assumed that only firms that produce goods can provide repair services for imports. In reality, however, there are cases where independent service organizations (ISOs) are providing repair services. In this section, we derive the equilibrium where an ISO provides repair services and compare it with the above three cases.

To make clear comparisons, we suppose the ISO has the same technology of repairs as firm $D$'s: that is, the unit cost of repairs and the fixed entry cost is given by $m_H$ and $K_D$ respectively. As above, it will set $r = V_F(x_D, x_F)$ at stage 3 and all broken units are repaired in equilibrium. The inverse demand for imports becomes $p_F = qV_F(x_D, x_F)$ by (3). The equilibrium profits of the ISO are given by $\pi_{ISO} = \{V_F(x_D, x_F) - m_H\}(1-q)x_F$. At stage 2, firm $D$ sets $x_D$ to maximize $\Pi_D = [V_D(x_D, x_F) - \{c + (1-q)m_L\}]x_D$ and firm $F$ sets $x_F$ to maximize $\Pi_F = [qV_F(x_D, x_F) - (c+t)]x_F$. By solving the first-order conditions, we obtain the equilibrium sales as

$$x_D^{ISO} = x_D^{NR}, \quad x_F^{ISO} = qx_F^{NR}. \tag{28}$$

The equilibrium profits of each firm are given by $\Pi_D^{ISO} = \Pi_F^{NR}$, $\Pi_F^{ISO} = q^2\Pi_F^{NR}$, $\pi_{ISO} = \{V_F(x_D^{ISO}, x_F^{ISO}) - m_H\}(1-q)\,x_F^{ISO}$. The consumer surplus, and the tariff revenue are respectively given by $CS^{ISO} = CS^{NR}$, $TR^{ISO} = qTR^{NR}$. Surprisingly, monopolistic service provision by an ISO results in the smaller amount of imports than the amount without repair services, though the domestic sales and the post-repair amount of the foreign good are unchanged between the two regimes. Furthermore, since $x_F^{ISO} = qx_F^{NR} < x_F^{DSM}$ by (2), the volume of imports are lower than that the domestic firm's service monopoly. We have the following proposition.

**Proposition 7** *Given the tariff level, a change from no repair services to monopolistic service provisions by the ISO has no effects on the profits of the domestic firm nor consumer surplus. The foreign firm, on the other hand, becomes worse off and its profits are lower than the DSM case.*

As in the DSM case, the 'perceived' demand for imports that firm $F$ faces in the ISO case is $1/q$ times smaller than that in the NR case. Hence, $x_F^{ISO} = qx_F^{NR}$ is satisfied. In the ISO case, on the other hand, all broken units of $x_F^{ISO}$ are repaired and so it coincides with the volume of consumption of good $F$. Since the amount of good $F$ that works correctly is unchanged and so firm $D$'s optimal supply is also unchanged. Note that in the DSM case, firm $D$ makes profits from the repair market and so it has an incentive to reduce $x_D$ at $x_D = x_D^{ISO}$ in order to expand the repair market and increase profits there. Hence, the amount of $x_D$ is higher in the ISO case than in the DSM case, and so the equilibrium amount of its substitute, $x_F$, is lower in the ISO case than in the DSM case.

The result suggests that as long as the repair market is monopolized, repair services for durable goods by a non-original producer hurts the original producer.[6] The damage is smaller, rather than larger, when the competitor in the product market provides the services since it weakens the product market competition.

The presence of ISOs also changes the equilibrium entry patterns in the repair market. When there are no entries, an ISO enters if $\pi_{ISO} \geq K_D$. If the original goods producers or other ISOs choose entry, the ISO never enter since it cannot earn positive profits. Let

[6] Even if there are no fixed costs of entry and ISOs realize perfect competition in the repair market, no repairs dominate repairs by ISOs for firm $F$ when ISOs have cost disadvantage in repairs and so the equilibrium price of repairs is high.

$\widehat{t}^{ISO}$ be the tariff level that satisfy $\pi_{ISO} = K_D$. Since $\partial\pi_{ISO}/\partial t < 0$, the ISO enters only if $t < \widehat{t}^{ISO}$. In addition, $\Delta\Pi_D > \pi_{ISO}$ means $\widehat{t}^{ISO} < \widehat{t}_D$. Hence, multiple equilibria of the DMS case and the ISO case emerge if either $\widehat{t}_F^H \leq \widehat{t}^{ISO} \leq t < \widehat{t}_D$ or $0 \leq t < \min[\widehat{t}^{ISO}, \widehat{t}_F^L]$ is satisfied.[7] This indicates that smaller import tariff may bring about the entry by an ISO, which is the worst situation for the foreign firm.

# 6 Conclusion

Using a duopoly model with horizontal product differentiation, this paper examines interaction between trade liberalization in commodities and FDI in services. Our focus is on the repair services for imports, that can be provided either by the foreign original producer or by the domestic rival producer.

When the fixed cost of FDI in repair services is high, a lower import tariff enhances the domestic firm's entry into the service market for the foreign good, and the entry benefits the domestic firm since the domestic firm can now 'supplies' a certain fraction of the foreign good through repairs. Since repaired goods and new goods are perfect substitutes, the domestic firm's repairs hurts the foreign firm. Furthermore, since the domestic firm reduces supplies of her own good and increases its price to expand repair markets (the 'self-collusion' in the two markets), consumer becomes worse off compared to the case without repairs. The FDI in repair services by the original producer, on the other hand, encourages competition in the product market and benefits consumers and the foreign firm. Trade liberalization in goods, however, does not necessarily encourage the service FDI unless the set-up cost is low enough.

These results indicates the importance of trade liberalization in services. The liberalization not only has a direct effect of reducing costs, but also an additional effect that reduces possibilities of some extraordinary consequences of trade liberalization in commodities and sustains the ongoing process of multilateral trade liberalization in the world.

There are some directions to extend our analysis. For instance, our result indicates that a tariff-jumping FDI in production may make consumers worse off by inviting the domestic firm's entry into the repair market. To guarantee consumer's benefits, a service

[7] Since $\Delta\Pi_F''' \equiv \Pi_F^{FDI} + \pi_F^{FDI} - \Pi_F^{ISO} > \Delta\Pi_F''$, $\widehat{t}_F^H$ is higher and $\widehat{t}_F^L$ is lower with $\widehat{t}^{ISO} \leq t$ than those without possible entries of ISOs.

FDI should accompany a tariff-jumping FDI. Considering the problem of parallel imports is an interesting extension since production firms sometimes refuse to repair goods sold by unauthorized distributers. Our result suggest such a refusal to repair may increase, rather than decrease, parallel imports.

# Appendix

## Proof of Lemma 1

Suppose the repair market is monopolized. At stage 3, the firm's maximization problem is as follows:

$$\max_{r} (r - m_k) x_R \quad \text{s.t.} \quad x_R \leq (1-q) x_F$$

where $k \in \{H, L\}$. Let the Lagrangian function as $L = (r - m_k) x_R + \lambda ((1-q) x_F - x_R)$ where $\lambda$ is the Lagrangian multiplier. The first-order conditions are

$$\begin{aligned} 2r - a + qx_D + bqx_F &= m_k + \lambda; \\ (1-q) x_F - x_R &\geq 0; \lambda \geq 0; \lambda [(1-q) x_F - x_R] = 0. \end{aligned}$$

Suppose $\lambda = 0$. In this case, the optimal repair price and the optimal amount of repairs become

$$\begin{aligned} r(x_D, x_F) &= \frac{a + m_k - qx_D - bqx_F}{2}, \\ x_R(x_D, x_F) &= \frac{a - m_k - qx_D - bqx_F}{2}. \end{aligned}$$

At stage 2, the consumer's maximization problem is $\max_{x_D, x_F} V(x_D, qx_F + x_R(x_D, x_F)) + Z$ subject to $p_D x_D + p_F x_F + r x_R(x_D, x_F) \leq I$. The first-order conditions yields $p_D = V_D(x_D, qx_F + x_R(x_D, x_F))$, $p_F = qV_F(x_D, qx_F + x_R(x_D, x_F))$. When only firm $D$ supplies repair services, firms' maximization problems are

$$\max_{x_D} \Pi_D + \pi_D = (p_D - c - (1-q) m_L) x_D + \{r(x_D, x_F) - m_H\} x_R(x_D, y_F),$$

$$\max_{x_F} \Pi_F = \{p_F - (c+t)\} x_F.$$

By the first-order conditions, we have the equilibrium supplies denoted as $x''_D$ and $x''_F$. Let $\Omega_d \equiv (1-q)\, x''_F - x_R\,(x''_D, x''_F)$ denote the amount of unfixed broken units. We have

$$\begin{aligned}
\frac{\partial \Omega_d}{\partial a} &= -\frac{\left(6-9q+4q^2\right)\left(4-2b-b^2\right)}{2\{(16-13b^2)\,(1-q)+2b^2q+8q^2\,(1-b^2)\}} < 0, \\
\frac{\partial \Omega_d}{\partial m_L} &= -\frac{b\,(1-q)\left(6-9q+4q^2\right)}{(16-13b^2)\,(1-q)+2b^2q+8q^2\,(1-b^2)} < 0, \\
\frac{\partial \Omega_d}{\partial m_H} &= \frac{6\left(4-b^2\right)-\left(20+b^2\right)q+8q^2}{2\{(16-13b^2)\,(1-q)+2b^2q+8q^2\,(1-b^2)\}} > 0, \\
\frac{\partial \Omega_d}{\partial t} &= -\frac{(8-5b^2)-2\left(2-b^2\right)q}{(16-13b^2)\,(1-q)+2b^2q+8q^2\,(1-b^2)} < 0.
\end{aligned}$$

Since $\partial^2\Omega_d/\partial k\partial l = 0$ for $k, l \in \{a, m_L, m_H, c, t\}$, $0 \le m_L < m_H \le c < a$ and $t \ge 0$,

$$\Omega_d < \Omega_d|_{a=m_H=c,t=m_L=0} = -\frac{2\,(1-q)\,\{4-3b^2+2\,(1-q)\left(2-b^2\right)\}c}{2\{(16-13b^2)\,(1-q)+2b^2q+8q^2\,(1-b^2)\}} < 0$$

and it contradicts the supposition that the domestic producer does not repair all broken units. Alternatively, when only firm $F$ supplies repair services, the firms' maximization problems are

$$\begin{aligned}
&\max_{x_D} \pi_D = (p_D - c - (1-q)\, m_L)\, x_D, \\
&\max_{x_F} \Pi_F + \pi_F = \{p_F - (c+t)\}x_F + \{r\,(x_D, x_F) - m_L\}x_R\,(x_D, y_F)\,.
\end{aligned}$$

By solving the first-order conditions, we have the equilibrium supply of each good, which is respectively denoted as $x'_D$ and $x'_F$. Let $\Omega_f \equiv (1-q)\, x'_F - x_R\,(x'_D, x'_F)$ denote the amount of unfixed broken units. We have

$$\begin{aligned}
\frac{\partial \Omega_f}{\partial a} &= -\frac{(2-q)\,(3-2q)\left(4-2b-b^2\right)}{2\{(16-9b^2)\,(1-q)+2b^2q+4q^2\,(1-b^2)\}} < 0, \\
\frac{\partial \Omega_f}{\partial m_L} &= \frac{6\left(4-2b-b^2\right)-\left(12-26b-b^2\right)q-2b\,(9+b)\,q^2+4bq^3}{2\{(16-9b^2)\,(1-q)+2b^2q+4q^2\,(1-b^2)\}} > 0, \\
\frac{\partial \Omega_f}{\partial t} &= -\frac{8-4q-3b^2}{2\{(16-9b^2)\,(1-q)+2b^2q+4q^2\,(1-b^2)\}} < 0.
\end{aligned}$$

Since $\partial^2\Omega_d/\partial k\partial l = 0$ for $k, l \in \{a, m_L, c, t\}$, $m_L < c < a$ and $t \ge 0$,

$$\Omega_f < \Omega_f|_{a=m_L=c,t=0} = -\frac{(1-q)\left(8+6b-3b^2-(4+7b)\,q+2bq^2\right)c}{\{(16-9b^2)\,(1-q)+2b^2q+4q^2\,(1-b^2)\}} < 0.$$

Hence, $(1-q)\, x'_F < x_R\,(x'_D, x'_F)$ and it contradicts the supposition that the foreign producer does not repair all broken units at stage 3.

When both firms enter and compete in service prices, the equilibrium service price becomes $r = m_H$ and the broken units are repaired by the foreign producer. By (11) and (12), the equilibrium repair price under service monopoly by the foreign firm is $r(x_D^{FDI}, x_F^{FDI})$. We have $\partial r(x_D^{FDI}, x_F^{FDI})/\partial m_H = 0$ and $\partial r(x_D^{FDI}, x_F^{FDI})/\partial m_L = (1-q)(1+b)/(2+b) > 0$. Since $0 \leq m_L \leq m_H \leq c$,

$$\begin{aligned} r(x_D^{FDI}, x_F^{FDI}) - m_H &\geq r(x_D^{FDI}, x_F^{FDI})\big|_{m_L=0} - c \\ &= \frac{(a-c)(2-b) + \left(2-b^2\right)t}{(4-b^2)} > 0. \end{aligned}$$

Hence, $r(x_D^{FDI}, x_F^{FDI}) > m_H$ and so consumers repair all the broken units.

When an ISO monopolizes the repair market, firms' maximization problems are $\max_{x_D} \Pi_D = \{p_D - c - (1-q)m_L\}x_D$ and $\max_{x_F} \Pi_F = \{p_F - (c+t)\}x_F$. The first-order condition yields the equilibrium supplies of each firm as $x_D'''$, $x_F'''$. As above, let $\Omega_{ISO} \equiv (1-q)x_F''' - x_R(x_D''', x_F''')$ denote the amount of imports that remain unrepaired. We have

$$\begin{aligned} \frac{\partial \Omega_{ISO}}{\partial a} &= -\frac{\left(6-9q+4q^2\right)\left(4-2b-b^2\right)}{2\{(1-q)(16-9b^2)+3b^2q+8q^2(1-b^2)\}} < 0, \\ \frac{\partial \Omega_{ISO}}{\partial m_H} &= \frac{3\{8(1-q)-2b^2+b^2q\}+4q\left(1-b^2q\right)+8q^2}{2\{(1-q)(16-9b^2)+3b^2q+8q^2(1-b^2)\}} > 0, \\ \frac{\partial \Omega_{ISO}}{\partial t} &= -\frac{8-4q-3b^2}{(1-q)(16-9b^2)+3b^2q+8q^2(1-b^2)} < 0, \end{aligned}$$

and so

$$\begin{aligned} \Omega_{ISO} &< \Omega_{ISO}\big|_{a=c+(1-q)m_L, m_H=0, t=0} \\ &= -\frac{(1-q)\left\{\left(16-6b^2-8q\right)c + \left(6-9q+4q^2\right)\left(4-b^2\right)m_L\right\}}{2\{(1-q)(16-9b^2)+3b^2q+8q^2(1-b^2)\}} < 0. \end{aligned}$$

Hence, $(1-q)x_F''' < x_R(x_D''', x_F''')$ and it contradicts the supposition that $(1-q)x_F > x_R$.

■

## Proof of Proposition 2

Suppose firm $D$ provides the repair services. As for the profits of firm $D$, we have

$$\frac{\partial(\Pi_D^{DSM} + \pi_D^{DSM})}{\partial t} = \frac{2B_1}{\{4-(2-q)b^2\}^2 q^2}$$

where $B_1 = abq(2-2b+qb) - 2qb(1-q)m_L + q(1-q)\{4-(2-q)b^2\}m_H - \{4(1-q)\left(1-b^2\right) + (2-bq)bq\}c - \gamma t$ and $\gamma \equiv 4(1-q)\left(1-b^2\right) - b^2q^2$. We have $\gamma \geq 0$ if $q$ and $b$ are small

enough to satisfy $4(1-q)\left(1-b^2\right) \geq b^2q^2$ and $\gamma < 0$ otherwise. Note that $\partial B_1/\partial m_L < 0$ and $\partial B_1/\partial m_H > 0$. When $t = 0$,

$$B_1|_{t=0} \gtreqqless 0 \Longleftrightarrow \frac{abq\{2-b(2-q)\} - 2qb(1-q)m_L + q(1-q)\left(4-(2-q)b^2\right)m_H}{4(1-q)(1-b^2)+(2-bq)bq} \equiv \widehat{c} \gtreqqless c.$$

We can verify that $\widehat{c} < \widehat{c}$ if

$$\frac{2a(1-b)\left(4-2b^2+b^2q\right)+2b(2-qb)m_L}{(2-qb)(4-2b^2+b^2q)} \equiv \widehat{m} > m_H$$

is satisfied. Hence, the above relationship is consistent with $x_F > 0$. There are four cases. Firstly, suppose $\widehat{c} < c < \overline{c}$ and $\gamma > 0$. In this case, since $B_1|_{t=0} < 0$ and $\partial B_1/\partial t < 0$, $\partial(\Pi_D^{DSM} + \pi_D^{DSM})/\partial t < 0$ and so trade liberalization always benefits the domestic firm. Secondly, suppose $\widehat{c} < c < \overline{c}$ and $\gamma < 0$. In this case, $B_1|_{t=0} < 0$ and $\partial B_1/\partial t > 0$. We have

$$B_1|_{t=\overline{t},m_H=\widehat{m},m_L=0} = \frac{(2-q)b\{4-(2-q)b^2\}\{a(2-b)q - c(2-bq)\}q}{2(2-bq)} > 0.$$

where the inequality is due to $c < \overline{c}$. Hence, $\partial(\pi_D^{DSM} + \pi_D^{DSM})/\partial t < 0$ is likely when $t$ and $m_H$ are small and $m_L$ large, and $\partial(\pi_D^{DSM} + \pi_D^{DSM})/\partial t > 0$ otherwise. Thirdly, suppose $c \leq \widehat{c}$ and $\gamma > 0$. In this case, $B_1|_{t=0} \geq 0$ and $\partial B_1/\partial t < 0$. We have

$$B_1|_{t=\overline{t},c=\widehat{c},m_L=m_H=0} = -\frac{aq(1-q)(1-b)\{4-(2-q)b^2\}q\left(4(1-q)\left(1-b^2\right)-b^2q^2\right)}{4(1-q)(1-b^2)+(2-bq)bq} < 0.$$

Hence, $\partial(\Pi_D^{DSM} + \pi_D^{DSM})/\partial t > 0$ when $t$ is small enough, and $\partial(\Pi_D^{DSM} + \pi_D^{DSM})/\partial t < 0$ when $t$ is large, $c$ is large, and $m_L$ and $m_D$ is small (note that $B_1$ is decreasing in $c$ and decreasing in $m_H$). Finally, suppose $c \leq \widehat{c}$ and $\gamma < 0$. Since $B_1|_{t=0} \geq 0$ and $\partial B_1/\partial t \geq 0$, $\partial(\Pi_D^{DSM} + \pi_D^{DSM})/\partial t \geq 0$ and so trade liberalization always hurts the domestic firm.

As for the profits of firm $F$, we have $\partial\Pi_F^{DSM}/\partial t = 2qx_F^{DSM}(\partial x_F^{DSM}/\partial t) < 0$ because $\partial x_F^{DSM}/\partial t < 0$. As for consumer surplus, we have

$$\begin{aligned}
\frac{\partial CS^{DSM}}{\partial t} &= -\frac{\left[\begin{array}{c} q\{2\left(1-b^2\right)(2-b)+b\left(2-b^2\right)q+b^2q^2\}a \\ -c(1+b)\{2(1-b)(2-qb)+b(2-b)q^2\} \\ +bq(1-q)\{2\left(1-b^2\right)-q\left(2-b^2\right)\}m_L - t\{4\left(1-b^2\right)+b^2q^2\} \end{array}\right]}{2\{4-(2-q)b^2\}^2q^2} \\
&< -\frac{b\{a-c-(1-q)m_L\}}{2\{4-(2-q)b^2\}} < 0.
\end{aligned}$$

where the inequalities is due to (6).

Next, suppose firm $F$ provides the repair services. Since $\partial x_D^{FDI}/\partial t > 0$ and $\partial x_F^{FDI}/\partial t < 0$, we have $\partial \Pi_D^{FDI}/\partial t = 2x_D^{FDI}(\partial x_D^{FDI}/\partial t) > 0$, $\partial(\Pi_F^{FDI}+\pi_F^{FDI})/\partial t = 2x_F^{FDI}(\partial x_F^{FDI}/\partial t) < 0$. Besides that, $\partial CS^{FDI}/\partial t = -[(4-3b^2)\{a-(t+c)\} + (a-c)\,b^3 - (1+b)(2-b)^2(1-q)m_L]/(4-b^2)^2 < -c(1-q)^2(4-3b^2)/(4-b^2)^2 < 0$ where the first inequality is due to (6) and $m_L \leq c$.

Lastly, suppose there are no repair services. Since $\partial x_D^{NR}/\partial t > 0$ and $\partial x_F^{NR}/\partial t < 0$, we have $\partial \Pi_D^{NR}/\partial t = 2x_D^{NR}(\partial x_D^{NR}/\partial t) > 0$, $\partial \Pi_F^{NR}/\partial t = 2q^2 x_F^{NR}(\partial x_F^{NR}/\partial t) < 0$. In addition, $\partial CS^{NR}/\partial t = -[\{aq-(t+c)\}\left(4-3b^2\right) + b^3 q\{a-c-(1-q)\,m_L\}]/\{\left(4-b^2\right)^2 q^2\} < -\{a-c-(1-q)\,m_L\}b/\{2\left(4-b^2\right)q\} < 0$ where the first inequality is due to (6). ■

## Proof of Lemma 3

By (20) and (7), we have

$$\Pi_D^{DSM} + \pi_D^{DSM} - \Pi_D^{NR} = \frac{(1-q)\,[\{a\,(2-b)+bc\}q + bq\,(1-q)\,m_L - 2\,(c+t)]B_2}{(4-b^2)^2\,\{4-(2-q)\,b^2\}^2 q^2}$$

where $B_2 = a\,(2-b)\,\{4\,(1-b)\,(2+b)^2 + (3+2b)\,b^4 + \left(4-2b^2-b^3\right)b^2 q\}q + 2\{16-20b^2+5b^4+2(2-b^2)b^2 q\}t + bq\,(1-q)\,\{16-4\,(1-q)\,b^2-b^4\}m_L - \left(4-b^2\right)^2\{4-(2-q)\,b^2\}qm_H + \{2\left(16-20b^2+5b^4\right)+(2+b)\,(8-2b^2-b^3)bq+4b^3q^2\}c$. Since $\partial B_2/\partial a > 0$, $\partial B_2/\partial m_L > 0$, and $\partial B_2/\partial m_H < 0$, $B_2 > B_2|_{a=m_H=c,m_L=0} = 2\{16-20b^2+5b^4+2(2-b^2)b^2 q\}\{t+(1-q)\,c\} > 0$. By Lemma 1 and (20) and (13), it is apparent that $\Pi_D^{FDI} < \Pi_D^{NR}$. Hence, $\Pi_D^{FDI} < \Pi_D^{NR} < \Pi_D^{DSM} + \pi_D^{DSM}$. By (20), (8), and (13), $\Pi_F^{DSM} - \Pi_F^{NR} = -\,(1-q)\,\{16\left(1-b^2\right)+(4-q)\,b^4\}\left(x_F^{FDI}\right)^2/\left(4-b^2\right)^2 < 0$, and $\Pi_F^{FDI} + \pi_F^{FDI} - \Pi_F^{NR} = 4\,(1-q)\,(c+t-qm_L)\,[\{a(2-b)+bc\}q - q\,(1-q)\,(1-b)\,m_L - (q+1)\,(c+t)]/(4-b^2)^2 q^2 > 2\,(1-q)^2\,(c+t-qm_L)\,\{a(2-b)+bc-(2-b+qb)\,m_L\}/(4-b^2)^2 q > 4\,(1-q)^2\,(c+t-qm_L)\,(c-qm_L)/(4-b^2)^2 q > 0$ where the inequalities are due to $t < \bar{t}$ and $a > \underline{a}$. Hence, $\Pi_F^{DSM} < \Pi_F^{NR} < \Pi_F^{FDI} + \pi_F^{FDI}$. ■

## Proof of Lemma 4

By (21) and (9),

$$CS^{DSM} - CS^{NR} = -\frac{(1-q)\,bx_D^{DSM}B_3}{2\,(4-b^2)^2\,\{4-(2-q)\,b^2\}q}$$

where$B_3 = q\,(2-b)\,\{16+4b-16b^2-b^3+4b^4+qb\left(4+4b-b^2-2b^3\right)\}a + 2b\{4-7b^2+2b^4-\left(4-3b^2+b^4\right)q\}t - q\left(4-3b^2\right)(1-q)\,\{8-b^2\,(3-q)\}m_L + \{2b\left(4-7b^2+2b^4\right) -$

$b^2\left(4-3b^2\right)q^2-q\left(2+b\right)\left(16-4b-16b^2+5b^3+2b^4\right)\}c$. Note that $\partial B_3/\partial a>0$. When $4-7b^2+2b^4<\left(4-3b^2+b^4\right)q$, $\partial B_3/\partial t<0$. In this case, $B_3>B_3|_{t=\overline{t}}=\left(4-b^2\right)\left(2-b^2\right)\{4-(2-q)\,b^2\}\left(a-c-(1-q)\,m_L\right)q>0$. When $4-7b^2+2b^4>\left(4-3b^2+b^4\right)q$, $\partial B_3/\partial t>0$. In this case, $B_3>B_3|_{t=0,a=\underline{a}}=2b\{4-7b^2+2b^4-\left(4-3b^2+b^4\right)q\}\left(1-q\right)\left(c-qm_L\right)>0$. Hence, $CS^{DSM}<CS^{NR}$.

By (21) and (14),

$$CS^{FDI}-CS^{NR}=\frac{\left(1-q\right)\left(t+c-qm_F\right)B_4}{2\left(4-b^2\right)^2q^2}$$

where $B_4=2q\left(b+1\right)\left(2-b\right)^2a-\{\left(4-3b^2\right)\left(1+q\right)+2b^3q\}c-\left(4-3b^2\right)\left(1+q\right)t-\left(4-3b^2+2b^3\right)\left(1-q\right)qm_L$. Since $\partial\left(B_4|_{t=\widehat{t}}\right)/\partial a>0$, $B_4>B_4|_{t=\overline{t}}>B_4|_{t=\overline{t},a=\underline{a}}=q\left(4-3b^2\right)\left(1-q\right)\left(c-qm_L\right)>0$. Thus, $CS^{NR}<CS^{FDI}$. ■

## Proof of Lemma 5

(i) By (23),

$$\frac{\partial(\Delta\Pi_D)}{\partial t}=-\frac{2\left(1-q\right)B_5}{\left(4-b^2\right)^2\{4-(2-q)\,b^2\}^2q^2}$$

where $B_5=(2-b)\{8-2\left(2+b\right)b+(2-q)\,b^3\}b^2qa+4\{16-20b^2+5b^4+2b^2\left(2-b^2\right)q\}t-(4-b^2)^2\{2\left(2-b^2\right)+b^2q\}qm_H+2b^3\{8-(3-q)\,b^2\}q\left(1-q\right)m_L+4\left(1+b\right)\left(2-b^2\right)b^2q+b^5\left(1+q\right)q\}c$. Since $\partial B_5/\partial a>0$ and $\partial B_5/\partial m_H<0$, $B_5>B_5|_{a=\underline{a},m_H=c}=(1-q)\left[\{16-(2-q)\,b^4\}qb^2m_L+4\{16-20b^2+5b^4+2b^2\left(2-b^2\right)q\}c\right]>0$. Hence, $\partial(\Delta\Pi_D)/\partial t<0$.

(ii) By (24) and (25), we have $\partial^2(\Delta\Pi'_F)/\left(\partial t\right)^2=-8(1-q^2)/\{(4-b^2)^2q^2\}<0$ and $\partial^2(\Delta\Pi''_F)/(\partial t)^2=-8(1-q)[(4-b^2)^2+\{8-(3-q)b^2\}b^2q]/[(4-b^2)^2\{4-(2-q)b^2\}^2q]<0$. Besides that, we have

$$\begin{aligned}
\left.\frac{\partial(\Delta\Pi'_F)}{\partial t}\right|_{t=0} &= \frac{4\left(1-q\right)\left[a\left(2-b\right)q+\{(2-b)\,q+b\}qm_L-\{2+q\left(2-b\right)\}c\right]}{\left(4-b^2\right)^2q^2},\\
\left.\frac{\partial(\Delta\Pi''_F)}{\partial t}\right|_{t=0} &= \frac{4\left(1-q\right)\begin{bmatrix} a\left(8-3b^2+b^2q\right)b^2q \\ +\{16+8b-12b^2-2b^3+3b^4+\left(8-(4-q)\,b^2\right)qb^2\}qm_L \\ -\{2\left(2-b\right)\left(2+b\right)^2+\left(8-3b^2+b^2q\right)b^2q\}c \end{bmatrix}}{\left(2-b\right)\left(2+b\right)^2\{4-(2-q)\,b^2\}^2q},\\
\left.\frac{\partial(\Delta\Pi'_F)}{\partial t}\right|_{t=\overline{t}} &= \left.\frac{\partial(\Delta\Pi''_F)}{\partial t}\right|_{t=\overline{t}}\\
&= -4\left(1-q\right)\frac{a\left(2-b\right)+bc}{\left(b-2\right)^2\left(b+2\right)^2}=-\frac{4\left(1-q\right)\{(a-m_L)\left(2-b\right)+b\left(c-qm_L\right)\}}{\left(4-b^2\right)^2}<0.
\end{aligned}$$

Hence, if $m_L$ is large enough and $c$ is small enough to satisfy $\{a(2-b)q + \{(2-b)q + b\}qm_L\}/\{2 + q(2-b)\} > c$, $\partial(\Delta\Pi'_F)/\partial t|_{t=0} > 0$ and so $\partial(\Delta\Pi'_F)/\partial t$ is an inverse U-shaped curve in $t \in [0, \bar{t})$. Otherwise, $\partial(\Delta\Pi'_F)/\partial t \leq 0$. Similarly, if $m_F$ is large enough and $c$ is small enough to satisfy $[a\left(8 - 3b^2 + b^2q\right)b^2q + \{16 + 8b - 12b^2 - 2b^3 + 3b^4 + \left(8 - (4-q)b^2\right)qb^2\}qm_L]/\{2(2-b)(2+b)^2 + \left(8 - 3b^2 + b^2q\right)b^2q\} > c$, $\partial(\Delta\Pi''_F)/\partial t$ is an inverse U-shaped curve in $t \in [0, \bar{t})$, and $\partial(\Delta\Pi''_F)/\partial t \leq 0$ otherwise. ■

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## Figures

Figure 1: Demand for Imports with Monopoly Repairs

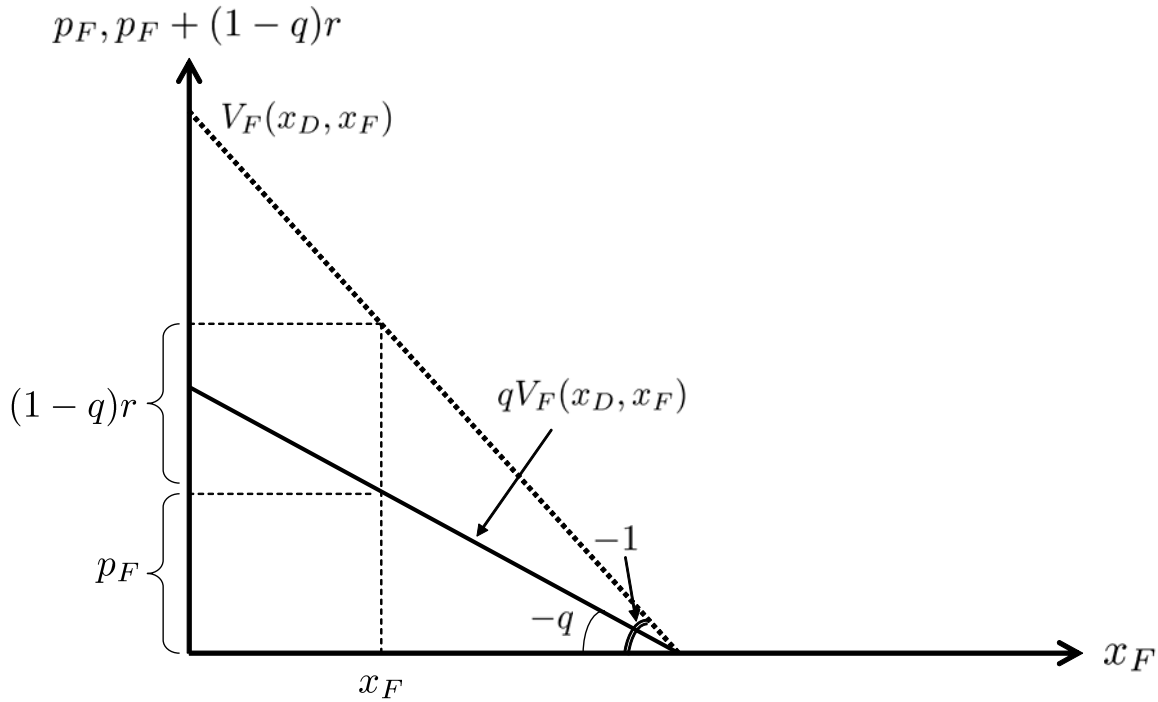



Figure 2: Demand for Imports without Repairs

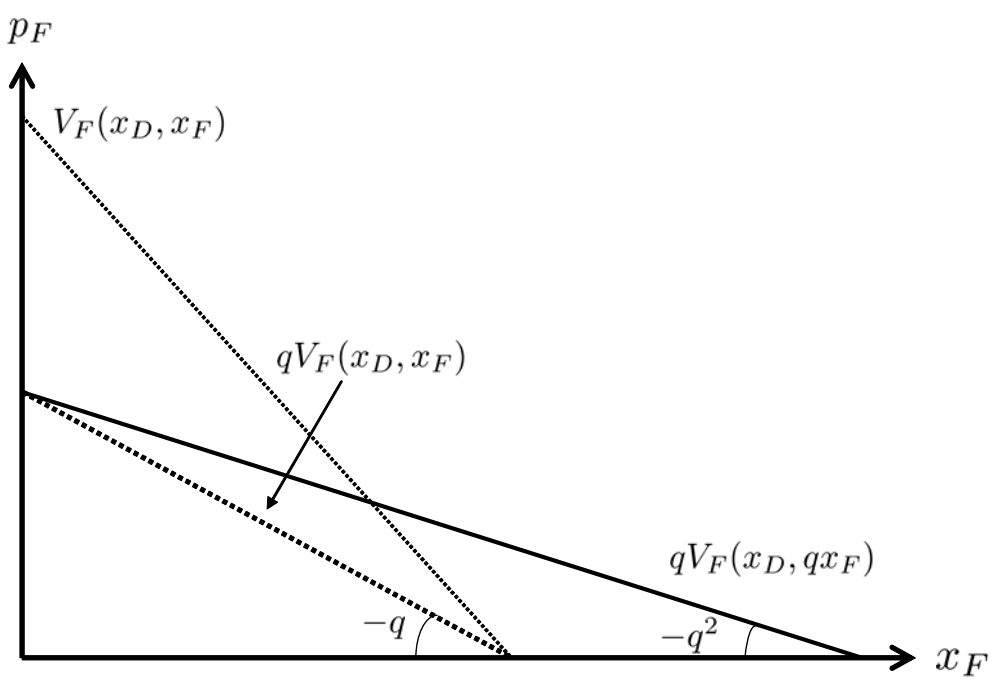


Figure 3: Possible Outcomes

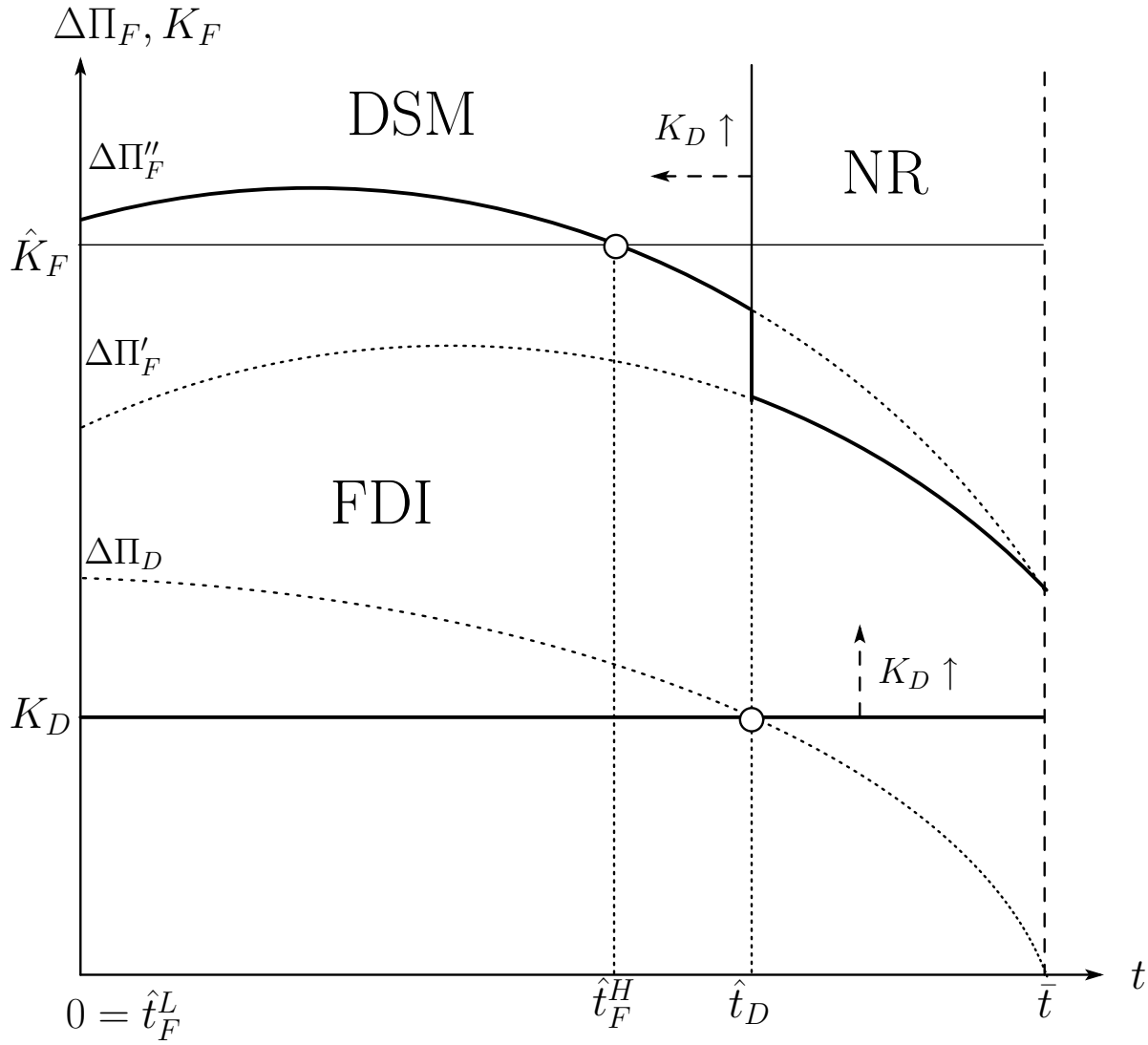


Figure 4: A Numerical Example

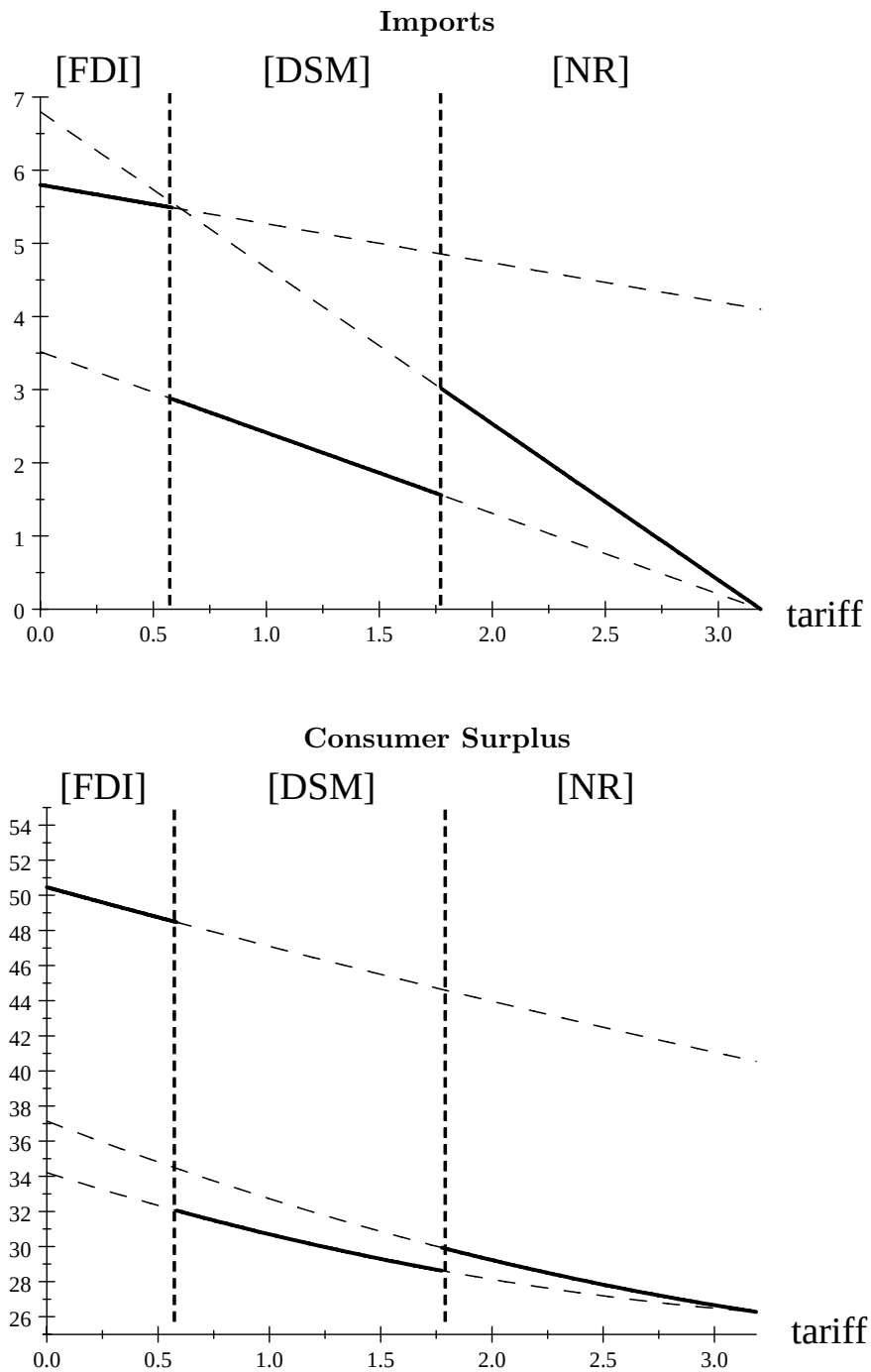
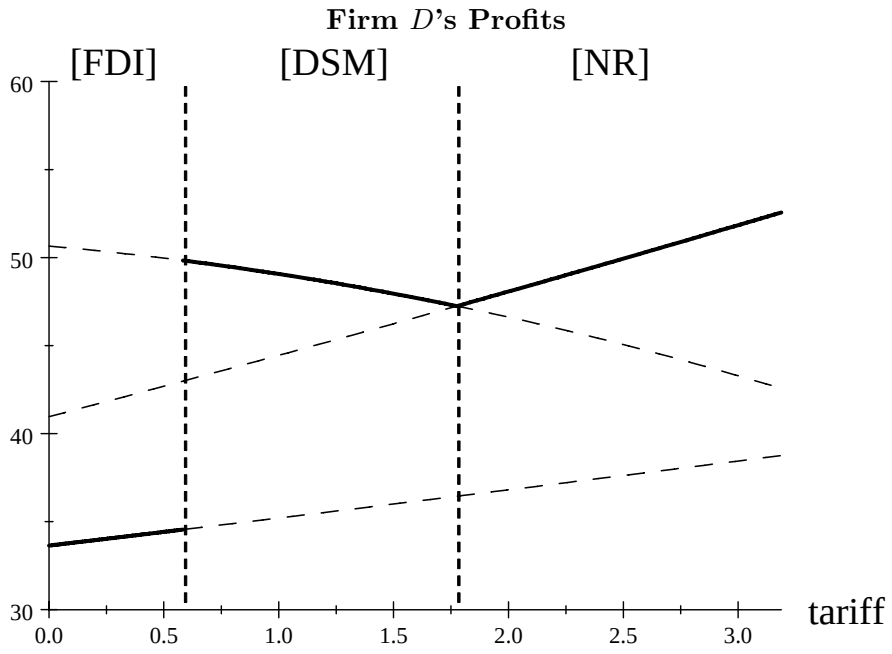


Figure 4 (continued)



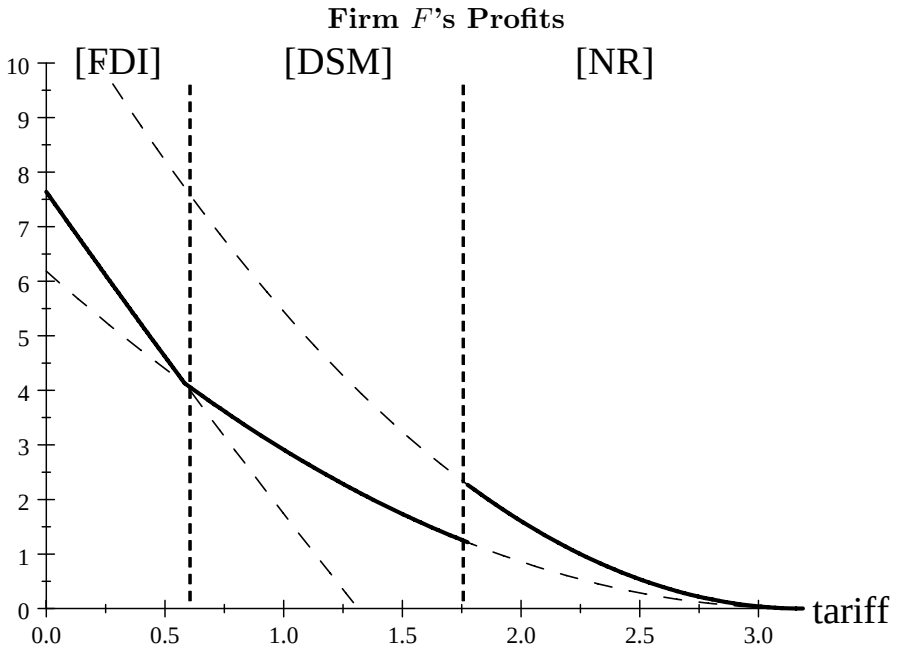



Figure 4 (continued)