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Abstract

This study investigates the effect of parallel imports when the producer of a durable good may refuse to provide repair and maintenance services for parallel imported units, or charge higher prices for those services. By doing so, the producer is able to weaken intra-brand competition and reduce the degree of market integration, thereby mitigating the negative effect of parallel imports on profits. Although the lower degree of market integration increases the producer's profit, it does not always mean that the producer wants to improve the durability of the product. If the producer invests in improving the durability of the good, the service discrimination against the parallel imported units could lower the durability of the product. In this case, consumers in the importing country may suffer by permitting parallel imports, and the negative effect is amplified by trade liberalization.

Keywords: Parallel imports, Aftermarket services, Trade liberalization, Price discrimination
JEL classification: F12, F13, F23, D43

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1 Introduction

When consumers purchase imported goods, these may be products imported in parallel through distributors not authorized by the original producers, who hold the property rights of those products. These goods are called "parallel imported (PI) goods" or "gray market goods." PI goods are not counterfeit goods. They are genuine goods purchased from authorized distributors in the source countries and transported to the destination countries without the consent of the property holders. The unauthorized distributors, or parallel traders, engage in such trade to profit from price differences of the same good between markets in different countries. Specifically, parallel traders earn profits by purchasing the good in a country where the price of the authorized good is low, and reselling it to consumers in a country where the price of the same good is high. The end user of a good might also be a parallel trader if he/she purchases a good in a foreign country and transports it to a different country.

Although parallel trade is typically observed for pharmaceutical products (e.g., Ganslandt and Maskus, 2004), it also occurs for many other products. NERA (1999) reported that PI goods within the European Union (EU) include footwear and leather goods, musical recordings, motorcars, consumer electronics, domestic appliances, cosmetics and perfumes, clothing, and so on. It is reported that the market share of parallel imported automobiles in Hong Kong and Singapore is 15%-25%, and is 15%-17% in the US and the UK (Yeung and Mok, 2013).

Parallel trade encourages international price arbitrage and promotes international market integration. From the viewpoint of original producers, parallel trade is usually harmful because it limits their abilities to discriminate prices among countries.[1] Basically, permitting parallel

[1]Some analyses have suggested that permitting parallel trade may increase the profit of the producer. Anderson and Ginsburgh (1999) suggest that a monopolist might use consumers' arbitrage activities through parallel importation to undertake second-degree price discrimination, if arbitrage costs differ across consumers. Knox and Richardson (2002) show that parallel imports may benefit the producer because they reduce the optimal tariff of the destination country. Raff and Schmitt (2007) found that, in the presence of demand uncertainty, parallel imports lead to larger orders from retailers because they enable retailers to ship unsold inventories to countries where demand turns out to be unexpectedly high. In a duopoly model, Matsushima and Matsumura (2010) found that permitting parallel imports increases profits of all firms because it serves as a commitment device to soften price competition in the destination country. Roy and Saggi (2012b) also showed a similar commitment effect of parallel imports in a different setting.

imports reduces prices in destination countries and raises prices in the source country. The price convergence benefits consumers in the countries that receive parallel imports and hurts consumers in the country that originates them. However, the welfare effects of parallel imports are much more complicated. Malueg and Schwartz (1994) investigated how uniform pricing induced by parallel importation affects global welfare. They showed that permitting parallel imports yields lower global welfare if many markets become unserved by the monopolist. Maskus and Chen (2004) used a model of vertical control to show that allowing parallel imports improves global welfare if the cost of undertaking parallel trade is low, but reduces global welfare if the cost is high.

These theoretical analyses focus mainly on the changes in prices induced by parallel imports. Another notable subject of parallel imports is their effect on producers' innovation activities. For example, parallel imports may lead to less cost-reducing R&D, or a deterioration of the quality of products and/or the quality of before- and after-sales services. This is because the inability to discriminate prices between markets may reduce the gains from producers' investments in improving the quality of their products and services (Grigoriadis, 2014). Li and Maskus (2006) explore how parallel imports inhibit the producer's cost-reducing R&D activities. Valletti (2006) shows that parallel imports reduce the quality of the product when differential pricing is demand based but raise the quality when it is cost based. In a North-South model, Grossman and Lai (2008) show that parallel trade promotes product innovation because it induces the Southern government to change their price control in favor of Northern firms.

Because there are no multilateral rules regarding the permission of parallel imports, each country can choose whether to permit or prohibit them.[2,3] Parallel imports are mostly permitted in Japan. However, they are only permitted for trademarked goods in the United States as long

[2]More specifically, countries choose between adopting national exhaustion and international exhaustion of intellectual property rights. Under national exhaustion, property rights expire only in the market where goods are initially sold. Thus, the trademark holders can legally prevent parallel imports. Under international exhaustion, parallel trade is allowed because property rights expire globally, irrespective of where goods are originally sold by the trademark holders.

[3]A few studies have investigated countries' choices of parallel import policies. In a monopoly model, Richardson (2002) showed that all countries permit parallel imports in a global Nash equilibrium if they can choose whether to prohibit parallel imports. Roy and Saggi (2012a) investigated strategic interdependence between countries' PI policies in a North-South model of international oligopoly.

as the US and foreign trademarks are held by the same owner, or different owners are in a parent-subsidiary relationship (Maskus, 2000). The EU members only allow parallel imports from other EU members. Russia has not liberalized parallel importation.

However, even if parallel importation is allowed and parallel traders are competitive, this does not always mean the price difference between countries is reduced to the marginal cost of parallel imports. This is because producers might use instruments to mitigate the negative effect of parallel imports. One possible way is to reduce the substitutability between the authorized units and the PI units by providing after-sales services, such as repair and maintenance services, only to authorized products. For instance, Nikon Inc. USA, a subsidiary of the Japanese company of optical instruments, Nikon, does not provide support or a warranty service on parallel imported items, including fee-based repair work.[4] Samsonite, the US luggage manufacturer, employs the same policy in Japan. World Commerce Corp, the Japanese authorized distributor of the Swiss watch company, Franck Muller, refuses to repair parallel imported watches. Firms also discriminate prices in after-sales services and set higher maintenance and repair prices for PI units, while they provide free repairs or charge a lower fee for authorized units. An empirical analysis supports the view that discrimination in after-sales services weakens intra-brand competition between authorized goods and parallel imported goods. Chen, Lai, and Yu (2013) investigated Taiwan's Yahoo! auctions of Nikon cameras and showed that authorized goods with a longer duration of warranty and that are repaired by the official dealers have higher transaction prices than PI goods.

Given this background, this study theoretically examines the effect of parallel imports when a monopolist producer may refuse to provide repair and maintenance services or may set a higher repair price for a PI good.[5] In this study, refusal of repairs and price discrimination in repair services are together referred to as "discrimination in repair services" or simply "service discrimination." Specifically, we investigate a producer's incentive to discriminate repair services,

[4]Nikon Inc. USA declares in its website: "Nikon Inc. USA cannot provide any technical support or warranty service on Gray Market items. Additionally Nikon Inc. USA cannot perform any fee-based repair work on Gray Market items. Please do not contact Nikon Inc. USA for help with any Gray Market products."

[5]Ishikawa, Morita, and Mukunoki (2014) investigate the welfare effects of repair services in the context of international trade. However, their focus is different to ours and does not consider parallel imports and service discrimination.

and how the welfare effect of parallel imports is associated with such a business practice. In our model, the difference in the demands for the good induces the producer to set different prices in different countries. There are many parallel traders, and the competition among them reduces the price of the PI good by an amount equal to the sum of the price of the authorized good in a low-priced country and trade costs.

We find that service discrimination works as a tool to weaken the intra-brand competition and makes the domestic and foreign markets only "partially" integrated. Partial integration means that the producer cannot fully discriminate prices, but can still charge a higher price in a high-demand country than in a low-demand country. Because of the price-discrimination effect, the producer always prefers discrimination in terms of repair services for the PI good. Compared to the case of full market integration, in which the price difference between the two countries reduces to the level of trade costs (tariff), the price in a high-demand country becomes higher and the price in a low-demand country becomes lower. The changes in prices benefit consumers in the source country and hurt consumers in the destination country.

We also investigate how a refusal to repair the PI good affects the quality of the good when the producer can engage in R&D activities to improve it. In this study, the producer can raise the quality of the good either (i) by increasing the durability of the good or (ii) by improving the quality of repair services. We show that parallel imports have different effects on these three quality-enhancing activities and the effect crucially depends on the firm's service discrimination. To the best of our knowledge, this is the first study to explore the effects of parallel imports when a producer has an option to discriminate repair services.[6]

Our findings show that if the producer does not discriminate services and parallel imports realize full market integration, permitting parallel imports either has no effect or has a negative effect on the quality of the good, irrespective of the type of quality. In contrast, if the producer

[6] A related paper is Ahmadi and Yang (2000). They show that if consumers discount their valuations on the PI goods because of the inconvenience due to market-specific product differentiation (e.g., right-hand drive or left-hand drive, manuals written in different languages) or due to service differentiation (e.g., the lack of technical support and warranty), allowing parallel imports can attract consumers in importing countries who would not otherwise have bought the good. However, they do not consider the effect of a change in the discounting factor of PI goods and the endogenous determination of the product quality. Furthermore, they do not investigate the effects of trade liberalization.

implements service discrimination, then the type of quality determines whether parallel imports improve or worsen the quality of the good. Specifically, parallel imports with service discrimination and the partial market integration worsens the durability of the good. Interestingly, the durability of the good under partial market integration might be *lower* than the durability under full market integration. This is because a lower durability reduces the substitutability between the authorized good and the PI good. This weakens intra-brand competition under the refusal of repairs, or generates a greater profit opportunity in the repair market of the PI good. Because trade liberalization reduces the cost of exporting the authorized good, but also decreases the cost of conducting parallel trade, this may induce the producer to invest less to improve the durability of the good. However, trade liberalization always raises the durability if the markets are either fully segmented or fully integrated. In this situation, permitting parallel imports with service discrimination can hurt consumers in the destination country, and this becomes more likely as trade costs fall.

With regard to the quality of repair services, the quality under partial market integration might be *higher* than the quality under full market segmentation, if the producer discriminates the repair services. The result is in sharp contrast to the change in product durability. This is because better after-market service leads to less substitutability between the authorized good and the PI good if repair services are not provided for the PI good, or if the producer charges a higher repair price for the PI good.

The remainder of the paper is organized as follows. Section 2 develops a monopoly model of durable-goods producers and repair services, and derives the equilibrium of three different regimes. Section 3 investigates the relationship between the durability of the good and the producer's profit. Section 4 examines the endogenous determination of the quality of the product. Section 5 relaxes some assumptions of the basic model and discusses the robustness of the results. Section 6 summarizes the paper and offers concluding remarks. Lastly, the appendix contains the proofs of lemmas and propositions in the paper.

2 Model

We consider a two-country model with a single firm in the domestic country (country D) that produces good x, which it supplies locally and to the foreign country (country F). An import tariff (or a trade cost), t, is imposed on good x by the foreign country. Each consumer purchases at most one unit of good x. Consumers in country i ($i = D, F$) are identical except in their willingness to pay for the good, which is denoted by v. If a consumer in country i purchases the good at price p_i, its utility is given by $U_i = v - p_i$. We assume each consumer's utility under no purchase is normalized to zero. The population in each country is identical and given by n, though the distribution of v is different across the two countries. In country F, v is uniformly distributed over the interval $[0, b]$ with density $f_F = \frac{1}{b}$. In country D, v is uniformly distributed over the interval $[0, kb]$ with density $f_D = \frac{1}{kb}$, where k is positive and $k < 1$. This means that consumers in country F, on average, attach a higher value to good x.

If parallel trade is allowed, consumers in each country can purchase the good from either authorized distributors controlled by the firm or other distributors who purchase the good in the other country and resell it through parallel trade without authorization. We call the good purchased from authorized distributors "the authorized good" and that purchased from parallel importers "the PI good."

After consumers purchase the goods, they may break down because of imperfect quality control. The probability of the good working correctly is $q \in (0, 1]$ and it is common to both the authorized good and the PI good. Hence, the probability of the good breaking down is $(1 - q)$. If the consumers utilize repair services provided by the producing firm, the broken good becomes consumable. However, without repair services, broken goods are useless and have zero scrap values. We assume if a consumer purchases the authorized good, the good is subject to free repairs.[7] However, the firm may refuse to repair the PI good or charge a fee for the repair. The unit cost of production for the firm is given by c (> 0), and the unit cost of repairs is given by m, which should be lower than c.

If parallel trade is allowed, many competitive parallel traders can purchase the good in the country where the price is low and sell it to the country where the price is high. For simplicity,

[7] We confirm that the firm is willing to offer a full warranty for the authorized good. See Section 5.1.

we assume parallel traders incur no additional cost other than the trade cost. We only focus on the situation where the firm always provides the good in both countries.

We consider the following three situations: (i) Regime N in which parallel imports are banned in country F; (ii) Regime I in which parallel imports are allowed and the firm provides the same repair services to the consumers purchasing the PI good as those provided to the consumers of the authorized good; and (iii) Regime R in which parallel imports are allowed and the firm discriminates the repair services against the PI good by either refusing to repair the PI good or charging a fee for the repair. We show that refusing repairs and charging for repairs of the PI good have the same effect on the equilibrium prices and welfare. These firms' behaviors are referred to collectively as service discrimination.

The model has three stages. In the first stage, the producer sets authorized prices in country D and country F. In the second stage, consumers in each country and authorized and parallel traders purchase the authorized product. In the third stage, parallel traders export the purchased good to other countries and sell it to consumers who purchase the PI good, if parallel traders earn non-negative profits. There is no time discounting between the second stage and the third stage. Thus, consumers always wait until the third stage if they anticipate that purchasing the PI good will generate higher utility.

2.1 No parallel imports

As a benchmark, we start with Regime N, where parallel imports are prohibited. In this case, the markets of the two countries are completely segmented (full segmentation). The monopolist is able to make independent decisions in setting the prices in each country. A consumer in country i purchases the good if

$$U_i = v - p_i \geq 0$$

holds. Under market segmentation, all consumers purchase the authorized good if they buy. The consumers whose willingness to pay for quality satisfies $v \geq p_i$ purchase the good. The demand for good x in each country is given by

$$x_D(p_D) = nf_D\{kb - p_D\} = n\left(1 - \frac{p_D}{kb}\right), \tag{1}$$

$$x_F(p_F) = nf_F\{b - p_F\} = n\left(1 - \frac{p_F}{b}\right). \tag{2}$$

The firm's profit is given by

$$\Pi\left(p_D, p_F\right) = \left[p_D - \left\{c + (1-q)\, m\right\}\right] x_D\left(p_D\right) + \left[p_F - \left\{c + t + (1-q)\, m\right\}\right] x_F\left(p_F\right). \tag{3}$$

The firm maximizes this profit with respect to p_D and p_F. By solving the first-order conditions, the equilibrium prices are given by

$$\widetilde{p}_D^N = \frac{kb + c + (1-q)\, m}{2}, \tag{4}$$

$$\widetilde{p}_F^N = \frac{b + c + t + (1-q)\, m}{2}. \tag{5}$$

To ensure positive sales in each market, $x_D\left(\widetilde{p}_D^N\right) > 0$ and $x_F\left(\widetilde{p}_F^N\right) > 0$, we assume $b > \max[\{c + (1-q)\, m\}/k,\, c + t + (1-q)\, m]$ holds.

By comparing the equilibrium prices, we have $\widetilde{p}_F^N - \widetilde{p}_D^N = (1-k)\left(b + t\right)/2 > 0$. This implies that the firm sets a higher price in the foreign country where consumers' willingness to pay for the good is, on average, higher than in the domestic country. The equilibrium cut-off level of v, above which consumers purchase the good in each country, becomes $\widetilde{v}_i^N = \widetilde{p}_i^N$. The equilibrium profits are given by $\Pi^N = \Pi\left(\widetilde{p}_D^N, \widetilde{p}_F^N\right)$ and the equilibrium consumer surplus in country D and country F are, respectively, given by

$$\begin{aligned} CS_D^N &= n_D f_D \int_{\widetilde{v}_D^N}^{kb} (v - \widetilde{p}_D^N) dv \\ &= \frac{n}{kb}\left(kb - \widetilde{v}_D^N\right)\left[\frac{kb + \widetilde{v}_D^N}{2} - \widetilde{p}_D^N\right] = \frac{n\left(kb - \widetilde{p}_D^N\right)^2}{2kb}, \end{aligned} \tag{6}$$

$$\begin{aligned} CS_F^N &= n f_F \int_{\widetilde{v}_F^N}^{b} (v - \widetilde{p}_F^N) dv \\ &= \frac{n}{b}\left(b - \widetilde{v}_F^N\right)\left[\frac{b + \widetilde{v}_F^N}{2} - \widetilde{p}_F^N\right] = \frac{n\left(b - \widetilde{p}_F^N\right)^2}{2b}. \end{aligned} \tag{7}$$

2.2 Parallel imports without service discrimination

If parallel trade is allowed, the price difference of good x between the two countries creates an opportunity for parallel trade. Since there are many competitive parallel traders, the price of the PI good in country F becomes $p_D + t$.

The firm is able to choose whether it provides free repair services for the good sold by unauthorized, parallel traders. Suppose it does do so (Regime I). Then, the good sold directly by the authorized distributors and the good sold by parallel importers are perfect substitutes. This

means that if $p_F > p_D + t$ holds, all consumers purchase the PI good. By (4) and (5),

$$\widetilde{p}_F^N - \left(\widetilde{p}_D^N + t\right) = \frac{(1-k)b - t}{2}. \tag{8}$$

We restrict our attention to the case where $(1-k)b > t$ is satisfied so that $\widetilde{p}_F^N > \left(\widetilde{p}_D^N + t\right)$ holds. Therefore, all consumers buy the PI good if the firm sets the same prices as those charged under full market segmentation. We can confirm that the firm has no incentive to set p_F lower than $p_D + t$ given $\widetilde{p}_F^N > \left(\widetilde{p}_D^N + t\right)$ holds. Then, the firm maximizes the profit such that $p_F = p_D + t$ holds. In other words, the threat of parallel trade makes the two markets completely integrated and the price difference is always equal to the tariff level.

Consumers purchase the good if $v \geq p_i$ holds, and the demand is given by (1) and (2). The firm maximizes (3) such that $p_F = p_D + t$ holds. Then, the respective equilibrium prices become:

$$\widetilde{p}_D^I = \frac{\widetilde{p}_D^N + k(\widetilde{p}_F^N - t)}{1+k}, \tag{9}$$

$$\widetilde{p}_F^I = \frac{\widetilde{p}_D^N + t + k\widetilde{p}_F^N}{1+k}. \tag{10}$$

Note that the equilibrium prices are the weighted average of the equilibrium prices under market segmentation. The equilibrium cut-off level of v in each country becomes $\widetilde{v}_i^I = \widetilde{p}_i^I$. The equilibrium profit becomes $\Pi^{IR} = \Pi\left(\widetilde{p}_D^I, \widetilde{p}_F^I\right)$ and the respective equilibrium consumer surplus in each country is given by

$$CS_D^I = nf_D \int_{\widetilde{v}_D^I}^{kb} (v - \widetilde{p}_D^N) dv = \frac{n\left(kb - \widetilde{p}_D^I\right)^2}{2kb}, \tag{11}$$

$$CS_F^I = nf_F \int_{\widetilde{v}_F^I}^{b} (v - \widetilde{p}_F^N) dv = \frac{n\left(b - \widetilde{p}_F^I\right)^2}{2b}. \tag{12}$$

2.3 Parallel imports with service discrimination

We now investigate Regime R, where the firm discriminates repair services by either (i) refusing to repair the PI good or (ii) charging a positive fee for the repair.

2.3.1 Refusal to repair

Suppose the firm refuses to repair the PI good (Regime I). If $q = 1$, the good never breaks down and the equilibrium profit coincides with Π^I. However, if $q < 1$, the authorized good and the PI

good generate different expected utilities, even if they are sold at the same price. Specifically, if a consumer in country F buys an authorized good at price p_F, his/her utility becomes

$$U_F^A = v - p_F. \tag{13}$$

If the consumer buys a PI good at price $p_D + t$, then his/her expected utility becomes[8]

$$U_F^{PI} = qv - (p_D + t). \tag{14}$$

Let v_F^A be the preference parameter of the consumer who is indifferent between buying an authorized good and a PI good ($U_F^A = U_F^{PI}$), and v_F^{PI} be the parameter for the consumer who is indifferent between buying a PI good and no purchase ($U_F^U = 0$). We have

$$v_F^A = \frac{p_F - (p_D + t)}{(1-q)}, \tag{15}$$

$$v_F^{PI} = \frac{p_D + t}{q}. \tag{16}$$

By comparing v_F^A and v_F^{PI}, we have

$$v_F^A - v_F^{PI} = \frac{qp_F - (p_D + t)}{(1-q)q}. \tag{17}$$

This means that if $p_F > (p_D + t)/q$ holds, which means that the "quality-adjusted price" of the PI good is lower than the price of the authorized good, consumers with preference parameter $v \in [v_F^A, b]$ buy the authorized good and consumers with parameter $v \in [v_F^{PI}, v_F^A]$ buy the PI good. Even if the price of the PI good is lower than that of the authorized good, the consumers with high v buy the authorized good because the price difference is insufficient for them to compensate for the risk of the good being broken down and not being repaired. The consumers with low v buy the PI good because they value the good less and are more sensitive to the price of the good.

Suppose $p_F > (p_D + t)/q$ holds, then the demand for the authorized good and the demand for the PI good in country F are, respectively, given by

$$x_F^A(p_F, p_D) = nf_F\left[b - v_F^A\right] = n\left[1 - \frac{p_F - (p_D + t)}{(1-q)b}\right], \tag{18}$$

$$x_F^{PI}(p_F, p_D) = nf_F\left[v_F^A - v_F^{PI}\right] = n\left[\frac{qp_F - (p_D + t)}{(1-q)qb}\right], \tag{19}$$

while the demand in country D is given by (1). An increase in p_D not only raises the price of the good in country D, but also the price of the PI good in country F. These price changes increase

[8] We assume consumers are risk neutral.

the demand for the authorized good and decrease the demand for the PI good. An increase in p_F, on the other hand, has the opposite effects.

The firm's profit is given by

$$\begin{aligned}\Pi'(p_D, p_F) &= [p_D - \{c + (1-q)\,m\}]x_D(p_D) + [p_F - \{c + t + (1-q)\,m\}]x_F^A(p_F, p_D) \\ &\quad + (p_D - c)x_F^{PI}(p_F, p_D). \end{aligned} \tag{20}$$

The third term is the profit earned from selling the good to the parallel traders. By solving $\partial\Pi'(p_D, p_F)/\partial p_D = 0$ and $\partial\Pi'(p_D, p_F)/\partial p_F = 0$, the equilibrium prices of this case become:

$$\widehat{p}_D = \widetilde{p}_D^N + \frac{k[b(q-k) - \{t + (1-q)\,m\}]}{2(q+k)}, \tag{21}$$

$$\widehat{p}_F = \widehat{p}_D + t + \frac{(1-q)(b+m)}{2}. \tag{22}$$

It is apparent that $\widehat{p}_F > \widehat{p}_D + t$ holds and the price difference between the two markets does not reduce to the level of the tariff. In other words, the two markets are not fully integrated, but only partially integrated. The extra price difference over the tariff level is due to the "quality premium" of the authorized good, because the authorized good is subject to free repair services and its expected quality is higher than that of the PI good. As q decreases, consumers in country F regard the authorized good and the PI good as becoming more vertically differentiated, and the firm is able to discriminate more on pricing. By substituting $\widehat{p}_D$ and $\widehat{p}_F$ into v_F^A and v_F^{PI}, the equilibrium cut-off level of v in the foreign country is given by $\widetilde{v}_F^A$ and $\widetilde{v}_F^{PI}$. The cut-off level in country D is given by $\widetilde{v}_D^I = v_D(\widetilde{p}_D^I)$.

These prices are consistent with the supposition that $p_F > (p_D + t)/q$ holds if

$$\widehat{p}_F - \frac{(\widehat{p}_D + t)}{q} = (1-q)\frac{\Gamma(q)}{2q(q+k)} > 0$$

is satisfied, where $\Gamma(q) = (b+2m)q^2 - \{kb + c + 2t + (1-k)m\}q - k(c+t)$. We have the following lemma.

Lemma 1 *If $b > \{(1+k)(c-m) + (2+k)\,t\}/(1-k)$ holds, then there exists a unique value of q, q_H, such that $\widehat{p}_F > (\widehat{p}_D + t)/q$ holds for $q \in (q_H, 1)$. Otherwise, $\widehat{p}_F \leq (\widehat{p}_D + t)/q$ holds for any q.*

Proof. $\Gamma(q)$ is either U-shaped or decreasing in $q \in [0,1]$. We have $\Gamma(0) = -k(c+t) < 0$ and $\Gamma(1) = (1-k)\,b - (1+k)(c-m) - (2+k)\,t$. If $b > \{(1+k)(c-m) + (2+k)\,t\}/(1-k)$

holds, then $\Gamma(1) > 0$ and $\Gamma(q)$ is U-shaped in q. Therefore, there exists a unique value of q, q_H $(\in (0,1))$, that satisfies $\Gamma(q_H) = 0$. This means that $\widehat{p}_F > (\widehat{p}_D + t)/q$ holds for $q \in (q_H, 1)$ and $\widehat{p}_F \leq (\widehat{p}_D + t)/q$ holds for $q \in (0, q_H]$. If $b \leq \{(1+k)(c-m) + (2+k)t\}/(1-k)$ holds, $\widehat{p}_F \leq (\widehat{p}_D + t)/q$ always holds for all $q \in [0,1]$. ■

Even if a decrease in q reduces the price of the good sold in the domestic country $(\widehat{p}_D)$, it increases the quality-adjusted price of the PI good $((\widehat{p}_D + t)/q)$ in the foreign country. The quality adjusted price approaches the infinity as q approaches zero. If a small decrease in q from $q = 1$ realizes $\widehat{p}_F > (\widehat{p}_D + t)/q$ (i.e., if $\Gamma(1) > 0$ holds), $x_F^U(\widehat{p}_F, \widehat{p}_D)$ is first increased and then decreased as q becomes smaller. This implies that if q is sufficiently small (i.e., $q \leq q_H$), consumers do not purchase the PI good. If a small decrease in q from $q = 1$ results in $\widehat{p}_F \leq (\widehat{p}_D + t)/q$ (i.e., if $\Gamma(1) \leq 0$ holds), no consumers purchase the PI good irrespective of the level of q if the repair services are not available. For expositional convenience, we set $q_H = 1$ in this case.

The consumer surplus in country F when the producer accommodates the PI good is given by

$$\begin{aligned} CS'_F(\widehat{p}_D, \widehat{p}_F) &= nf_F \left[\int_{\widetilde{v}_F^A}^{b} (v - \widehat{p}_F) dv + \int_{\widetilde{v}_F^{PI}}^{\widetilde{v}_F^A} \{qv - (\widehat{p}_D + t)\} dv \right] \\ &= \frac{n\{b(1-q) + (\widehat{p}_D + t) - \widehat{p}_F\}\{(b - 2\widehat{p}_F)(1-q) + \{\widehat{p}_F - (\widehat{p}_D + t)\}}{2b(1-q)^2} \\ &\quad + \frac{n\{q\widehat{p}_F - (\widehat{p}_D + t)\}^2}{2bq(1-q)^2 d}. \end{aligned} \tag{23}$$

The first term of (23) represents the surplus from consuming the authorized good and the second term is the surplus from consuming the PI good.

If $q \leq q_H$ is satisfied, $v_F^{PI} \geq v_F^A$ holds and all consumers in country F prefer the authorized good, if they buy one. In this case, if $\widetilde{p}_F^N < \left(\widetilde{p}_D^N + t\right)/q$ holds, the firm is able to block parallel imports, even if it completely discriminates the prices between the two countries. Therefore, the producer charges $\widetilde{p}_N^N$ and $\widetilde{p}_F^N$ in equilibrium. We have the following lemma.

Lemma 2 *There exists a unique value of q, q_L $(\in (0, q_H))$ such that $\widetilde{p}_F < (\widetilde{p}_D + t)/q$ holds for $q \in (0, q_L)$.*

Proof. See Appendix. ■

If q is sufficiently small such that it satisfies $q \leq q_L$, the firm's refusal to repair the PI good blocks parallel imports, making the two markets completely segmented.

If $q_L < q < q_H$ holds, the firm opts to block parallel imports by setting $p_F = (p_D + t)/q$, rather than accommodating them. In this case, the firm maximizes (3) subject to $p_F = (p_D + t)/q$.

The optimal prices become:

$$\widehat{p}'_D = \frac{q^2\widetilde{p}^N_D + k(q\widetilde{p}^N_F - t)}{q^2 + k}, \tag{24}$$

$$\widehat{p}'_F = \frac{q(\widetilde{p}^N_D + t) + k\widetilde{p}^N_F}{q^2 + k}. \tag{25}$$

Because $(p_D + t)/q > p_D + t$ holds, the firm is able to make the price differential between the two countries more than the tariff level. The quality premium of the price difference is

$$\widehat{p}^{'}_F - (\widehat{p}'_D + t) = \frac{(1-q)}{q}(\widehat{p}'_D + t) > 0. \tag{26}$$

In summary, the equilibrium price in country i, $\widetilde{p}^R_i$, becomes $\widetilde{p}^R_i = \widetilde{p}^I_i$ if $q = 1$, $\widetilde{p}^R_i = \widehat{p}_i$ if $q_H \neq 1$ and $q \in (q_H, 1)$, $\widetilde{p}^R_i = \widehat{p}'_i$ if $q \in (q_L, q_H]$, and $\widetilde{p}^R_i = \widetilde{p}^N_i$ if $q \in (0, q_L]$. We have the following proposition.

Proposition 1 *If $q \neq 1$ and the firm refuses to repair the PI good, the firm sets: (i) the prices such that some consumers purchase the authorized good and other consumers purchase the PI good for $q \in (q_H, 1)$; (ii) the prices such that all consumers purchase the authorized good for $q \in (q_L, q_H)$; and (iii) the same prices as those under no parallel imports and all consumers purchase the authorized good for $q \in [0, q_L)$.*

The equilibrium profit when the firm refuses to repair the PI good becomes

$$\Pi^R = \begin{cases} \Pi^I & \text{if} \quad q = 1 \\ \Pi'(\widehat{p}_D, \widehat{p}_F) & \text{if} \quad q_H \neq 1 \text{ and } q \in (q_H, 1) \\ \Pi(\widehat{p}'_D, \widehat{p}'_F) & \text{if} \quad q \in (q_L, q_H] \\ \Pi^N & \text{if} \quad q \in (0, q_L] \end{cases}.$$

The equilibrium consumer surplus in each country is given by

$$CS^I_D = \frac{n\left(bk - \widetilde{p}^R_D\right)^2}{2kb},$$

$$CS^I_F = \begin{cases} CS'_F(\widehat{p}_D, \widehat{p}_F) & \text{if } q_H \neq 1 \text{ and } q \in (q_H, 1) \\ n\left(b - \widetilde{p}^R_F\right)^2/2b & \text{otherwise} \end{cases}.$$

2.3.2 Price discrimination in repair services

The monopolist may provide repair services for the PI good, but a repair price is charged against the PI good. Let r denote the repair price the firm charges for the PI good in country F. If a consumer in country F buys a PI good and pays for repair services, his/her expected utility becomes

$$U_F^{I,r} = v - (p_D + t) - (1 - q)r. \tag{27}$$

By comparing (13) and (27), consumers prefer to buy the authorized good, rather than purchasing the PI good and paying for the repair services, if the overall price of the PI good is less than the price of the authorized good, $p_F > p_D + t + (1 - q)r$. Because the expected quality of the authorized good and the quality of the PI good become identical, the consumers purchase the good with the lower overall price. If $p_F = p_D + t + (1 - q)r$ holds, consumers are indifferent between the authorized good and the PI good. If $p_F < p_D + t + (1 - q)r$ holds, all consumers prefer the authorized good because the repair price is too high. This case can be regarded as the refusal of repairs.

Given that $p_F \geq p_D + t + (1 - q)r$ holds, let r^* denote the equilibrium repair price for the PI good, and p_D^* and p_F^* denote the equilibrium price of the authorized good in countries D and F, respectively. We assume the firm continues to provide a full warranty for the authorized good. We have the following proposition.

Proposition 2 *In equilibrium, the overall price of the PI good under the fee-based repair service is the same as the price of the authorized good under the refusal of repairs.*

Proof. See Appendix. ■

The intuitive explanation is as follows. Under the refusal of repairs, the firm differentiates the quality of the good between the authorized good and the parallel imported good. If the firm accommodates the PI good, (22) suggests $\widehat{p}_F - (\widehat{p}_D + t) = (1 - q)(b + m)/2$ holds in equilibrium, where the price difference between the authorized good and the PI good, $(\lambda - q)(b + m)/2$, is the quality premium of the authorized good. Here, instead of refusing the repair services and differentiating the quality, the firm closes the quality gap by providing the repair services and

charging a fee. The amount of the fee is set to extract the quality premium that would have been generated had the repair services for the PI good not been provided: $(1-q)r^* = (1-q)(b+m)/2$.

Because the expected repair price is equal to the quality premium generated by the refusal of repairs, the price gap between the unrepaired good and the repaired good remain unchanged. This implies that the firm sets the same price in the domestic country and $p_D^* = \widehat{p}_D$ and $p_D^* + t + (1-q)r^* = \widehat{p}_F$. Then, any price of the authorized good that satisfies $p_F^* \geq p_D^* + t + (1-q)r^*$ becomes the equilibrium price of the authorized good. Consequently, we have $p_D^* = \widehat{p}_D$ and $p_F^* \geq \widehat{p}_F = \widehat{p}_D + t + (1-q)r^*$.

If the firm blocks the PI good by setting $p_F = (p_D + t)/q$, the quality premium in equilibrium becomes $\widehat{p}_F' - (\widehat{p}_D' + t) = (1-q)(\widehat{p}_D' + t)/q$ (see (26)). Again, the repair price is set such that $(1-q)r^*$ is equal to the quality premium. Hence, we have $p_D^* = \widehat{p}_D'$ and $p_F^* \geq \widehat{p}_F' = \widehat{p}_D' + t + (1-q)r^*$.

Therefore, the refusal of repairs and the fee-based repair services for the PI good are qualitatively indifferent for the firm and consumers, and their effects on the durability of the product and the quality of repair services are also indifferent. In other words, the equilibrium in the case of the fee-based repairs of the PI good practically coincides with the equilibrium under the refusal of repairs.

The equilibrium pricing of the firm is summarized as follows: the firm sets (i) the prices such that some consumers of the PI good are unwilling to repair the broken units for $q \in (q_H, 1)$; (ii) the prices such that all consumers of the authorized good and the PI good repair the broken units for $q \in (q_L, q_H)$; and (iii) the same overall prices as those under no parallel imports and all consumers repair the broken units for $q \in [0, q_L)$.

2.4 Comparison

Now, we compare the equilibrium prices under the three regimes. We have the following proposition.

Proposition 3 *Given the level of q, allowing parallel imports decreases the price of the good in the foreign country and increases the price in the domestic country under no service discrimination. Under service discrimination, allowing parallel imports leads to the same direction of price*

changes if $q > q_L$ holds, but has no effect if $q \leq q_L$ holds. Service discrimination reduces the extent of the price changes.

Proof. See Appendix. ■

By comparing Π^R and Π^I, we can confirm that $\Pi^R \geq \Pi^I$ always holds given the level of q.

Proposition 4 *The producer always prefers to discriminate repair services against the parallel imported good.*

Proof. See Appendix ■

Service discrimination makes the quality of the authorized good higher than that of the PI good when the firm refuses to repair the PI good, or it enables the firm to earn additional profits in the repair market for the PI good when the firm charges more to repair the PI good. As a result, the firm is able to sustain the price difference between the two countries above the tariff level. Note that the firm always has an option to block the PI good by manipulating the level of prices. This means that if the firm sets the prices such that some consumers purchase the PI good (or some consumers of the PI good are refrain from paying the repair price), the firm earns a higher profit than if it blocks the PI. More specifically, the firm accommodates parallel trade because it can earn an additional profit from selling the good to parallel traders and the (overall) price in each country becomes closer to the price under market segmentation. However, if q is small, the prices that accommodate parallel imports substantially reduce the profits from selling the authorized good. Thus, the firm chooses to block them.

3 Parallel imports and the durability of the good

Here, we explore the effect of a change in q on the firm's profit. If parallel imports are banned, or the firm cannot discriminate the repair services, a decline in q always reduces the firm's profit. This is because the presence of the repair cost means the increased probability of the good breaking down increases the firm's expected cost of undertaking the repairs. We call this effect **the cost-increasing effect** of a decline in durability. By differentiating Π^N and Π^I with respect

to q, we have $\partial\Pi^N/\partial q = \partial\Pi^I/\partial q = N[(1+k)\,[bk - \{c+(1-q)m\}]+\{(1-k)b-t\}k]m/\{2bk\} > 0$, because $b > \{c+(1-q)m\}/k$ and $(1-k)b > t$ hold. Therefore, a higher durability always increases the firm's profit, and the magnitude of the effect is unaffected by parallel imports.

However, if parallel imports are allowed and the firm refuses to repair the PI good (or provides fee-based repairs), the effect of a decline in q becomes more complicated. On top of the cost-increasing effect, a decline in q has two additional effects on the firm's profit.

Firstly, it increases the importance of the repair services and the firm is able to charge a higher price for the authorized good or charge a higher repair price for the PI good. Hence, service discrimination makes the price difference between countries D and F much closer to the price difference under full market segmentation. This effect is called **the market-segmentation effect**. Secondly, if the market for the authorized good and the market for the PI good coexist in country F ($q \in (q_H, 1)$), this affects the profit from selling the good to parallel traders since a decrease in q changes the relative demand for the PI good. We call this effect **the PI-market effect**.

The cost-increasing effect has a negative effect on the firm's profit, while the market-segmentation effect has a positive effect. The PI-market effect is either positive or negative because the demand for the PI good is an inverse-U shaped in q. Whether a decrease in q increases or decreases the firm's profit depends on the relative magnitudes of these effects.

Therefore, in the presence of parallel imports, a lower durability of the good may generate higher profits. This is because, by discriminating the repair services against the PI good, the firm can mitigate the pressure of price arbitrage. We show a numerical example of the effect of q on the firm's profit. In what follows, the parameters other than q are set as follows: $n = 100$, $b = 40$, $k = 1/3$, $c = 5$, $m = 1$, and $t = 3$. In this case, the cut-off levels of q become $q_H = 0.68758$ and $q_L = 0.51191$. Figure 1 shows that Π^R is decreasing in q for $q \in (q_H, 1]$ and an inverse-U shaped in q for $q \in (q_L, q_H]$.

[Insert Figure 1 around here]

In this case, Π^R is an inverse-U shaped in q, and it is maximized at $q = q^* = 0.52611$ ($\in (q_L, q_H)$), where the firm blocks the PI good by refusing to provide repair services, or sets the repair price for the PI good so that all consumers of the PI good pay the repair price for repairing

the good.

Proposition 5 *If the firm discriminates repair services against the parallel imported good, then a decrease in q may increase the profit of the firm. Under no parallel imports or no service discrimination, a decrease in q always decreases the profit of the firm.*

This proposition suggests that service discrimination substantially changes the relationship between the durability of the good and the profit of the firm.

3.1 Endogenous durability of the product

As explained in the Introduction, one concern over allowing parallel imports is that the reduced profits of firms owing to market integration will decrease the gains from firms' innovation activities and will lead to a deterioration of product quality. Here, we investigate how parallel imports affect the producer's incentive to provide greater product durability that increases the "quality" of the good in the sense that consumers worry less about the good breaking down. To this end, we add a new stage before the first-stage (i.e., stage zero) in which the producer chooses the durability of the product. Existing studies that have examined the quality effect of parallel imports have not explicitly considered the possibility that the good breaks down and the durability of the good. We examine endogenous determinations of the product durability.

We suppose the producer must incur the fixed cost, $C(q)$, to produce the good with the durability, q. The fixed cost reflects the costs of conducting a more intensive durability inspection (e.g., increasing the percentage of units to be tested), using more durable parts and components in the manufacturing process, and so on.

It is natural to suppose that this fixed cost is increasing in q. Hence, it is assumed that $C(0) = 0$, $C'(q) > 0$ and $C''(q) \geq 0$. Without loss of generality, we suppose the fixed cost is quadratic in q and given by $C(q) = \beta q^2/2$, where β is positive and constant.

Different effects of a change in q on Π^N, Π^I, and Π^R imply that the firm will choose different levels. The firm chooses the optimal level of q so that it maximizes the profit net of the fixed cost, $C(q)$. Let $\widetilde{q}^N$, $\widetilde{q}^I$, and $\widetilde{q}^R$ respectively represent the profit-maximizing levels of q under Regime N, IR, and I. By Proposition 5, $\widetilde{q}^N = \widetilde{q}^I$ always holds. However, $\widetilde{q}^R$ may be lower than them.

For instance, if $\beta = 100$, then we have $\widetilde{q}^N = \widetilde{q}^I = 0.69737 > \widetilde{q}^R = 0.51538$. In this case, service discrimination induces the firm to choose lower durability.

Proposition 6 *In the presence of service discrimination against the parallel imported good, parallel imports may reduce the product durability. If there is no service discrimination, parallel imports has no effect on the durability.*

Note that, if $\widetilde{q}^N > \widetilde{q}^R$ holds, it becomes ambiguous whether parallel imports benefit consumers in country F. This is because, while the direct effect of parallel trade reduces p_F, it decreases the durability of the good that, in turn, increases p_F. If the latter effect is relatively significant, then parallel imports hurt consumers in the importing country. In fact, under this numerical example, $CS_D^I\big|_{q=\widetilde{q}^R} - CS_D^N\big|_{q=\widetilde{q}^N} = -4.0936$ and $CS_F^I\big|_{q=\widetilde{q}^R} - CS_F^N\big|_{q=\widetilde{q}^N} = -0.70619$, and parallel imports hurt consumers in the importing country.

Corollary 1 *When the firm can change the durability of the good and implement service discrimination, parallel imports may hurt consumers in both countries.*

When the producer optimally manipulates q, the level of country F's import tariff, t, affects the level of q. This implies that trade liberalization may have a negative effect on the consumer surplus in country F. On the one hand, trade liberalization enhances the firm's incentive to increase q by increasing the profit in the foreign country and, thereby, the gains from increasing the durability. On the other hand, trade liberalization decreases the durability because it increases the producer's damage from parallel imports and, thereby, diminishes its gains from providing higher q. We have $\partial^2\Pi^N/(\partial t\partial q) = \partial^2\Pi^I/(\partial t\partial q) = -Nm/2b < 0$. Thus, without service discrimination or without parallel imports, the former effect always dominates the latter, and trade liberalization leads to a higher level of q.

However, with service discrimination, trade liberalization may induce the producer to reduce q. This is because, by reducing q, the producer can partly offset the damage from the increased arbitrage pressure.

For instance, if $\beta = 120$, trade liberalization from $t = 4$ to $t = 0$ increases the optimal level of durability under no parallel imports from $\widetilde{q}^N\big|_{t=4} = 0.56522$ to $\widetilde{q}^N\big|_{t=0} = 0.60870$. However, it decreases the optimal level of durability under service discrimination from $\widetilde{q}^R\big|_{t=4} = 0.54224$ to $\widetilde{q}^N\big|_{t=0} = 0.41919$.

Proposition 7 *Trade liberalization increases the durability of the good if parallel imports are banned or there is no service discrimination against the parallel imported good. In the presence of service discrimination, there is a case where trade liberalization decreases the durability of the good.*

Thus, trade liberalization may widen the gap between $\widetilde{q}^N$ and $\widetilde{q}^R$ and worsen the consumers' losses from allowing parallel imports in both countries. With the numerical calculations above, changes in consumer surplus become: $\left(CS_F^I\big|_{q=\widetilde{q}^R} - CS_F^N\big|_{q=\widetilde{q}^N}\right)\Big|_{t=4} = 0.004874$ and $\left(CS_F^I\big|_{q=\widetilde{q}^R} - CS_F^N\big|_{q=\widetilde{q}^N}\right)\Big|_{t=0} = -0.66338$.

Corollary 2 *When the firm can change the durability of the good, there is a case where allowing parallel imports benefits consumers in the importing country when the import tariff is high and hurts consumers when the import tariff is low.*

4 Discussion

In this section, we explore the robustness of these results by relaxing some assumptions made in the basic model.

4.1 Full warranty assumption for the authorized good

We have assumed that the firm offers a full warranty to the buyers of the authorized good. Here, we show that this assumption does not affect the qualitative results of our basic model and the firm actually prefers the full warranty in some cases. Suppose parallel importation is prohibited and let s_i denote the repair price that the firm sets for repairing the authorized unit in country i. Consumers repair the broken units of the authorized good if $v_i \geq s_i$ holds. That is, the utility gain from the repair exceeds the repair price. Consumers primarily purchase the authorized good if $qv_i \geq p_i$. These inequalities suggest that there exist consumers who buy the authorized good, but never purchase the repair services if and only if $s_i > p_i/q$ holds.

Given that $s_i > p_i/q$ holds, the profit of the firm in country i is given by

$$\pi_i(p_i, s_i) = [p_i + (1-q)s_i - \{c + (1-q)\, m\}]x_i^s(p_i) + nf_i(p_i - c)\left(\frac{qs_i - p_i}{\delta q}\right), \tag{28}$$

where $x_D^s(p_D) = nf_D(kb - s_D)$ and $x_F^s(p_F) = nf_F(b - s_F)$. By maximizing $\pi_i(p_i, s_i)$ with respect to p_i and s_i, the optimal prices become $\dot{p}_D = (c + bkq)/2$, $\dot{p}_F = (c + bq)/2$, $\dot{s}_D = (bk + m)/2$, and $\dot{s}_F = (b + m)/2$. However, these prices fail to satisfy the supposition that $s_i > p_i/q$ holds.

Therefore, the firm sets the repair prices such that every consumer of the authorized good prefers to pay for the repair services. In this case, consumers whose willingness to pay satisfies $v_i \geq p_i + (1-q)s_i$ buy the good and all of them purchase the repair services. Let $P_i = p_i + (1-q)s_i$ denote the overall price of the authorized good. Then, the firm's overall profit becomes

$$\dot{\Pi}(P_D, P_F) = \sum_{i=D,F} \pi_i(P_i) = (P_i - \{c + (1-q)\,\delta m\})\, x_i(P_i), \tag{29}$$

where $x_i(\cdot)$ is defined in (1) and (2). Because (29) has the same functional form as (3), the profit-maximizing level of each price also coincides ($\widetilde{P}_i = \widetilde{p}_i$), as does the equilibrium profit: $\dot{\Pi}(\widetilde{P}_D, \widetilde{P}_F) = \Pi\left(\widetilde{p}_D^N, \widetilde{p}_F^N\right)$.

Because the firm's profit is larger when all consumers utilize the repair services, the combination of the good's price and the repair prices does not matter to the firm, as long as the overall price is equals to $\widetilde{p}_i$ and they are consistent with $s_i \leq p_i/q$. If the firm set a higher repair price, the good's price becomes lower. If the firm provides a full warranty, it means that the firm sets a higher price to cover the cost of the repairs.

In the presence of parallel imports, the firm becomes more willing to provide the full warranty in country D to keep the price of the authorized good high and to mitigate the arbitrage pressure. If the firm does not provide a full warranty in country F, the authorized good and the PI good becomes perfectly substitutable and the firm captures the quality premium of the authorized good by setting a high repair price. After all, the overall price of the authorized good in country F becomes the same as the price of the authorized good with the full warranty.

4.2 Repair services by ISOs

Until now, we have restricted our attention to the case where only the original producer can provide the repair services. Here, we consider the case in which independent service organizations (ISOs) are also able to provide the repair services for the PI good. We assume there are many ISOs and the competition among them reduces the repair prices to their marginal cost.

The original producer of the good should have more technical information about the good

than the ISOs, and will stock more parts and components that are necessary to repair the good. Hence, it is natural to assume that the quality of the repair services performed by the firm is not lower than the quality performed by the ISOs. Let $\mu \in (0, 1]$ represents how well a repair recovers the original quality of good x. As μ approaches one, the quality gap between the unbroken unit and the repaired unit narrows, and the quality is fully recovered when $\mu = 1$. The level of μ reflects the extent to which the repair services performed by ISOs recover the "physical" quality of the good.

Let μw denote the unit cost of undertaking repair services when performed by ISOs. The unit cost of repairs is increasing in μ because it should be more costly for the firm to return the quality to the original quality. The ISOs may also incur a higher unit cost of repairs, but their less effective repair services may come with a lower cost. Therefore, we leave w to be either higher or lower than m.

Firstly, suppose $\mu = 1$. In other words, ISOs provide the same quality of repair services as the original producer. In this case, even if the firm refuses to repair the PI good, consumers can repair the PI good by paying δw to an ISO. The overall price of the PI good becomes $p_D + t + (1-q)\delta w$. Then, the firm needs to set $p_F \leq p_D + t + (1-q)\delta w$ to sell the authorized good. If $(1-q)\delta w$ is larger than $\widetilde{p}_F^N - \left(\widetilde{p}_D^N + t\right)$ given by (8), the firm can set the same prices as those under full market integration. Otherwise, the equilibrium international price difference becomes $t + (1-q)\delta w$, and becomes larger as q becomes smaller. Note that, unless $w = 0$, the entry of competitive ISOs realizes a higher profit for the firm than the profit that is realized if the firm cannot discriminate repair services.

Secondly, suppose $\mu < 1$. To make clear the analysis, we set $w = 0$ so that ISOs provides virtually free repairs. However, the free repairs cannot realize full market integration because the authorized unit and the PI unit repaired by ISOs are imperfect substitutes. If the firm refuses to provide the repair services for the PI good, it can attract consumers to buy the authorized good by setting p_F and p_D, such that

$$p_F = \frac{p_D + t}{\mu}$$

holds. Because $\mu < 1$, we have $p_F - (p_D + t) = (1-\mu)(p_D + t)/\mu > 0$. If this price difference is larger than $\widetilde{p}_F^N - \left(\widetilde{p}_D^N + t\right)$, the full market segmentation is realized by the service discrimination.

If $\mu < 1$ and $w > 0$: the equilibrium price difference reflects the above two effects. Accordingly, if the ISOs' quality of repair services is lower than the firm's quality or the ISOs incur a positive cost of repair services, the presence of competitive ISOs does not realize full market integration. The original producer's service discrimination becomes less effective, but it is still effective, and a decrease in q may expand the international price difference and increase the producer's profit.

5 Conclusion

In this study, we have re-examined the effect of parallel imports when the producer (trademark holder) of a durable good might discriminate after-market services against a parallel imported good. We have shown that the producer is willing to differentiate the authorized good and the parallel imported good by not providing repair and maintenance services for the parallel imported units. A refusal to repair parallel imported goods realizes full market segmentation between countries if the durability of the good is sufficiently low. In the middle range of durability, the producer successfully blocks parallel importation even if the price of the authorized good is higher than the price of the parallel imported good. If the durability is sufficiently high, the producer accommodates the parallel imported good and consumers in the importing country buy either the authorized good or the parallel imported good, depending on their willingness to pay for the quality. In the latter two cases, the two markets are only partially integrated. Instead of refusing the repair services, the firm can also mitigate the pressure of price arbitrage by charging a relatively high repair price for the parallel imported good. Although the entry of many competitive independent service organizations helps to narrow the international price gap, it is not sufficient to eliminate the firm's service discrimination.

Although service discrimination decreases the extent of market integration and realizes a higher profit for the firm, it does not always increase the producer's incentive to improve the durability of the good. This is because the durability of the product is itself a strategic tool to manipulate the degree of vertical differentiation between the authorized good and the parallel imported good. Specifically, the service discrimination may reduce the durability of the good below the level under full market integration and under full market segmentation. When the durability decreases, consumers in the importing country may suffer by permitting parallel imports, and the

negative effect of parallel importation will be amplified as trade liberalization proceeds. There is a case where allowing parallel imports benefits consumers in the importing country when an import tariff is high, but hurts consumers under free trade.

There is room for further research. Introducing other producers that provide the same good, but of different quality will enable us to investigate how competition among producers is influenced by service discrimination. Then, it would be interesting, though cumbersome, to consider the endogenous determination of the tariff level.

Appendix

Proof of Lemma 2

We have $\widetilde{p}_F^N - \left(\widetilde{p}_D^N + t\right)/q = -\Omega(q)/(2q)$ where $\Omega(q) = (1-q)^2(kb+m) + (1-q)\{(2k-1)qb + c + 2t\} + q\{t - (1-k)qb\}$. Since $\Omega(q)$ is a quadratic function in q, $\Omega(0) = kb + c + 2t + m > 0$, and $\Omega(1) = -\{(1-k)b - t\} < 0$, there exists a unique value of q, q_L $(\in (0,1))$, that satisfies $\Omega(q_L) = 0$. This means that $\widetilde{p}_F^N \geq \left(\widetilde{p}_D^N + t\right)/q$ holds for $q \in [q_L, 1)$ and $\widetilde{p}_F^N < \left(\widetilde{p}_D^N + t\right)/q$ holds for $q \in (0, q_L]$.

By comparing $\widetilde{p}_F^N - \left(\widetilde{p}_D^N + t\right)/q$ and $\widehat{p}_F - \left(\widehat{p}_D + t\right)/q$, we have

$$\left(\widetilde{p}_F^N - \frac{\widetilde{p}_D + t}{q}\right) - \left(\widehat{p}_F - \frac{\widehat{p}_D + t}{q}\right) = \frac{\left(q^2 + k\right)\{(b+m)q - (kb + t + m)\}}{2q\left(q + k\right)}.$$

The above equation tells us that $\left[\widetilde{p}_F^N - \left(\widetilde{p}_D + t\right)/q\right] - \left[\widehat{p}_F - \left(\widehat{p}_D + t\right)/q\right]$ is positive if $q > q_1 \equiv (kb + t + m)/(b + m)$ is satisfied. At $q = q_1$, we have

$$\begin{aligned}\left(\widetilde{p}_F^N - \frac{\widetilde{p}_D^N + t}{q}\right)\Bigg|_{q=q_1} &= \left(\widehat{p}_F - \frac{\widehat{p}_D + t}{q}\right)\Bigg|_{q=q_1} \\ &= -\frac{\{(1-k)b - t\}q_1}{2\left(kb + t + m\right)^2}\left[b\left(c - km\right) + m\left(c - m\right) + bt\right] < 0.\end{aligned}$$

This means that $q_L > q_1$ and $\widetilde{p}_F^N - \left(\widetilde{p}_D^N + t\right)/q = 0$ and $\widehat{p}_F - \left(\widehat{p}_D + t\right)/q < 0$ is satisfied at $q = q_L$. Therefore, q_H at which $\widehat{p}_F - \left(\widehat{p}_D + t\right)/q = 0$ holds is higher than q_L. ■

Proof of Proposition 2

For the time being, let us suppose $p_F > (p_D + t) + (1-q)r$ holds and all consumers in country F purchase the PI good. If a consumer buys a PI good but does not utilize the repair services

provided by the firm, then her expected utility is given by (14). Therefore, consumers purchase the repair services if their willingness to pay for quality satisfies $v \geq r$. By comparing r and v_F^{PI}, we have

$$r - v_F^{PI} = \frac{qr - (p_D + t)}{q}$$

If $r > (p_D + t)/q$ holds, which means that the repair price for the PI good is sufficiently high, consumers with parameter $v \in [v_F^{PI}, r]$ buy the PI good but do not purchase the repair services. Suppose this inequality holds, the demand for the authorized good and the demand for the PI good in country F are respectively given by

$$\begin{aligned} x_F^{PI,r}(r) &= nf_F[b - r] = n\left[1 - \frac{r}{b}\right], \\ x_F^{PI,nr}(p_D, r) &= nf_F\left[r - v_F^{PI}\right] = n\left[\frac{qr - (p_D + t)}{qb}\right], \end{aligned}$$

while the demand in country D is given by (1). The firm' profit is given by

$$\begin{aligned} \Pi''(p_D, r) &= [p_D - \{c + (1-q)m\}]x_D(p_D) + [p_D + (1-q)r - \{c + (1-q)m\}]x_F^{PI,r}(r) \\ &\quad + (p_D - c)x_F^{IP,nr}(p_D, r). \end{aligned}$$

By maximizing $\Pi''(p_D, r_I)$ with respect to p_D and r, we have the optimal prices as

$$\begin{aligned} p_D^* &= \frac{(2qb - t)k + mq(1-q) + c(k+q)}{2(k+q)}, \\ r^* &= \frac{(b+m)}{2}. \end{aligned}$$

We confirm that $p_D^* = \widehat{p}_D$ holds. By using (22), $\widehat{p}_F = \widehat{p}_D + t + (1-q)(b+m)/2 = p_D^* + t + (1-q)r^*$ holds. Therefore, the overall price for the PI good in country F coincides with the price of the authorized good under the refusal to repair. The condition of $x_F^{IP,nr}(p_D^*, r^*) > 0$, $r^* > (p_D^* + t)/q$, can be transformed into $\widehat{p}_F > (\widehat{p}_D + t)/q$, the condition under which the firm accommodates the PI good in the case of the refusal of repairs. Therefore, some consumers who purchased the PI good leave the PI good unrepaired if $q \in (q_H, 1)$ holds.

If $r^* \leq (p_D^* + t)/q$ holds, which means that $q \leq q_H$ holds, we have $x_F^{PI,nr}(p_D^*, r^*) \leq 0$ with p_D^* and r^*. In this case, $x_F^{PI,nr}(p_D, r) \geq 0$ becomes binding constraint and the firm cannot set p_D and r separately. In this case, the firm sets the prices such that all consumers who purchase the PI good also purchase the repair services (i.e., $x_F^{PI,nr}(p_D, r) = 0$). The firm maximizes

$\Pi''(p_D, r_I)$ such that $r = (p_D + t)/q$ holds, and we confirm the equilibrium prices satisfy $\widehat{p}'_F = p_D^{*\prime} + t + (1-q)\, r_I^{*\prime}$.

Under full market segmentation, by (8), $\widetilde{p}_F^N = \widetilde{p}_D^N + t + \{(1-k)b - t\}/2$ holds. This implies that if the firm sets $(1-q)r^{*\prime\prime} = \{(1-k)b - t\}/2$ and $r^{*\prime\prime} < (\widetilde{p}_D^N + t)/q$ is satisfied, the firm can practically set the same prices as those under the full price discrimination. The inequality can be transformed into $\widetilde{p}_F < (\widetilde{p}_D + t)/q$, the same condition under which the refusal of repairs realizes the full market segmentation. The full market segmentation occurs if $q \in (0, q_L)$ holds.

In sum, the overall price of the good in each country and the cut-off values of q that are obtained with the price discrimination in repair services becomes the same as those obtained with the refusal of repairs. ■

Proof of Proposition 3

By comparing $\widetilde{p}_i^N$ and $\widetilde{p}_i^I$, we have $\widetilde{p}_D^I - \widetilde{p}_D^N = k\{\widetilde{p}_F^N - (\widetilde{p}_D^N + t)\}/(1+k) > 0$ and $\widetilde{p}_F^I - \widetilde{p}_F^N = -\{\widetilde{p}_F^N - (\widetilde{p}_D^N + t)\}/(1+k) < 0$. By comparing $\widetilde{p}_i^N$ and $\widehat{p}_i$, we have $\widetilde{p}_D^N - \widehat{p}_D = k(q - q_1)/2[(b+m)(q+k)]$ and $\widetilde{p}_F^N - \widehat{p}_F = -q(q-q_1)/2(q+k)$ where q_1 is defined in the proof of Lemma 2. Since $q > q_1$ holds whenever $q > q_L$ holds, $\widetilde{p}_D^N > \widehat{p}_D$ and $\widetilde{p}_F^N < \widehat{p}_F$ are always satisfied. With regard to $\widetilde{p}_i^N$ and $\widehat{p}'_i$, $\widetilde{p}_D^N - \widehat{p}'_D = -k\{q\widetilde{p}_F^N - (\widetilde{p}_D^N + t)\} < 0$ and $\widetilde{p}_F^N - \widehat{p}'_F = q\{q\widetilde{p}_F^N - (\widetilde{p}_D^N + t)\}/(q^2 + k) > 0$ hold. Therefore, parallel imports always raises the price in country D and reduces the price in country F.

Next, we compare the prices under Regime I and those under Regime R. We have $\widehat{p}'_D - \widetilde{p}_D^I = -k(1-q)\{t + (1+k)m + 2kb\}/\{2(k+1)(q+k)\} < 0$ and $\widehat{p}'_F - \widetilde{p}_F^I = (1-q)\left[\left(k+q^2\right)(p_D+t) + k(1+q)\{q\widetilde{p}_F^N - (\widetilde{p}_D^N + t)\}\right]/\{q\left(k+q^2\right)(k+1)\} > 0$ for $q \in (q_L, 1)$ because $q\widetilde{p}_F^N - (\widetilde{p}_D^N + t) > 0$ holds. Besides that, for $q \in (q_H, 1)$, $\widehat{p}_D - \widehat{p}'_D = -\{q\widehat{p}_F - (\widehat{p}_D + t)\}kq/\left(k+q^2\right) < 0$ and $\widehat{p}_F - \widehat{p}'_F = \{q\widehat{p}_F - (\widehat{p}_D + t)\}q^2/(k+q^2) > 0$ hold because $q\widehat{p}_F - (\widehat{p}_D + t) > 0$ holds in this range of q.

Putting it all together, $\widetilde{p}_D^I > \widetilde{p}_D^N$ and $\widetilde{p}_F^N > \widetilde{p}_F^I$ hold for $q \in [0, q_L)$, $\widetilde{p}_D^I > \widehat{p}'_D > \widetilde{p}_D^N$ and $\widetilde{p}_F^N > \widehat{p}'_F > \widetilde{p}_F^I$ hold for $q \in (q_L, q_H]$, and $\widetilde{p}_D^I > \widehat{p}_D > \widetilde{p}_D^N$ and $\widetilde{p}_F^N > \widehat{p}_F > \widetilde{p}_F^I$ hold for $q \in (q_H, 1]$. This means that parallel imports raise the price in country D and reduce the price in country F, and the degrees of the changes are moderate when the firm refuses to repair the PI good. ■

Proof of Proposition 4

For $q \in (0, q_L]$, $\Pi^R = \Pi^N$ holds, and we have $\Pi^N - \Pi^I = n\{(1-k)\,b - t\}^2 / \{4\,(1+k)\,b\} > 0$. When the firm provides the repair services for the PI good, the firm's profit function becomes the same as that under no parallel imports and it is given by (3). For $q \in (q_L, 1]$, if the firm eliminates parallel imports by setting $p_D = \widehat{p}'_D$ and $p_F = \widehat{p}'_F$, the firm's profit function is also given by (3). Under no parallel imports, the firm sets the price that maximizes the profit it can earn in each market. This means that the profit earned in each country is higher as the price becomes closer to the optimal price under no parallel imports. By Proposition 2, $\widetilde{p}^I_D > \widehat{p}'_D > \widetilde{p}^N_D$ and $\widetilde{p}^N_F > \widehat{p}'_F > \widetilde{p}^I_F$ and so $\Pi(\widehat{p}', \widehat{p}'_F) > \Pi^I$ holds for $q \in (q_L, 1]$. If $q_H \neq 1$, $\Pi'\,(\widehat{p}_D, \widehat{p}_F) > \Pi(\widehat{p}'_D, \widehat{p}'_F)$ holds for $q \in (q_H, 1)$ because the firm chooses $\widehat{p}_D$ and $\widehat{p}_F$ that satisfies $q\widehat{p}_F > \widehat{p}_D + t$ and accommodates the imports of the PI good even if it can choose $\widehat{p}'_F$ and $\widehat{p}'_D$ that satisfies $q\widehat{p}'_F = \widehat{p}'_D + t$ to block the imports of the PI good. Therefore, $\Pi^R > \Pi^I$ holds for all $q \in [0, 1)$. ■

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Figure 1: The product durability and the firm's profit