Essays on international trade and policy

by

Mian Muhammad Farrukh Raza

M.Sc., University of Engineering and Technology, Taxila, 2008
M.A., Western Illinois University, 2014

AN ABSTRACT OF A DISSERTATION

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Abstract

Leaders around the world have introduced various trade policies including subsidies, tariffs, anti-dumping duties or price undertakings throughout the trade history. These trade policies have benefitted states in different ways. For example, some countries achieved economic development by supporting their firms through various subsidies and helping them to enhance their product qualities and become competitive in the international market. Whereas, in other cases leaders engage in imposing tariffs - a policy helps leaders to protect their producers and generate revenue. Such trade policies are not only limited to the benefits; however, they may incur costs too. As such, the imposition of trade policies affects the social welfare of all parties engaged in trade. Recently, we have seen that US-China engaged in a trade war where the United States has imposed tariff duties against China, and China responded with its tariffs on US products. This trade war has affected the social welfare one way or another. Such trade practices in the past have led scholars to address questions related to trade policies. Despite the work on trade policies, there is still a wide variety of questions yet to be answered regarding trade policies. This dissertation address three important questions related to international trade policies and their impact on social welfare.

The first chapter is motivated by the observation of the quality difference between imported and local products in Pakistan. This chapter addresses the question of whether import-competing markets where foreign products are of high quality, are domestic firms doomed to produce low-quality products? What are policy options available to an importing country government that has the multiple objectives of maximizing consumer surplus, domestic profit and welfare, besides generating product quality reversal? Using a duopoly framework of vertical product differentiation, we analyze and compare three policy options: an import tariff, free trade,

and a quality-upgrading R&D subsidy. We identify the conditions under which the *quality-based* R&D subsidy policy is a *win-win-win* strategy in that consumer surplus, domestic profit, and social welfare are all at their maximum levels, in addition to product quality reversal.

The second chapter is motivated by the contemporary US-China trade war and its welfare implications. This paper analyzes differences in welfare implications between import tariffs and antidumping (AD) duties within a unified model of trade in quality-differentiated products under international duopoly. Specifically, the model allows for product quality choices by two competing firms located separately in a developed country (DC) and a less-developed country (LDC), where there is a different degree of international market competition. We show that dumping arises as an LDC firm sells a low-quality product that is "dumped" into the DC market. Compared to import tariffs, imposing AD duties (based on the dumping margin) by the DC government makes its firm better off. Whether DC consumers are better off and whether there is welfare improvement for DC are shown to depend on the degree of market competition. We further identify conditions under which a tariff policy is preferred over an AD policy (or the other way around) from the world perspective of welfare.

The third paper investigates which types of firms (DC or LDC) tend to practice dumping, using a two-market equilibrium model of trade in "like" products with quality differentiation. Specifically, within the framework of duopolistic competition between a DC firm and an LDC firm, we show that the DC firm sells a high-quality product without practicing dumping. In contrast, the LDC firm sells a low-quality product that is dumped into the DC market at a price less than the price of the product in its LDC market. The imposition of antidumping duties by the DC government increases domestic welfare. It is welfare increasing to LDC when its exporting firm accepts a price-undertaking, rather than practicing dumping. From the perspective of world welfare, defined by aggregating the welfare of DC and LDC as trading partners, the trade damage measure of an antidumping policy is Pareto superior to free trade (under which dumping takes place) and price-undertakings.

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Major Professor
Yang-Ming Chang

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Dedication

I dedicate this work to my lovely grandmother, **Kundan Bibi (*Amman Wadi*)**, and my parents, **Sakina Bibi** and **Mian Mehboob Ali Chhajra**. Their unconditional love, support and passion over the years made it possible for me to move beyond the status quo set for the children of an agrarian society.

Chapter 1 - Import Competition, Product Quality Reversal, and Welfare

1. Introduction

Voluminous studies have contributed to our understanding of strategic trade policy and endogenous choice of product quality by firms in imperfectly competitive markets.[1]Recognizing the contributions in the literature, we observe two important questions that are constantly challenging firms and policymakers in importing countries. In import-competing markets where foreign products are of high quality, are domestic firms doomed to produce low-quality products? What are policy options available to an importing country government that has the multiple objectives of maximizing consumer surplus, domestic profit and welfare, besides generating product quality reversal? This paper attempts to provide preliminary answers to the questions.

The present study complements the recent contribution of Kováč and Žigić(2014). The authors examine trade policy and R&D investment for product quality improvement when an import-competing market is partially covered. We analyze the case of a full covered market where each individual purchases either an imported or a domestic product, which is considered as a necessity to all consumers in an importing country.[2] We introduce a quality-upgrading equation for each firm. This approach permits us to derive reduced-form solutions for optimal

[1]See, e.g., Das and Donnenfeld (1987), Flam and Helpman (1987), Krishna (1987), Reitzes (1992), Motta, Thisse, and Cabrales (1997), Herguera, Kujal, and Petrakis (2002), Zhou, Spencer, and Vereinsky (2002), Moraga-Gonzalez and Viaene, (2005), Amiti and Khandelwal (2013), and Kováč and Žigić (2014).

[2] We borrow the assumption of a full covered market from the literature that uses a vertical product differentiation framework (see, e.g., Cremer and Thisse, 1994; Crampes and Hollander, 1995; Wauthy 1996; Ecchia and Lambertini, 1997; Maxwell 1998; and Andaluz, 2000).

levels of quality upgrades, R&D investments, firm profits and domestic welfare, as well as an optimal government policy in the case of a three-stage game. We analyze and compare three policy options: an import tariff, free trade, and a quality-upgrading R&D subsidy. We find that a tariff policy does not serve the dual purposes of domestic welfare maximization and product quality reversal. Moreover, we show that among the three regimes, unless the domestic firm's quality-upgrading R&D investment is extremely cost-ineffective, the quality-based subsidy policy is able to encourage the domestic firm to undertake R&D investment for achieving quality reversal, with the result that consumer surplus, domestic profit and welfare are all at their maximum levels.

1.2. The Model

1.2.1 *Basic Assumptions*

We consider an import-competing duopoly market where foreign and domestic firms produce vertically differentiated products and engage in Bertrand price competition. Denote p_f and p_d as the prices of the products charged by the foreign and domestic firms, respectively. In the market, consumers are uniformly distributed over a unit line, $\theta \in [0,1]$. Each individual buys one unit of the product, which is a necessity to all consumers in the importing country. The indirect utility of consumer θ is specified as follows:

$$V(\theta) = \begin{cases} \theta q_f - p_f & \text{if buy the foreign product;} \\ \theta q_d - p_d & \text{if buy the domestic product.} \end{cases} \tag{1}$$

where q_i represents product quality for firm $i\,(i = f, d)$. To allow for the possibility of upgrading product quality through investment, we assume that

$$q_f = 1 + s_f \text{ and } q_d = 1 + s_d , \tag{2}$$

where $s_i (\geq 0)$ represents "quality upgrade" resulting from R&D by firm $i\,(i = f, d)$. This implies that in the absence of quality upgrades by the firms $(s_f = s_d = 0)$, each one's product quality is normalized to one $(q_f = q_d = 1)$.

Empirical findings suggest that $q_f > q_d \geq 0$, i.e., foreign product quality is relatively higher.[3] Based on (2), this implies that $s_f > s_d \geq 0$. In our analysis, the levels of quality upgrades s_f and s_d are endogenously chosen by the firms. As in the R&D investment literature, each firm's quality-upgrading expenditure is taken to be a quadratic form: $E_i = \gamma_i s_i^2 / 2$, where parameter γ_i reflects the cost-effectiveness of investment for firm i $(i = f, d)$.[4] Following Kováč and Žigić(2014), we define parameter μ as the degree of technological spillovers where $\mu \in [0,1)$.

Given consumer heterogeneity in tastes for quality that $\theta \in [0,1]$, the marginal consumer who is indifferent between the two products implies that $(1+s_f)\theta - p_f = (1+s_d)\theta - p_d$. The critical value of θ is $\hat{\theta} = \dfrac{p_f - p_d}{s_f - s_d}$, which means that $1 > \hat{\theta} > 0$ for $p_f > p_d > 0$ and $s_f > s_d \geq 0$. Market demands for the foreign and domestic products are:

$$D_f(p_f, p_d) = 1 - \hat{\theta} = 1 - \frac{p_f - p_d}{s_f - s_d} \text{ and } D_d(p_f, p_d) = \hat{\theta} = \frac{p_f - p_d}{s_f - s_d}. \qquad (3)$$

[3]See, e.g., Amiti and Khandelwal (2013). Quality-upgrading investment is endogenously determined by each firm in our analysis, but we consider that the inequality condition holds initially in order to see what effective measures would be available to an importing country for generating product quality reversal. In other words, it is the objective of this paper to uncover such measures or policies.

[4]That is, the lower the value of γ_i the higher the cost-effectiveness of R&D investment.

Utilizing this framework of vertical product differentiation, we examine three policy options: (i) an import tariff, and (ii) free trade, and (iii) a quality-upgrading R&D subsidy.

1.2.2 *Three Policy Options*

1.2.2.1 Import Tariff

Under tariff protection, there is a three-stage game. At stage one, the firms determine quality upgrades, $\{s_f, s_d\}$, that maximize their respective profits, with the foreign firm being the quality leader and the domestic firm being the quality follower. At stage two, the domestic government determines an optimal tariff rate, t, on the foreign import. At stage three, the firms set their optimal prices $\{p_f, p_d\}$ by engaging in Bertrand competition. We use backward induction to solve for the sub-game perfect Nash equilibrium.

At the price competition stage, the firms solve their profit-maximization problems:[5]

$$\underset{\{pf\}}{\text{Max}}\ \pi_f^{TARIFF} = (p_f - t)D_f - \frac{1}{2}\gamma_f s_f^2 \text{ where } D_f = 1 - \frac{p_f - p_d}{s_f - s_d}; \tag{4a}$$

$$\underset{\{pd\}}{\text{Max}}\ \pi_d^{TARIFF} = [p_d D_d - \frac{1}{2}(1-\mu)\gamma_d s_d^2] \text{ where } D_d = \frac{p_f - p_d}{s_f - s_d} \text{ and } \mu \in [0,1). \tag{4b}$$

The first-order conditions (FOCs) for the firms imply that the equilibrium prices are:

$$p_f = \frac{2(t + s_f - s_d)}{3} \text{ and } p_d = \frac{(t + s_f - s_d)}{3}. \tag{5}$$

Substituting (5) back into (3) yields the product demands:

$$D_f = 1 - \hat{\theta} = \frac{2(s_f - s_d) - t}{3(s_f - s_d)} \text{ and } D_d = \hat{\theta} = \frac{(s_f - s_d) + t}{3(s_f - s_d)}. \tag{6}$$

[5] As in Kováč and Žigić (2014), we assume zero production costs for analytical simplicity in order to focus the analysis on costly R&D investments by the competing firms.

At the policy stage, the government determines a specific tariff to maximize social welfare, which is taken to be the sum of overall consumer surplus (from the domestic and foreign products), domestic profit (net of its R&D cost), and tariff revenues. That is, $SW^{TARIFF} = CS^{TARIFF} + \pi_d^{TARIFF} + t(1-\hat{\theta}).$ The government solves the following problem:

$$\underset{\{t\}}{\text{Max}}\ SW^{TARIFF} = \underbrace{\int_0^{\hat{\theta}}[(1+s_d)\theta - p_d]d\theta + \int_{\hat{\theta}}^{1}[(1+s_f)\theta - p_f]d\theta}_{CS^{TARIFF}} + \underbrace{[p_d\hat{\theta} - \frac{1}{2}\gamma_d(1-\mu)s_d^2]}_{\pi_d^{TARIFF}} + \underbrace{t(1-\hat{\theta})}_{Tariff\ Revenues},$$

where prices and demands are given in (5) and (6). The optimal tariff is calculated as

$$t^* = (s_f - s_d) > 0 \text{ when } s_f > s_d. \tag{7}$$

At the R&D stage, the firms optimally determine their quality upgrades. Being the quality follower, the domestic firm determines s_d as a function of s_f. The FOC for the domestic firm is:

$$\frac{\partial \pi_d^{TARIFF}}{\partial s_d} = -[\frac{4}{9} + \gamma_d(1-\mu)s_d] < 0, \text{which implies that}$$

$$s_d^{TARIFF} = 0. \tag{8}$$

Thus, quality-upgrading investment is unprofitable to the domestic firm since R&D expenditure is zero $(E_d = \gamma_d s_d^2 / 2 = 0).$ This may explain why many firms in developing countries show no interests in costly R&D investments for quality improvement.

The foreign firm determines an optimal quality upgrade s_f that maximizes its profit function. It follows from (4a), (6), and (7) that

$$\pi_f^{TARIFF} = \frac{[(s_f - s_d) - 2s_f + 2s_d]^2}{9(s_f - s_d)} - \frac{1}{2}\gamma_f s_f^2.$$

Solving for the optimal quality upgrade yields

$$s_f^{TARIFF} = \frac{1}{9\gamma_f} > 0, \tag{9}$$

which implies that the foreign firm's R&D expenditure on product upgradation is:

$$E_f^{Tariff} = \gamma_f \frac{1}{2}(\frac{1}{9\gamma_f})^2 = \frac{1}{162\gamma_f} > 0.$$

The resulting equilibrium prices and welfare are calculated as follows:

$$p_f^{TARIFF} = \frac{4}{27\gamma_f},\ p_d^{TARIFF} = \frac{2}{27\gamma_f},\ \pi_d^{TARIFF} = \frac{4}{81\gamma_f},\ \text{and}\ SW^{TARIFF} = \frac{27\gamma_f + 1}{54\gamma_f}. \qquad (10)$$

We thus have

PROPOSITION 1. *Despite the imposition of a specific tariff on foreign product whose quality is relatively higher in an import-competing market, the domestic firm has no incentive in product quality upgradation*.

The result in Proposition 1 is consistent with several studies that empirically test how import tariffs affect quality reversal. For example, Feenstra (1988) investigates imports of Japanese compact trucks and finds that there is no sustained quality upgradation despite the increased tariffs. In analyzing trade policy and quality upgradation in developing economies, Moraga-González and Viaene (2005) find that import tariffs help to reap foreign rents but do not help for quality reversal.[6]

1.2.2.2 Free Trade

Under free trade, there is a two-stage game. At stage one, the firms determine their quality upgrades (and hence R&D investments). At stage two, the firms set their product prices by engaging in Bertrand competition.

[6]Lenway, Morck, and Yeung (1996) examine the effect of protectionism on innovation in American Steel Industry. Though the study did not specifically focus on the tariffs as a protectionism policy, it does suggest that protectionism in steel industry discourage innovation that eventually lead the firms to exit.

At stage two, the firms solve their profit-maximization problems:

$$\underset{\{pf\}}{\text{Max}}\ \pi_f^{FT} = p_f D_f - \frac{1}{2}\gamma_f s_f^2 \quad \text{and} \quad \underset{\{pd\}}{\text{Max}}\ \pi_d^{FT} = p_d D_d - \frac{1}{2}(1-\mu)(\gamma_d s_d^2).$$

It is easy to verify that the optimal prices are:

$$p_f = \frac{2(s_f - s_d)}{3} > 0 \quad \text{and} \quad p_d = \frac{s_f - s_d}{3} > 0. \tag{11}$$

Substituting (11) back into (3) yields the product demands:

$$D_f = 1 - \hat{\theta} = \frac{2}{3} \quad \text{and} \quad D_d = \hat{\theta} = \frac{1}{3}. \tag{12}$$

At stage one, the firms optimally determine their quality upgrades. The profit maximization problems of the firms are:

$$\underset{\{sf\}}{\text{Max}}\ \pi_f^{FT} = p_f D_f - \frac{1}{2}\gamma_f s_f^2 \quad \text{with} \quad p_f = \frac{2(s_f - s_d)}{3} \quad \text{and} \quad D_f = \frac{2}{3};$$

$$\underset{\{sd\}}{\text{Max}}\ \pi_d^{FT} = p_d D_d - \frac{1}{2}\gamma_d(1-\mu)s_d^2 \quad \text{where} \quad p_d = \frac{(s_f - s_d)}{3} \quad \text{and} \quad D_d = \frac{1}{3}.$$

Solving for the optimal quality upgrades yields

$$s_f^{FT} = \frac{4}{9\gamma_f} > 0 \quad \text{and} \quad s_d^{FT} = 0, \tag{13}$$

which imply that the firms' R&D expenditure on product upgradation is:

$$E_f^{FT} = \frac{1}{2}\gamma_f (s_f^{FT})^2 = \frac{8}{81\gamma_f} > 0 \quad \text{and} \quad E_d^{FT} = 0.$$

Thus, R&D investment is profitable to the foreign firm, but not to the domestic firm. Making use of (11)-(13), we calculate the equilibrium prices and domestic profit:

$$p_f^{FT} = \frac{8}{27\gamma_f},\ p_d^{FT} = \frac{4}{27\gamma_f}, \quad \text{and} \quad \pi_d^{FT} = \frac{4}{81\gamma_f}. \tag{14}$$

We then calculate domestic welfare, which is $SW^{FT} = CS^{FT} + \pi_d^{FT}$. It follows from (12)-(14) that

$$SW^{FT} = \underbrace{\int_0^{\hat{\theta}} [(1+s_d)\theta - p_d] d\theta + \int_{\hat{\theta}}^{1} [(1+s_f)\theta - p_f] d\theta}_{CS^{FT}} + \underbrace{[p_d \hat{\theta} - \frac{1}{2}\gamma_d (1-\mu) s_d^2]}_{\pi_d^{FT}} = \frac{1}{2}. \quad (15)$$

PROPOSITION 2. *In an import-competing duopoly market where foreign product is of higher quality, the domestic firm has no incentive to undertake costly R&D for product quality upgradation under free trade.*

1.2.2.3 Quality-upgrading R&D Subsidy

Under this subsidy policy, there is a three-stage game. At stage one, the government commits an industrial policy under which total subsidy (*S*) to the domestic firm is proportional to its quality upgrade. That is, $S = \alpha s_d$ where α represents a subsidy for each unit of quality upgrade.[7] At stage two, the foreign and domestic firms determine their quality upgrades (and investments). At stage three, the firms engage in Bertrand competition.

At the price competition stage, the profit-maximization problems of the firms are:

$$\underset{\{pf\}}{\text{Max}}\ \pi_f^{Q-R\&D} = p_f D_f - \frac{1}{2}\gamma_f s_f^2 \text{ and } \underset{\{pd\}}{\text{Max}}\ \pi_d^{Q-R\&D} = [p_d D_d - \frac{1}{2}\gamma_d (1-\mu) s_d^2] + \alpha s_d.$$

Solving for the optimal prices yields

$$p_f = \frac{2(s_f - s_d)}{3} \text{ and } p_d = \frac{s_f - s_d}{3}. \quad (16)$$

Substituting (16) back into (3) yields the product demands:

[7] It should be noted that evaluating government-sponsored programs such as R&D subsidy is technically difficult due to the complicated linkages between policy input and performance output (Hsu et al, 2009). To tackle this problem, concept of *additionality* is adopted in order to determine the additional work of the firms involved in R&D programs after being supported by the public funds, that would not have otherwise happened (Luukkonen, 2000). The aforementioned studies rely on behavioral and output additionality approach to examine the impact of R&D subsidy. It has been found that government R&D subsidy does stimulate the private firms to invest more in R&D programs and improves their product quality.

$$D_f = 1 - \hat{\theta} = \frac{2}{3} \text{ and } D_d = \hat{\theta} = \frac{1}{3}. \tag{17}$$

At the R&D stage, given (16) and (17), the profit-maximization problems of the firms are:

$$\underset{\{s_f\}}{\text{Max}} \ \pi_f^{Q-R\&D} = \frac{4(s_f - s_d)}{9} - \frac{1}{2}\gamma_f s_f^2$$

$$\underset{\{s_d\}}{\text{Max}} \ \pi_d^{Q-R\&D} = \frac{(s_f - s_d)}{9} - \frac{1}{2}\gamma_d (1-\mu) s_d^2 + \alpha s_d.$$

Solving for the optimal quality upgrades yields

$$s_f^{Q-R\&D} = \frac{4}{9\gamma_f} > 0 \text{ and } s_d^{Q-R\&D} = \frac{1}{2\gamma_d(1-\mu)} > 0, \tag{18a}$$

which implies that the domestic firm's R&D investment for quality upgradation is positive:

$$E_d^{Q-R\&D} = \frac{1}{2}\gamma_d (s_d^{Q-R\&D})^2 = \frac{1}{8\gamma_d(1-\mu)^2} > 0. \tag{18b}$$

The results in (18) indicate that the government's quality-based R&D subsidy policy is effective in promoting the domestic firm's R&D activities for quality upgradation.[8]

Making use of (16)-(18), we calculate equilibrium prices and domestic profit:

$$p_f^{Q-R\&D} = \frac{9\gamma_f - 8(1-\mu)\gamma_d}{27\gamma_f\gamma_d(1-\mu)},\ p_d^{Q-R\&D} = \frac{9\gamma_f - 8(1-\mu)\gamma_d}{54\gamma_f\gamma_d(1-\mu)},\ \pi_d^{Q-R\&D} = \frac{81\gamma_f + 32(1-\mu)\gamma_d}{648\gamma_f\gamma_d(1-\mu)}. \tag{19}$$

8Some interesting cases may serve as examples to show the positive impact that government R&D subsidies have on private R&D activities for product quality improvement. Lach (2002) examines Israeli manufacturing firms and evaluates how firms would have spent on R&D in the absence of subsidy. The result posits that R&D subsidies do create a positive incentive for smaller firms to undertake investments in R&D for product improvement. In analyzing subsidy effectiveness in Spanish manufacturing firms, González, Jaumandreu, and Pazó (2005) find that government subsidies to small firms significantly promote their innovative activities. These firms would not undertake R&D without government support. Investigating a manufacturing industry in Eastern Germany, Czanitzki and Licht (2006) document that government R&D subsidies positively stimulate private firms' use of innovation input and encourage them to launch R&D for product improvement.

At the policy stage, the government determines a subsidy rate α that maximizes domestic welfare: $SW^{Q-R\&D} = CS^{Q-R\&D} + \pi_d^{Q-R\&D} - \alpha s_d$. The government solves the following problem:

$$\underset{\{\alpha\}}{\text{Max}}\ SW^{Q-R\&D} = \underbrace{\int_0^{\hat{\theta}}[(1+s_d)\theta - p_d]d\theta + \int_{\hat{\theta}}^{1}[(1+s_f)\theta - p_f]d\theta}_{CS^{Q-R\&D}} + [p_d\hat{\theta} - \frac{1}{2}\gamma_d(1-\mu)s_d^2 + \alpha s_d] - \alpha s_d.$$

where prices, demands, and investments are given in (17)-(19). The FOC for the government yields the optimal per-unit subsidy: $\alpha^* = 11/18$. The equilibrium welfare is calculated as

$$SW^{Q-R\&D} = \frac{(4-\mu)\gamma_d + 1}{8(1-\mu)\gamma_d}. \tag{20}$$

We thus have

PROPOSITION 3. *An industrial policy designed to provide subsidies for quality-based R&D is effective in encouraging the domestic firm to undertake quality upgradation, compared to the cases under tariff protection and free trade.*

1.3. Comparison and Policy Recommendations

In this section, we conduct a comparison of the three alternative regimes. We first look at the firms' quality upgrades. It follows from (9), (13), and (18a) that

$$s_f^{Q-R\&D} = s_f^{FT} > s_f^{TARIFF} > 0.$$

In response to the quality-based R&D subsidies to the domestic firm, the foreign firm set a higher level of quality upgrade $(s_f^{Q-R\&D})$ relative to its choice under the tariff policy.

For the domestic firm, we have from (8), (13), and (18a) that

$$s_d^{Q-R\&D} > s_d^{TARIFF} = s_d^{FT} = 0.$$

As mentioned in Proposition 3, the subsidy policy is effective in encouraging the domestic firm to invest in quality upgradation. More importantly, this quality-based subsidy policy is capable of generating product quality reversal if the following condition is satisfied:

$$s_d^{Q-R\&D} > s_f^{Q-R\&D} \text{ if } \frac{\gamma_d}{\gamma_f} < \frac{9}{8(1-\mu)}.$$

We, therefore, have

PROPOSITION 4. *Quality reversal (* $q_d^{Q-R\&D} > q_f^{Q-R\&D}$ *) is more likely to emerge when (i) the cost-effectiveness of the domestic firm's R&D investment relative to that of the foreign firm's is greater and (ii) the degree of technological spillovers is higher*.

An examination of consumer surplus for the three regimes reveals that[9]

$$CS^{Q-R\&D} > CS^{FT} > CS^{TARIFF}.$$

This implies that consumer surplus ranks the highest under the quality-based subsidy policy. For a comparison of domestic profit, we have from (10), (15), and (19) that

$$\pi_d^{Q-R\&D} > \pi_d^{TARIFF} = \pi_d^{FT}.$$

Domestic profit is thus at its highest level under the quality-based subsidy policy. Finally, we look at domestic welfare. It follows from (10), (15), and (20) that

$$SW^{TARIFF} > SW^{Q-R\&D} > SW^{FT} \text{ if } \frac{\gamma_d}{\gamma_f} > \frac{27}{4(1-\mu)}; \quad (21a)$$

$$SW^{Q-R\&D} > SW^{TARIFF} > SW^{FT} \text{ if } \frac{\gamma_d}{\gamma_f} < \frac{27}{4(1-\mu)}. \quad (21b)$$

[9] Overall consumer surplus for the three regimes are calculated as follows: $CS^{TARIFF} = (81\gamma_f - 11)/(162\gamma_f)$, $CS^{FT} = (81\gamma_f - 8)/(162\gamma_f)$, and $CS_d^{Q-R\&D} = [99\gamma_f + (162\gamma_f\gamma_d - 16\gamma_d)(1-\mu)]/[324\gamma_f\gamma_d(1-\mu)]$.

Under the subsidy policy, domestic welfare ranks the highest when the cost-effectiveness of the domestic firm's quality-upgrading R&D investment is sufficiently high, as shown in (21b). We thus have

PROPOSITION 5. *Among the three policy options we consider, unless the domestic firm's quality-upgrading investment is extremely cost-ineffective, the quality-based R&D subsidy policy is able to generate product quality reversal. As a result, consumer surplus, domestic profit, and domestic welfare are all at their maximum levels.*[10]

1.4. Conclusion

This paper has contributed to the literature by explicitly identifying the conditions under which there is product quality reversal for domestic firms in import-competing markets. The conditions are shown to depend on the relative cost-effectiveness of quality-upgrading R&D investments between domestic and foreign firms, and the degree of technological spillovers. Moreover, we derive the conditions to show that an importing country's quality-upgrading R&D subsidy policy is effective in achieving a *win-win-win* equilibrium in which consumer surplus, domestic profit, and social welfare are all at their maximum levels, due to product quality reversal.

[10] Note that we use a linear form of subsidy for analytical simplicity and tractability. An alternative approach is to examine the case where an R&D subsidy for quality improvement is proportional to a firm's R&D expenditure. In this case, we can find conditions under which there is product quality reversal such that consumer surplus and social welfare are at their maximum levels. But domestic profit turns out to be lower under the expenditure-based R&D subsidy than under import tariff and free trade regimes. We thank an anonymous referee for the valuable suggestion to investigate this alternative approach.

Chapter 2 - Dumping, Antidumping Duties, and Price Undertakings: Policy Implications of Trade in Quality-Differentiated Products

2.1. Introduction

Unfair trade practices such as dumping products into U.S. markets continue to make business news headlines and appear to show no signs of abating. Dating back to 2011, Whirlpool Corporation, an American manufacturer of household appliances, filed a petition to the U.S. International Trade Commission (ITC) against cheap imports of South Korean and Mexican washing machines. Later in 2013, the ITC documented that Mexican manufacturers were dumping washing machines on the U.S. market at about 36% to 72% below their local market prices, and South Korean manufacturers undercut the prices by 9% to 82%. The ITC's findings further confirmed that such unfair trade practices by the Mexican and South Korean manufacturers materially injured the U.S. companies. Consequently, the U.S. government imposed antidumping (AD) duties on both Mexican and South Korean washers at 72% and 82%, respectively.[11] The use of AD duties by the U.S. government was not limited to products like washing machines. In 2014, the U.S. Commerce Department imposed AD charges against exporters of solar panels from China after finding that the products were sold at low prices, which significantly hurt U.S. manufacturers.[12] These cases exemplify the practices of dumping

11 See Press Release, Whirlpool Corp., "Victory for American Washer Industry: Ruling Supports U.S. Workers and Consumers" (2013) at: https://www.prnewswire.com/news-releases/victory-for-american-washer-industry-ruling-supports-us-workers-and-consumers-188052991.html. See, also, Reuters (2012) and Metal Bulletin (2014).

12 See Reuters (2014).

products at lower prices in a developed country (DC), where its government opts for policy choices such as antidumping duties as unfair trade remedies.[13]

From the global perspective of trade, there are significant issues concerning (i) which types of firms (DC or LDC) tend to practice dumping and (ii) whether DC or LDC governments are likely to launch antidumping investigations into imports. How is dumping related to trade in "like" products with quality differentiation? Given the growing concern over the large-scale dumping of cheap products to DCs, would LDCs be better off if governments restrain their exporting firms not to practice dumping? Is the use of antidumping duties effective in protecting domestic firms and is it proved to be a welfare-improving policy for its economy? How would the Pareto superiority of free trade in the world trading system be affected by the global dumping of low-quality products? Can world welfare (defined by aggregating the welfare of DC and LDC as trading partners) be higher under an AD policy than under free trade in the presence of dumping? In this paper, we answer these questions by developing a two-market equilibrium analysis of trade in quality-differentiated products.

In retrospect, voluminous academic studies have contributed to our understanding of the issues on dumping and antidumping regulations.[14]Recognizing the contributions in the literature,

[13]Note that the use of antidumping duties is not restricted to DCs, as recently some LDCs started imposing AD duties on exporting firms from DCs. For details on traditional (DCs) and new antidumping duty users (LDCs), see the systematic analysis and review by Blonigen and Prusa (2016).

[14]Viner (1923) is among the first to define dumping as the practice of international price discrimination. Contemporary studies on dumping under the traditional antidumping law include Prusa (1992, 1994, 2001), Fischer (1992), Reitzes (1993), Anderson, Schmitt, and Thisse (1995), Blonigen and Prusa (2003), Gao and Miyagiwa (2005), Dinlersoz and Dogan (2010), and Wu et. al. (2014). For studies that address issues on the political economy of antidumping see, e.g., Finger, Hall, and Nelson (1982), Tharakan (1991), and Nelson (2006). For recent issues on antidumping such as the Continued Dumping and Subsidy Offset Act implemented by the U.S. government under

we follow the GATT/WTO guidelines to determine conditions under which dumping arises by comparing the equilibrium prices of products sold by DC and LDC firms.[15] The equilibrium price comparison for a product sold in both DC and LDC markets helps identify the firm type (DC or LDC) that practices dumping.[16] For analyzing international duopoly under free trade, we employ a two-stage game where quality choice is determined before the firms engage in price competition in both the DC and LDC markets. We consider that consumers in the two markets are characterized by inter-country income differentials (i.e., there are different degrees of market competition). Within the two-way trade model of competition in quality-differentiated products between DC and LDC firms,[17] we show that the DC firm sells a high-quality product due to its economic incentive to invest in R&D for quality improvements. In contrast, the LDC firm sells a low-quality product as it does not engage in R&D for quality upgradation. These results are consistent with the empirical findings that a DC firm's strategic choice of product quality is relatively higher than that of an LDC firm (Amiti and Khandelwal 2013). Moreover, our results

which the revenues from AD duties are redistributed to domestic firms alleging harm see, e.g., Collie and Vandenbussche (2006), and Chang and Gayle (2006). For issues concerning antidumping measures and economic effects see, e.g., Vandenbussche and Wauthy (2001), Pauwels and Springael (2002), Belderbos et al. (2004), Moore (2005), and Ishikawa and Miyagiwa (2008). Blonigen and Prusa (2016) present a systematic review on dumping and antidumping activity.

15The "technical information on dumping" put forth by the GATT/WTO on its official website permits member countries to identify circumstances under which dumping in international trade emerges. It states that:

"*Dumping is, in general, a situation of international price discrimination, where the price of a product when sold in the importing country is less than the price of that product in the market of the exporting country. Thus, in the simplest of cases, one identifies dumping simply by comparing prices in two markets*."

16 The analysis does not rely on the usual assumption of an exogenously-determined "normal value" for a dumped product in a one-market analysis.

17 Our analytical framework is fundamentally similar to a North-South trade model where one firm in the North (a developed country) competes with one firm in the South (a less developed country) in both the northern and southern markets. That is, the DC-LDC trade is equivalent to the North-South trade.

show that the DC firm does not practice dumping, whereas the LDC firm dumps its low-quality product into the DC market by setting a price less than the product's price in its local market. These results suggest that, in international price competition, dumping is a signal of low product quality.

Our model of trade in *like* products with quality differentiation permits us to see how consumers and producers in two trading partner countries (DC and LDC) are affected by alternative trade regimes (free trade, antidumping, and a price-undertaking). The bilateral trade analysis suggests that both DC's consumers and producers gain the highest surplus respectively by consuming and producing more of the high-quality good when their government imposes AD duties against the dumping action of the low-quality producing LDC firm. Consequently, DC's overall welfare is the highest under the anti-dumping policy. However, DC consumers and producers confront the highest economic costs when their government offers a price-undertaking to the LDC's firm, which it accepts. Thus, the *win-win-win* equilibrium associated with AD duties may explain why under the auspices of antidumping regulations, the U.S. government favors the use of AD policies, rather than granting the option of price-undertakings to foreign dumpers.[18]

As for effects on LDC, we find that LDC consumers are better off when the DC government imposes AD duties than when there is free trade. The economic reason behind this

[18] It is instructive to mention at the outset that, practically, authorities may not pursuit social welfare maximization as an objective in setting an optimal AD duty. In our study, we aim to see whether authorities' practice or mode of regulation (e.g., free trade, an AD policy, or a price taking) can be explained by the equilibrium outcomes under welfare maximization. One possible reason why AD protection is opposed is that it explicitly ignores *overall welfare*, which we mean consumers, producers, and government revenue. This promotes us to consider welfare maximization as a country's objective when choosing an optimal policy in response to unfair trade practices such as dumping.

result is as follows. Under an AD policy, gains in consumer surplus by consuming an imported product with a relatively higher quality (due to DC's R&D investment in quality improvement) outweigh the losses in consumer surplus through consuming the low-quality product with an increased price. However, LDC’s firm enjoys the highest surplus by dumping a low-quality product under free trade, regardless of the inter-country income differential (countries are different in terms of their income levels).Third, LDC's overall welfare is the highest when its exporting firm accepts a price-undertaking, but is the lowest when the exporter dumps its low-quality product and pays AD duties.

From the perspective of world welfare, calculated by aggregating the welfare of trading partners (DC and LDC in the present study), we show that the trade damage measure of imposing AD duties is Pareto superior to free trade (under which dumping takes place) and price-undertakings. Our analysis provides a theoretical justification for the use of duties against foreign dumping which, in turn, suggests that an AD policy is fundamentally WTO-consistent from the world perspective of welfare.

This paper contributes to the literature by (i) identifying the firm type (DC or LDC) that tends to practice dumping and (ii) showing whether DCs or LDCs are likely to launch AD actions against foreign dumpers. Prusa (2001) documents empirically that until the 1980s approximately 95% of the AD disputes are initiated by DCs against imports from LDCs. Vandenbussche and Zanardi (2008) find that the later trend shows that LDCs are also highly involved in AD actions. Bown (2011a, b) indicates that AD actions are generally concentrated across traditional users(DCs) and new AD users (LDCs).[19] Interestingly, Bown (2013) further

[19] Traditional AD users (DCs) include the United States, the European Union, Canada, and Australia, whereas the leading new users include Argentina, Brazil, China, India, and Turkey (Blonigen and Prusa 2016).

remarks that most of the new AD disputes launched by LDCs have targeted imports of cheaper products from other LDCs -- the so-called "South-South protectionism."[20] Blonigen and Prusa (2016) document systematically that, based on the *size* of AD duties, DCs remain to be the largest AD policy users against the unfair practices of dumping by firms from LDCs.Hansen and Neilsen (2009) show that differences in the quality of products lead high-quality firms to solicit for tariff protection, which suggests that product differentiation makes AD policy more beneficial to the firms manufacturing and exporting products of high-quality (that is, the developed world).

It should be mentioned at the outset that our analysis of unilateral dumping by an LDC firm deviates from the reciprocal dumping model of Brander and Krugman (1983) in two crucial respects. First, we examine trade in quality-differentiated products, while Brander and Krugman examine trade in an identical product without allowing for quality differentiation. Second, we look at trade between a DC and an LDC with an inter-country income differential, which reflects a different degree of international market competition. Brander and Krugman analyze trade between two DCs with similar or identical economies. The contribution by Flam and Helpman (1987) is among the first to analyze north-south trade in vertically differentiated products, but their focuses are on issues other than dumping.

[20] We also consider whether our model of a DC-LDC (North-South) trade, where there is an income differential between a DC and an LDC, can be applied to an LDC-LDC (South-South) trade model when two trading LDCs differ in their national incomes and engage in imports and exports of quality-differentiated products. In the latter case of an LDC-LDC trade, we infer that an LDC firm from a relatively higher income country sells a product of relatively higher quality and does not practice dumping. In contrast, the other LDC firm from a relatively lower income country sells a "like" product of relatively lower quality and practices dumping. In terms of initiating AD disputes, we can apply the findings of this paper and predict that there is "LDC-LDC protectionism" or "South-South protectionism" as the case examined in Bown (2013).

Our present paper is closely related to the recent contribution of González and Viaene (2015), which adopts a vertical product differentiation approach to analyzing issues on dumping behavior and antidumping regulations. The key differences between the two studies should be mentioned. First, our results indicate that, under free trade, the LDC firm produces a low-quality product that is dumped into the DC market. Dumping thus is a signal of low quality. In contrast, Gonzales and Viaene (2015) find that DC firm dumps a high-quality product into the LDC market. Second, our analysis shows that the use of AD duties by the DC government improves its domestic welfare, as well as the aggregate welfare of the world (i.e., DC and LDC taken together). This result is different from the finding of Gonzales and Viaene (2015) that an AD policy by the LDC government improves its domestic welfare at the expense of world welfare.

We organize the remainder of the paper as follows. In Section 2, we first lay out an analytical framework of trade in quality-differentiated products to analyze competition between a DC firm and an LDC firm in both of their markets. We consider three different trade regimes: free trade with the presence of dumping, an antidumping policy, and a price undertaking. In Section 3, we compare firm profits, consumer surplus, and social welfare in DC and LDC under alternative trade regimes. Section 4 contains policy implications and concluding remarks.

2.2. A Model of Trade in Quality-Differentiated Products

2.2.1 *Basic Assumptions*

To be consistent with the GATT/WTO guidelines on dumping, we present a two-market analysis to compare the equilibrium prices of a product sold in both home and foreign countries (i.e., DC and LDCdue to their income differentials).We first identify conditions under which dumping arises, and then evaluate the resulting impacts on DC and LDC under different trade regimes. Specifically, we consider a model of trade under international duopoly in which a DC firm and an LDC firm produce "like" products with vertical differentiation and compete in their domestic markets, as well as in the markets abroad.

The firm located in DC, where consumers are relatively more affluent in the market, will be shown to manufacture and export a high-quality product. For notational convenience, we denote variables for the DC firm with a subscript "*h*," representing that its product quality is high. The firm located in LDC, where consumers are relatively less affluent in the market, will be shown to manufacture and export a low-quality product. We denote variables for the LDC firm with a subscript "*l*," representing that its product quality is low. We adopt the plausible assumption that DC consumers have relatively higher incomes on average than LDC consumers, other things (e.g., product quality and consumer preferences) being equal. This assumption allows us to introduce a parameter $\lambda \in (0,1)$ that reflects the degree of inter-country income differential. We shall show that this approach helps determine the condition under which dumping takes place.

2.2.1.1 ***LDC market***

We first look at the market in an LDC where consumers are uniformly distributed along a unit line, $\theta \in [a, a+1]$, for $a > 0$. Each consumer purchases one unit of a product (domestic or foreign), which is taken to be a necessity to all citizens in the LDC.[21] Denote p_h as the price of the high-quality product and p_l as that of the low-quality product in the LDC market. Following the literature on vertical product differentiation, we specify the indirect utility function of an LDC consumer located at point θ as follows:

21 That is, we consider the case of a full covered market. This consideration is consistent with the literature that uses a vertical product differentiation framework (see, e.g., Crampes and Hollander 1995; Wauthy 1996; Andaluz 2000; Chang and Raza 2018).

$$V_{LDC}(\theta)=\begin{cases}\theta q_h - p_h \text{ if buys high quality product at price } p_h;\\ \theta q_l - p_l \text{ if buys low quality product at price } p_l.\end{cases} \quad (1)$$

where q_i represents product quality of firm $i(=h,l)$.

To allow for the possibility of product quality upgradation through a firm's costly R&D investment, we follow the approach in Chang and Raza (2018) by assuming that

$$q_i = 1 + s_i, \quad (2)$$

where $s_i(\geq 0)$ denotes "quality-upgrade" resulting from R&D by firm $i(=h,l)$. The absence of quality-upgrades $(s_h = s_l = 0)$ by both firms implies that product quality is standardized or normalized to one $(q_h = q_l = 1)$. Several empirical studies posit that $q_h > q_l \geq 0$, which means that the DC firm's strategic choice of product quality is higher than that of the LDC firm's.[22] That is, $s_h > s_l \geq 0$. In our analysis, each firm's quality-upgrade decision is determined endogenously. As in the R&D investment literature, we postulate that each firm's quality-upgrading expenditure is a quadratic form: $E_i = \gamma_i s_i^2/2$, where parameter $\gamma(>0)$ denotes the cost-effectiveness of investment by firm $i(=h,l)$.

Given LDC consumers' heterogeneity in tastes for quality, $\theta \in [a, a+1]$, the marginal consumer who is indifferent between the high-quality product and the low-quality product implies that $\theta(1+s_h) - p_h = \theta(1+s_l) - p_l$. Solving for the critical value of θ yields $\hat{\theta} = (p_h - p_l)/(s_h - s_l)$, where $1 > \hat{\theta} > 0$ for $p_h > p_l > 0$ and $s_h > s_l \geq 0$. It follows that demands for the low- and high-quality products in the LDC market are:

$$D_l(p_h, p_l) = \hat{\theta} = \frac{p_h - p_l}{s_h - s_l} \text{ and } D_h(p_h, p_l) = 1 - \hat{\theta} = 1 - \frac{p_h - p_l}{s_h - s_l}. \quad (3)$$

22 See, e.g., Amiti and Khandelwal (2013).

Note that market demand for the high-quality product, $D_h(p_h, p_l)$, defines the LDC import.

2.2.1.2 ***DC market***

For the DC market, we use a superscript "*" to denote all the related variables. We assume that there is a uniform distribution of DC consumers over a unit line, $\theta^* \in [a, a+1]$, with each consumer buying one unit of a product which is a necessity. Denote p_h^* as the price of the high-quality product and p_l^* as that of the low-quality product in the DC market.

As addressed earlier, there is an income differential between DC and LDC, which is captured by the parameter $\lambda \in (0,1)$. We specify the indirect utility function of a DC consumer located at point θ^* as follows:

$$V_{DC}(\theta^*) = \begin{cases} \lambda\theta^* q_h - p_h^* & \text{if consumer buys high quality product at } p_h^*; \\ \lambda\theta^* q_l - p_l^* & \text{if consumer buys low quality product at } p_l^*. \end{cases} \quad (4)$$

The use of λ in (4) follows directly from the notion of Tirole (1988) that consumer taste for quality is *inversely* related to the marginal utility of income. This indicates that, other things being equal, the marginal utility of consumption is relatively *lower* in DC than in LDC. An income differential between DC and LDC thus implies that $\lambda\theta^* q_i < \theta q_i$, for $\theta^* = \theta$ and a given level of product quality $i (= h, l)$. The parameter λ reflects the degree of market similarity/dissimilarity between DC and LDC. There are two cases of interest: (i) When the value of λ increases and approaches 1, the DC and LDC markets resemble each other such that the degree of international competition is *high*. (ii) When the value of λ decreases and approaches to 0, the two markets increasingly become dissimilar such that the degree of international competition is *low*. We shall demonstrate that λ (as the degree of market similarity/dissimilarity) plays a role in characterizing price competition for trade in quality-differentiated products between the DC and LDC firms.

Given quality upgradation for the competing firms $(q_i = 1 + s_i$ for $i = h, l)$, the marginal consumer in the DC market is determined by $\lambda\theta^*(1+s_h) - p_h^* = \lambda\theta^*(1+s_l) - p_l^*$. Solving for the critical value of θ^*, we have $\tilde{\theta}^* = (p_h^* - p_l^*)/[\lambda(s_h - s_l)]$, where $1 > \tilde{\theta}^* > 0$ for $p_h^* > p_l^* > 0$ and $s_h > s_l \geq 0$. It follows that demands for the low- and high-quality products in the DC market are:

$$D_l^*(p_h^*, p_l^*) = \tilde{\theta}^* = \frac{p_h^* - p_l^*}{\lambda(s_h - s_l)} \text{ and } D_h^*(p_h^*, p_l^*) = 1 - \tilde{\theta}^* = 1 - \frac{p_h^* - p_l^*}{\lambda(s_h - s_l)}. \quad (5)$$

Note that market demand for the low-quality product, $D_l^*(p_h^*, p_l^*)$, defines the DC import.

Based on the framework of trade in quality-differentiated products, our next step of the analysis is to identify conditions under which dumping arises. We then analyze and compare equilibrium outcomes under three policy options, which are: free trade, trade damage measure of imposing an antidumping duty, and a price undertaking. We begin with the case of free trade.

2.2.2*Free trade (under which dumping takes place)*

Under free trade (*FT*), we use a two-stage game to characterize the duopolistic competition between DC and LDC firms. At stage one, the firms determine quality-upgrades, s_h^{FT} and s_l^{FT}, to maximize their respective profits. At stage two, the firms set their profit-maximizing prices, $\{p_h^{FT}, p_h^{*FT}\}$ and $\{p_l^{FT}, p_l^{*FT}\}$, respectively, in the DC and LDC markets by engaging in Bertrand competition. Using backward induction, we derive the sub-game perfect Nash equilibrium for the two-stage game.

At the second stage of the game, the DC and LDC firms respectively solve their profit maximization problems as follows:

$$\underset{\{p_h^{FT}, p_h^{*FT}\}}{\text{Max}} \ \Pi_{DC}^{FT} = p_h^{FT} D_h^{FT}(p_h^{FT}, p_l^{FT}) + p_h^{*FT} D_h^{*FT}(p_h^{*FT}, p_l^{*FT}) - \frac{1}{2}\gamma_h (s_h^{FT})^2,$$

$$\underset{\{p_l^{FT}, p_l^{*FT}\}}{\text{Max}} \ \pi_{LDC}^{FT} = p_l^{FT} D_l(p_h^{FT}, p_l^{FT}) + p_l^{*FT} D_l^{*FT}(p_h^{*FT}, p_l^{*FT}) - \frac{1}{2}\gamma_l (s_l^{FT})^2, \tag{6}$$

where D_h^{FT} and D_l^{FT} are given in (3) while D_h^{*FT} and D_l^{*FT} are given in (5).The first-order conditions (FOCs) for the firms imply that the optimal prices of the high- and low-quality products in the DC market are:

$$p_h^{*FT} = \frac{2\lambda(s_h^{FT} - s_l^{FT})}{3} \text{ and } p_l^{*FT} = \frac{\lambda(s_h^{FT} - s_l^{FT})}{3}, \tag{7}$$

and those of the high- and low-quality products in the LDC market are:

$$p_h^{FT} = \frac{2(s_h^{FT} - s_l^{FT})}{3} \text{ and } p_l^{FT} = \frac{(s_h^{FT} - s_l^{FT})}{3}, \tag{8}$$

The prices of the products, as shown in (7) and (8), permit one to investigate whether any firm sells a product in the foreign market at a price <u>lower</u> than the product's price in its domestic market. In this case, dumping arises.

We first compare p_h^{*FT} and p_h^{FT}, the prices of the high-quality product in the DC and LDC markets. It follows from (7)-(8) that

$$\frac{p_h^{*FT}}{p_h^{FT}} = \frac{\left[\dfrac{2\lambda(s_h^{FT} - s_l^{FT})}{3}\right]}{\left[\dfrac{2(s_h^{FT} - s_l^{FT})}{3}\right]} = \lambda < 1, \tag{9}$$

which implies that $p_h^{FT} > p_h^{*FT}$.

The result in (9) indicates that, in equilibrium, the price of the high-quality product is *higher* in the LDC market than in the DC market. The DC firm finds it profitable *not* to practice dumping in the LDC market.

Next, we compare p_l^{*FT} and p_l^{FT}, the prices of the low-quality product in the DC and LDC markets. It follows from (7)-(8) that

$$\frac{p_l^{*FT}}{p_l^{FT}} = \frac{\left[\dfrac{\lambda(s_h^{FT} - s_l^{FT})}{3}\right]}{\left[\dfrac{(s_h^{FT} - s_l^{FT})}{3}\right]} = \lambda < 1,$$

which implies that $p_l^{*FT}(= \lambda p_l^{FT}) < p_l^{FT}$. (10)

The result in (10) indicates that the price of the low-quality product is *lower* in the DC market than in the LDC market. Based on the WTO/GATT guidelines, dumping arises! The LDC firm, a low-quality producer, takes advantage of free trade and wallows in trade abuse activity of practicing dumping in the DC market under this regime.

Substituting the product prices from (7)-(8) back into (3) and (5), we have the equilibrium demands (i.e., market shares) of the high- and low-quality products in the DC and LDC markets:

$$D_h^{*FT} = \frac{2}{3},\ D_l^{*FT} = \frac{1}{3};\ D_h^{FT} = \frac{2}{3} \text{ and } D_l^{FT} = \frac{1}{3}. \tag{11}$$

At the second stage of the game, the DC and LDC firms determine their quality-upgrades, $\{s_h^{FT}, s_l^{FT}\}$. To find the solution, we first plug the products' prices from (7)-(8) and their demands from (11) back into the firms' profit functions in (6). The FOCs for the firms imply that

$$s_h^{FT} = \frac{4(1+\lambda)}{9\gamma_h} > 0 \text{ and } s_l^{FT} = 0. \tag{12a}$$

It follows that R&D expenditures on quality improvements by the DC and LDC firms are:

$$E_h^{FT} = \frac{1}{2}\gamma_h (s_h^{FT})^2 = \frac{8(1+\lambda)^2}{81\gamma_h} > 0 \text{ and } E_l^{FT} = \frac{1}{2}\gamma_l (s_l^{FT})^2 = 0. \tag{12b}$$

These results lead to the first corollary:

COROLLARY 1. *In the vertical product differentiation model of competition between a DC and an LDC under free trade, the DC firm (a high-quality producer) has an economic incentive to invest in R&D activities for quality improvements. Nevertheless, the LDC firm (a low-quality producer) has no economic incentives to undertake quality upgradation.*

By substituting s_h^{FT} and s_l^{FT} from (11) back into (7)-(8), we calculate the equilibrium prices of the high- and low-quality products in the DC and LDC markets:

$$p_h^{*FT} = \frac{8\lambda(1+\lambda)}{27\gamma_h},\ p_l^{*FT} = \frac{4\lambda(1+\lambda)}{27\gamma_h};\ p_h^{FT} = \frac{8(1+\lambda)}{27\gamma_h},\ p_l^{FT} = \frac{4(1+\lambda)}{27\gamma_h}. \qquad (13)$$

Making use of the demands in (11), the prices in (13), and the profit function in (6), we calculate total profit for the DC firm:

$$\Pi_{DC}^{FT} = \frac{8(1+\lambda)^2}{81\gamma_h}. \qquad (14a)$$

The surplus of DC consumers is: $CS_{DC}^{FT} = CS_l^{FT} + CS_h^{FT}$, where CS_l^{FT} and CS_h^{FT} represent benefits to consumers in DC from buying the low- and high-quality products. That is,

$$CS_{DC}^{FT} = \underbrace{\int_a^{\tilde{\theta}^{*FT}} [\theta^{FT}\lambda(1+s_l^{FT}) - p_l^{*FT}]dF(\theta)}_{CS_l^{FT} \text{ in DC}} + \underbrace{\int_{\tilde{\theta}^{*FT}}^{a+1} [\lambda\theta^{*FT}(1+s_h^{FT}) - p_h^{*FT}]dF(\theta)}_{CS_h^{FT} \text{ in DC}}. \qquad (14b)$$

By substituting the equilibrium demands, prices, and quality-upgrades from (7)-(8) and (11)-(13) into (14b), we have

$$CS_{DC}^{FT} = \frac{\lambda[(81\gamma_h - 8\lambda - 8) + a(48 + 48\lambda + 162\gamma_h + 36a + 36a\lambda)]}{162\gamma_h}. \qquad (14c)$$

Defining DC's social welfare as $SW_{DC}^{FT} = CS_{DC}^{FT} + \Pi_{DC}^{FT}$, we substitute CS_{DC}^{FT} and Π_{DC}^{FT} from (14a) and (14c) into the welfare expression. This yields

$$SW_{DC}^{FT} = \frac{(24\lambda + 81\lambda\gamma_h + 8\lambda^2 + 16) + a(48\lambda + 48\lambda^2 + 162\lambda\gamma_h + 36a\lambda + 36a\lambda^2)}{162\gamma_h}. \qquad (14d)$$

Turning to LDC, we compute total profit for the LDC firm by plugging the equilibrium demands, prices, and quality-upgrades from (7)-(8) and (11)-(13) back into (6). This yields

$$\pi_{LDC}^{FT} = \frac{4(1+\lambda)^2}{81\gamma_h}. \tag{15a}$$

The surplus of LDC consumers is: $CS_{LDC}^{FT} = CS_l^{FT} + CS_h^{FT}$, where CS_l^{FT} and CS_h^{FT} represent economic benefits to consumers in LDC from buying the low- and high-quality products. That is,

$$CS_{LDC}^{FT} = \underbrace{\int_a^{\hat{\theta}^{FT}} [\theta^{FT}(1+s_l^{FT}) - p_l^{FT}]dF(\theta)}_{CS_l^{FT} \text{ in LDC}} + \underbrace{\int_{\hat{\theta}^{FT}}^{a+1} [\theta^{FT}(1+s_h^{FT}) - p_h^{FT}]dF(\theta)}_{CS_h^{FT} \text{ in LDC}}. \tag{15b}$$

Making use of the equilibrium demands, prices, and quality-upgrades in (7)-(8) and (11)-(13), we follow (15b) to calculate the LDC's consumer surplus. This yields

$$CS_{LDC}^{FT} = \frac{(81\gamma_h - 8\lambda - 8) + a(48 + 48\lambda + 162\gamma_h + 36a + 36a\lambda)}{162\gamma_h}. \tag{15c}$$

The LDC's social welfare is: $SW_{LDC}^{FT} = CS_{LDC}^{FT} + \pi_{LDC}^{FT}$, where CS_{LDC}^{FT} and π_{LDC}^{FT} are given by (15a) and (15c). It is easy to verify that

$$SW_{LDC}^{FT} = \frac{(8\lambda + 81\gamma_h + 8\lambda^2) + a(48 + 48\lambda + 162\gamma_h + 36a + 36a\lambda)}{162\gamma_h}. \tag{15d}$$

The results of the above analyses permit us to establish the first proposition:

PROPOSITION 1. *In the two-way free trade where DC firm produces a high-quality product, and LDC firm produces a low-quality product, the DC firm does not practice dumping. Nevertheless, the LDC firm dumps the low-quality product at a price less than the product's price in its local market.*

Proposition 1 has significant implications for the WTO guidelines on identifying the circumstances under which dumping arises. Considering trade between DCs and LDCs in "like" products with quality differentiation, DC firms manufacturing and selling high-quality products do not practice dumping. However, LDC firms manufacturing and selling low-quality products find it profitable to practice dumping. These results help to explain why we frequently observe the large-scale dumping of cheap low-quality products by LDC firms in international markets.

The practice of dumping by LDC firms is a severe problem in the import-competing markets of developed countries. Our theoretical prediction is supported by several empirical findings showing that DCs had been the target of dumping by exporting firms from LDCs. For instance, Prusa (2001) finds that until the 1980s, about 95% of the AD actions are taken by DCs against dumping by LDC firms. Neufeld (2001) indicates that the AD duties as a trade remedy rose to 42% from 38% as a response to the LDC dumping during the 1994-1999 period. Blonigen and Prusa (2016) document that DCs are the largest AD policy users against the practice of dumping by firms from LDCs. The empirical findings promote us to examine the next case when the DC government imposes an antidumping policy on LDC dumping.

2.2.3 *Antidumping policy*

We have shown (in Section 2.2) that LDC firm exports a low-quality product and practices dumping by setting a price, p_l^{*FT}, less than the product's price in its local market, p_l^{FT}. In this section, we analyze the economic effects of antidumping policy.

In response to the LDC dumping, the DC government imposes an *ad valorem* duty, denoted as *t*, up to the *dumping margin*. That is,

$$t = \frac{p_l^{FT} - p_l^{*FT}}{p_l^{FT}},$$

which is the price difference between p_l^{FT} and p_l^{*FT} as a proportion of the LDC's local price p_l^{FT}. It follows from this dumping margin equation that $p_l^{FT} - p_l^{*FT} = tp_l^{FT}$, which implies that

$$p_l^{FT} = \frac{1}{(1-t)} p_l^{*FT}.$$

This indicates that, through its AD laws, the DC government can elevate the price of the low-quality product up to p_l^{FT}, which is the product's free-trade price in the LDC market. In terms of notation, we re-define p_l^{FT} as p_l^{*AD}, that is, $p_l^{FT} \equiv p_l^{*AD}$, where p_l^{*AD} stands for the price of the low-quality product in the DC market after the *ad valorem* duty, *t*, is imposed. We thus have

$$p_l^{*AD} = (\frac{1}{1-t}) p_l^{*FT},$$

which implies that

$$p_l^{*FT} = (1-t) p_l^{*AD}.$$

Given that p_l^{*AD} is set identical to the LDC's local price p_l^{FT}, the above equation implies that $p_l^{*AD} - p_l^{*FT} = tp_l^{*AD}$.

Multiply both sides of the above equation by D_l^{*AD}, the quantity of the low-quality product imported by DCunder the AD regime, we have the total amount of *duty revenue*:

$$(p_l^{*AD} - p_l^{*FT}) D_l^{*AD} = tp_l^{*AD} D_l^{*AD}.$$

Under the AD regime with an *ad valorem* duty, t, which remains to be determined by the DC government, consumer demands for the low- and high-quality products in the DC market will change accordingly. Given the demand equations in (5), we replace the free-trade price, p_l^{*FT}, with $(1-t) p_l^{*AD}$. This yields:

$$D_l^{*AD}(p_h^{*AD}, p_l^{*AD}) = \tilde{\theta}^{*AD} = \frac{p_h^{*AD} - (1-t) p_l^{*AD}}{\lambda(s_h^{AD} - s_l^{AD})};$$

$$D_h^{*AD}(p_h^{*AD}, p_l^{*AD}) = 1 - \tilde{\theta}^{*AD} = 1 - \frac{p_h^{*AD} - (1-t) p_l^{*AD}}{\lambda(s_h^{AD} - s_l^{AD})}; \qquad (16a)$$

Whereas demand equations for the low- and high-quality products in the LDC market remain unchanged (see equation 16b). That is,

$$D_l^{AD}(p_h^{AD}, p_l^{AD}) = \hat{\theta}^{AD} = \frac{p_h^{AD} - p_l^{AD}}{s_h^{AD} - s_l^{AD}};\ D_h^{AD}(p_h^{AD}, p_l^{AD}) = 1 - \hat{\theta}^{AD} = 1 - \frac{p_h^{AD} - p_l^{AD}}{s_h^{AD} - s_l^{AD}}. \quad (16b)$$

To characterize the two-market equilibrium solution under the AD regime, we consider a three-stage game. At stage one, the DC and LDC firms determine optimal quality-upgrades, s_h^{AD} and s_l^{AD}, to maximize their respective profits. At stage two, the DC government imposes an optimal *ad valorem* duty on the low-quality product dumped in the DC market. At stage three, the competing firms determine profit-maximizing prices for their products in the DC and LDC markets by engaging in Bertrand competition. To solve for the sub-game perfect Nash equilibrium, we use backward induction.

At the third and last stage of the game, the DC and LDC firms set their product prices by solving the following profit maximization problems:

$$\underset{\{p_h^{AD}, p_h^{*AD}\}}{\text{Max}}\ \Pi_{DC}^{AD} = p_h^{AD} D_h^{AD}(p_h^{AD}, p_l^{AD}) + p_h^{*AD} D_h^{*AD}(p_h^{*AD}, p_l^{*AD}) - \frac{1}{2}\gamma_h (s_h^{AD})^2,$$

$$\underset{\{p_l^{AD}, p_l^{*AD}\}}{\text{Max}}\ \pi_{LDC}^{AD} = p_l^{AD} D_l^{AD}(p_h^{AD}, p_l^{AD}) + p_l^{*AD} D_l^{*AD}(p_h^{*AD}, p_l^{*AD}) - \frac{1}{2}\gamma_l (s_l^{AD})^2, \quad (16c)$$

where demands D_h^{AD}, D_h^{*AD}, D_l^{AD}, and D_l^{*AD} are given in (16a)-(16b). The FOCs for the firms imply that the optimal prices of their products in the DC and LDC markets are:

$$p_h^{*AD} = \frac{2\lambda(s_h^{AD} - s_l^{AD})}{3},\ p_l^{*AD} = \frac{\lambda(s_h^{AD} - s_l^{AD})}{3(1-t)},\ p_h^{AD} = \frac{2(s_h^{AD} - s_l^{AD})}{3},\ p_l^{AD} = \frac{(s_h^{AD} - s_l^{AD})}{3}. \quad (17a)$$

Substituting the prices from (17a) back into (16a)-(16b) yields product demands (or market shares) in DC and LDC:

$$D_l^{*AD} = \tilde{\theta}^{*AD} = \frac{2t-1}{3t-3},\ D_h^{*AD} = 1 - \tilde{\theta}^{*AD} = \frac{2-t}{3(1-t)},\ D_l^{AD} = \hat{\theta}^{AD} = \frac{1}{3},\ D_h^{AD} = 1 - \hat{\theta}^{AD} = \frac{2}{3}. \quad (17b)$$

A comparison between p_l^{*AD} and p_l^{AD} in (17a), which are the prices of the low-quality product sold in the DC and LDC markets, respectively, allows one to see the impact of the AD policy. That is,

$$\frac{p_l^{*AD}}{p_l^{AD}} = \frac{\lambda}{1-t} \text{ implies that } p_l^{*AD}\left(= \frac{\lambda p_l^{AD}}{1-t}\right) > p_l^{*FT}\left(= \lambda p_l^{FT}\right). \tag{17c}$$

The imposition of an *ad valorem* duty, t, raises the price of the low-quality product, compared to the product's price under free trade. The result in (17c) thus indicates that the AD policy of imposing duties on foreign dumping is effective in promoting "fair" price competition.

At the second stage of the game, the DC government determines an optimal *ad valorem* duty that maximizes its overall welfare, $SW_{DC}^{AD} = (CS_l^{AD} + CS_h^{AD}) + \Pi_{DC}^{AD} + tp_l^{*AD} D_l^{*AD}$, which is the sum of consumer surplus (from purchasing the two products), firm profit (net of R&D cost), and duty revenue. That is, the DC government solves the following welfare maximization problem:

$$\underset{\{t\}}{\text{Max}}\, SW_{DC}^{AD} = \underbrace{\int_0^{\tilde{\theta}^{*AD}} [\theta^{*AD}\lambda(1+s_l^{AD}) - p_l^{*AD}]dF(\theta)}_{CS_l^{AD} \text{ in DC}} + \underbrace{\int_{\tilde{\theta}^{*AD}}^{1} [\lambda\theta^{*AD}(1+s_h^{AD}) - p_h^{*AD}]dF(\theta)}_{CS_h^{AD} \text{ in DC}}$$
$$+ \underbrace{[p_h^{AD} D_h^{AD} + p_h^{*AD} D_h^{*AD} - \frac{1}{2}\gamma_h (s_h^{AD})^2]}_{\Pi_{DC}^{AD}} + \underbrace{tp_l^{*AD} D_l^{*AD}}_{\text{Duty Revenue}}, \tag{17d}$$

where the prices and demands are given in (17a)-(17b). Note that duty revenue in the last term of the welfare function is: $tp_l^{*AD} D_l^{*AD} = (p_l^{*AD} - p_l^{*FT})D_l^{*AD}$. The DC government's FOC implies that its optimal AD duty is:[23]

$$t^{AD} = \frac{a+2}{a+3}. \tag{17e}$$

Substituting t^{AD} from (17e) back into (17a)-(17b), we calculate the equilibrium prices and demands in the DC market:

23 See Appendix A-1 for a detailed derivation of the optimal AD duty.

$$p_h^{*AD} = \frac{2\lambda(s_h - s_l)}{3}, \; p_l^{*AD} = \lambda(s_h - s_l), \; D_l^{*AD} = \theta^{*AD} = 0, \text{ and } D_h^{*AD} = 1 - \theta^* = 1. \tag{17f}$$

At the first stage of the three-stage game, the DC and LDC firms decide on their quality-upgrades. The LDC firm determines an optimal level s_l^{AD} to maximize its profits. It follows from π_{LDC}^{AD} in (16c), where prices and demands are given in (17a), (17b), and (17f), that we have

$$\frac{\partial \pi_{LDC}^{AD}}{\partial s_l^{AD}} = \gamma_l s_l^{AD} - \gamma_l s_l^{AD} - \frac{1}{9} = -\frac{1}{9} < 0,$$

which implies there is a corner solution:

$$s_l^{AD} = 0. \tag{18a}$$

Quality upgradation is thus economically unattractive to the LDC firm since its R&D expenditure is zero $(E_l^{AD} = \gamma_l (s_l^{AD})^2 / 2 = 0)$. This result is consistent with the observations that low-quality product firms in LDCs may have no incentives to undertake costly R&D for quality improvements.

The DC firm decides on an optimal quality-upgrade s_h that maximizes its profits. Substituting the prices and demands from (17f) back into (16c), we have the profit maximization problem of the DC firm:

$$\underset{\{s_h^{AD}\}}{\text{Max}} \; \Pi_{LDC}^{AD} = \frac{2(s_h^{AD} - s_l^{AD})(3\lambda + 2)}{9} - \frac{1}{2}\gamma_h (s_h^{AD})^2. \tag{18b}$$

The FOC for the DC firm implies that its optimal quality-upgrade is:

$$s_h^{AD} = \frac{2(3\lambda + 2)}{9\gamma_h} > 0. \tag{18c}$$

Following from (18c), the DC firm's optimal R&D expenditure on quality improvement is:

$$E_h^{AD} = \frac{1}{2}\gamma_h (s_h^{AD})^2 = \frac{2(3\lambda+2)^2}{81\gamma_h} > 0. \tag{18d}$$

Substituting s_h^{AD} and s_l^{AD} from (18a)-(18c) back into (17f), we obtain the equilibrium prices and demands of the high- and low-quality products in the DC market:

$$p_h^{*AD} = \frac{4\lambda(3\lambda+2)}{27\gamma_h},\ p_l^{*AD} = \frac{2\lambda(3\lambda+2)}{9\gamma_h},\ D_h^{*AD} = 1-\tilde{\theta}^{*AD} = 1,\ D_l^{*AD} = \tilde{\theta}^{*AD} = 0. \tag{18e}$$

Similarly, substituting s_h^{AD} and s_l^{AD} from (18a)-(18c) back into (17a)-(17b), we have the equilibrium prices and demands of the high- and low-quality products in the LDC market:

$$p_h^{AD} = \frac{4(3\lambda+2)}{27\gamma_h},\ p_l^{AD} = \frac{2(3\lambda+2)}{27\gamma_h},\ D_h^{AD} = 1-\hat{\theta}^{AD} = \frac{2}{3}, \text{and } D_l^{AD} = \hat{\theta}^{AD} = \frac{1}{3}. \tag{18f}$$

The final step of the analysis is to calculate profits, consumer surplus, and social welfare under the AD regime. First, substituting (18f) back into (16c) yields the DC firm's profit:

$$\Pi_{DC}^{AD} = \frac{2(3\lambda+2)^2}{81\gamma_h}. \tag{19a}$$

The surplus of DC consumers is: $CS_{DC}^{AD} = CS_l^{AD} + CS_h^{AD}$, that is,

$$CS_{DC}^{AD} = \underbrace{\int_a^{\tilde{\theta}^{*AD}} [\theta^{*AD}\lambda(1+s_l^{AD}) - p_l^{*AD}]dF(\theta)}_{CS_l^{AD}} + \underbrace{\int_{\tilde{\theta}^{*AD}}^{a+1} [\lambda\theta^{*AD}(1+s_h^{AD}) - p_h^{*AD}]dF(\theta)}_{CS_h^{AD}}. \tag{19b}$$

By plugging the equilibrium prices, demands, and quality-upgrades from (18c)-(18f) into (19b), we have the DC's consumer surplus:

$$CS_{DC}^{AD} = \frac{\lambda[(27\gamma_h - 6\lambda - 4) + a(32+48\lambda+54\gamma_h+36a+54a\lambda)]}{54\gamma_h}. \tag{19c}$$

The DC's social welfare is: $SW_{DC}^{AD} = CS_{DC}^{AD} + \Pi_{DC}^{AD} + t^{AD} p_l^{*AD} D_l^{*AD}$, where the terms on the RHS of the equation are given in(17e), (18e), and (19a)-(19c). After calculating, we have:

$$SW_{DC}^{AD} = \frac{(36\lambda+81\lambda\gamma_h+18\lambda^2+16) + a\lambda(96+144\lambda+162\gamma_h+108a+162a\lambda)}{162\gamma_h}. \tag{19d}$$

We turn to the LDC case for determining firm profits, consumer surplus, and social welfare. Plugging prices and demands from (18a) and (18f) back into (16c) yields

$$\pi_{LDC}^{AD} = \frac{6\lambda + 4}{81\gamma_h}. \tag{20a}$$

The surplus of LDC consumers is: $CS_{LDC}^{AD} = CS_l^{AD} + CS_h^{AD}$, that is,

$$CS_{LDC}^{AD} = \underbrace{\int_0^{\hat{\theta}^{AD}} [\theta(1+s_l^{AD}) - p_l^{AD}]dF(\theta)}_{CS_l^{AD} \text{ in LDC}} + \underbrace{\int_{\hat{\theta}^{AD}}^1 [\theta(1+s_h^{AD}) - p_h^{AD}]dF(\theta)}_{CS_h^{AD} \text{ in LDC}}.$$

Substituting the equilibrium prices, demands, and quality-upgrade from (18a)-(18f) into the above expression yields

$$CS_{LDC}^{AD} = \frac{(81\gamma_h - 12\lambda - 8) + a(48 + 72\lambda + 162\gamma_h + 36a + 54a\lambda)}{162\gamma_h}. \tag{20b}$$

The LDC's social welfare is: $SW_{LDC}^{AD} = CS_{LDC}^{AD} + (\pi_{LDC}^{AD} - t^{AD} p_l^{*AD} D_l^{*AD})$, where the terms on the RHS of the equation are given in (17e)-(17f) and (20a)-(20b). After calculating, we have

$$SW_{LDC}^{AD} = \frac{27\gamma_h + a(16 + 24\lambda + 54\gamma_h + 12a + 18a\lambda)}{54\gamma_h}. \tag{20c}$$

The results in (17f), which show that $D_l^{*AD} = \tilde{\theta}^{*AD} = 0$ and $D_h^{*AD} = 1 - \tilde{\theta}^{*AD} = 1$, have interesting and important implications for the AD policy as summarized in the following proposition:

PROPOSITION 2. *In the model of trade in quality-differentiated products where the LDC firm practices dumping, the imposition of an optimal AD duty by the DC government causes the dumper to leave the DC market* (*i.e.*, $\tilde{D}_l^{*AD} = 0$).

Several studies analyzing the impact of antidumping duty through partial and general equilibrium approaches suggest that AD duties remarkably reduce imports (e.g., Murray and Rousslang 1989; Gallaway et al. 1999; Bloneign 2016; Besedeš and Prusa 2017). Particularly, Besedeš and Prusa (2017) empirically investigate how AD duties affect US imports in terms of the timings of antidumping actions. This study finds that firms negatively affected by AD investigations tend not to return to the market even after the AD order is no longer in effect. Besedeš and Prusa (2017) further remark that AD actions are likely to "cause exporters to abandon the US market."Proposition 2 is consistent with the empirical observation that market demand for a dumped product is likely to be zero $(\tilde{D}_l^{*AD} = 0)$ under the AD regime.[24]

2.2.4 *Price undertaking*

When an LDC firm's low-quality product is placed on antidumping order because it dumps the product at a price less than that in its local market, the firm may consider the option of accepting a price undertaking (*PU*). This option serves as a business strategy for a foreign dumping firm to evade its payment of an AD fine. In this section, we analyze the economic effects of a price undertaking regime under which an LDC firm sets its product price identical to that in the firm's local market.

Within the two-market framework of trade, the LDC firm agrees to set p_l^{PU} identical to p_l^{*PU} when making its profit maximization decision (see equation 3). As such, demands for the high- and low-quality products in the DC and LDC markets become the following:

$$D_h^{*PU} = 1 - \frac{p_h^{*PU} - p_l^{*PU}}{\lambda(s_h^{PU} - s_l^{PU})},\ D_l^{*PU} = \frac{p_h^{*PU} - p_l^{*PU}}{\lambda(s_h^{PU} - s_l^{PU})};\ \bar{D}_h^{PU} = 1 - \frac{p_h^{PU} - p_l^{*PU}}{s_h^{PU} - s_l^{PU}},\ \bar{D}_l^{PU} = \frac{p_h^{PU} - p_l^{*PU}}{s_h^{PU} - s_l^{PU}}. \quad (21)$$

We solve the price undertaking regime as a two-stage game. At stage one, the DC and LDC firms determine their optimal quality-upgrades, $\{s_h^{PU}, s_l^{PU}\}$. At stage two, the firms set their product prices in both the DC and LDC markets by engaging in Bertrand competition.

24Prusa (1997) indicates that AD duty reduces the imports from the targeted country, but increases total imports through trade diversion. Also, Choi (2017) empirically test the impact of AD duties on imports by focusing on the United States, the European Union, China, and India from 1996 to 2015. The findings demonstrate that AD duties reduce imports in the short term, while such a relationship disappears in the long run and becomes positive.

Starting at the second stage of the game, the DC firm's profit maximization problem is:

$$\underset{\{p_h^{*PU}, p_h^{PU}\}}{\text{Max}} \Pi_{DC}^{PU} = p_h^{PU} \bar{D}_h^{PU} + p_h^{*PU} D_h^{*PU} - \frac{1}{2}\gamma_h (s_h^{PU})^2, \tag{22a}$$

where $\bar{D}_h^{PU}$ and D_h^{*PU} are given in (21). The LDC firm's profit maximization problem is:

$$\underset{\{p_l^{*PU}\}}{\text{Max}} \ \pi_{LDC}^{PU} = p_l^{*PU} \bar{D}_l^{PU} + p_l^{*PU} D_l^{*PU} - \frac{1}{2}\gamma_l (s_l^{PU})^2, \tag{22b}$$

where $\bar{D}_l^{PU}$ and D_l^{*PU} are given in (21). Using (22a)-(22b), we derive FOCs for the firms and solve for the optimal product prices in both the DC and LDC markets. This yields

$$p_h^{*PU} = \frac{\lambda(5+3\lambda)(s_h^{PU} - s_l^{PU})}{6(1+\lambda)}, \ p_h^{PU} = \frac{(3+5\lambda)(s_h^{PU} - s_l^{PU})}{6(1+\lambda)}, \ p_l^{PU} = \frac{2\lambda(s_h^{PU} - s_l^{PU})}{3(1+\lambda)} = p_l^{*PU}. \tag{22c}$$

Substituting the prices from (22c) back into (21), we calculate demands for the high- and low-quality products in the DC and the LDC markets:

$$D_h^{*PU} = \frac{3\lambda+1}{6(1+\lambda)}, \ D_h^{*PU} = \frac{3\lambda+5}{6(1+\lambda)}; \ \bar{D}_l^{PU} = \frac{\lambda+3}{6(1+\lambda)}, \ \bar{D}_h^{PU} = \frac{5\lambda+3}{6(1+\lambda)}. \tag{22d}$$

At the first stage of the game, the DC and LDC firms determine their optimal quality-upgrades, $\{s_h^{PU}, s_l^{PU}\}$. Plugging the prices and demands from (22c)-(22d) back into the profit functions in (22a)-(22b), we have the profit maximization problems for the DC and LDC firms:

$$\underset{\{s_h^{PU}\}}{\text{Max}} \ \Pi_{DC}^{PU} = \frac{(s_h^{PU} - s_l^{PU})(9\lambda^2 + 46\lambda + 9)}{36(1+\lambda)} - \frac{1}{2}\gamma_h (s_h^{PU})^2;$$
$$\underset{\{s_l^{PU}\}}{\text{Max}} \ \pi_{LDC}^{PU} = \frac{4\lambda(s_h^{PU} - s_l^{PU})}{9(1+\lambda)} - \frac{1}{2}\gamma_l (s_l^{PU})^2. \text{(23a)}$$

Using (23a), we derive FOCs for the firms and solve for their optimal quality-upgrades:

$$s_h^{PU} = \frac{46\lambda + 9\lambda^2 + 9}{36\gamma_h(1+\lambda)} > 0 \text{ and } s_l^{PU} = 0. \tag{23b}$$

Substituting s_h^{PU} and s_l^{PU} from (23b) back into (22c)-(22d), we calculate the equilibrium prices and demands of the high- and low-quality products in the DC market:

$$p_h^{*PU} = \frac{\lambda(3\lambda+5)(9\lambda^2+46\lambda+9)}{216\gamma_h(1+\lambda)^2},\ p_l^{*PU} = \frac{\lambda(9\lambda^2+46\lambda+9)}{54\gamma_h(1+\lambda)^2};$$

$$D_h^{*PU} = \frac{3\lambda+5}{6(1+\lambda)},\ D_l^{*PU} = \frac{3\lambda+1}{6(1+\lambda)}, \tag{23c}$$

as well as those of the high- and low-quality products in the LDC market:

$$p_h^{PU} = \frac{(5\lambda+3)(9\lambda^2+46\lambda+9)}{216\gamma_h(1+\lambda)^2},\ p_l^{PU} = \frac{\lambda(9\lambda^2+46\lambda+9)}{54\gamma_h(1+\lambda)^2};$$

$$D_h^{PU} = \frac{5\lambda+3}{6(1+\lambda)},\ D_l^{PU} = \frac{\lambda+3}{6(1+\lambda)}. \tag{23d}$$

Note that under a price undertaking, we have $p_l^{PU} = p_l^{*PU}$.

A comparison of equilibrium demands for the two products in the DC market reveals that

$$D_l^{*FT} > D_l^{*PU} > D_l^{*AD} = 0 \text{ and } D_h^{*AD} > D_h^{*PU} > D_h^{*FT} > 0. \tag{23e}$$

We thus have

PROPOSITION 3. *Unlike the optimal AD policy that causes an LDC dumper to leave the DC market, a price-undertaking allows the LDC firm to have a positive market share in the DC market.*[25] *The DC firm's market share is higher under a price-undertaking than under free trade (with the presence of LDC dumping).*

Having determined the equilibrium prices and demands, we calculate profits, consumer surplus, and social welfare. First, making use of the prices in (23c), the demands in (23d), and the profit function in (22a), we calculate the DC firm's total profit:

$$\Pi_{DC}^{PU} = \frac{(9\lambda^2+46\lambda+9)^2}{2592\gamma_h(1+\lambda)^2}. \tag{24a}$$

The surplus of DC consumers is: $CS_{DC}^{PU} = CS_l^{PU} + CS_h^{PU}$. That is,

[25]This finding is supported by the study of Konings et al. (1998) that price undertaking helps foreign firms to maintain their market shares in importing countries.

$$CS_{DC}^{PU} = \underbrace{\int_a^{\theta^{PU}}[\lambda\theta^{PU}(1+s_l^{PU}) - p_l^{*PU}]dF(\theta)}_{CS_l^{PU} \text{ in DC}} + \underbrace{\int_{\theta^{PU}}^{a+1}[\lambda\theta(1+s_h^{PU}) - p_h^{*PU}]dF(\theta)}_{CS_h^{PU} \text{ in DC}}. \quad (24b)$$

Substituting the prices and demands from (23c)-(23d) into (24b), after re-arranging terms, yields

$$CS_{DC}^{PU} = \frac{\lambda(1296\gamma_h - 1220\lambda - 954\lambda^2 + 252\lambda^3 + 81\lambda^4 + 3888\lambda\gamma_h + 3888\lambda^2\gamma_h + 1296\lambda^3\gamma_h - 207)}{2592\gamma_h(1+\lambda)^3}$$
$$+ \frac{a\lambda(540 + 324a + 2304a\lambda + 3960a\lambda^2 + 2304a\lambda^3 + 324a\lambda^4)}{2592\gamma_h(1+\lambda)^3}$$
$$+ \frac{a\lambda(3624\lambda + 5280\lambda^2 + 2520\lambda^3 + 324\lambda^4 + 2592\gamma_h + 7776\lambda\gamma_h + 7776\lambda^2\gamma_h + 2592\lambda^3\gamma_h)}{2592\gamma_h(1+\lambda)^3}.$$

(24c)

The DC's social welfare is: $SW_{DC}^{PU} = CS_{DC}^{PU} + \Pi_{DC}^{PU}$, where Π_h^{PU} is in (24a) and CS_{DC}^{PU} is in (24c). It follows that

$$SW_{DC}^{PU} = \frac{702\lambda + 1886\lambda^2 + 2152\lambda^3 + 1161\lambda^4 + 162\lambda^5 + 1296\lambda\gamma_h + 3888\lambda^2\gamma_h + 3888\lambda^3\gamma_h + 1296\lambda^4\gamma_h + 81}{2592\gamma_h(1+\lambda)^3}$$
$$+ \frac{a\lambda(540 + 324a + 2304a\lambda + 3960a\lambda^2 + 2304a\lambda^3 + 324a\lambda^4)}{2592\gamma_h(1+\lambda)^3}$$
$$+ \frac{a\lambda(3624\lambda + 5280\lambda^2 + 2520\lambda^3 + 324\lambda^4 + 2592\gamma_h + 7776\lambda\gamma_h + 7776\lambda^2\gamma_h + 2592\lambda^3\gamma_h)}{2592\gamma_h(1+\lambda)^3}.$$

(24d)

As for the LDC, we first calculate total profit for the LDC firm by using the equilibrium prices and demands in (23c)-(23d). This yields

$$\pi_{LDC}^{PU} = \frac{\lambda(9\lambda^2 + 46\lambda + 9)}{81\gamma_h(\lambda+1)^2}. \quad (25a)$$

The surplus of LDC consumers is: $CS_{LDC}^{PU} = CS_l^{PU} + CS_h^{PU}$. That is,

$$CS_{LDC}^{PU} = \underbrace{\int_a^{\hat{\theta}}(\theta(1+s_l) - p_l)dF(\theta)}_{CS_l^{PU} \text{ in LDC}} + \underbrace{\int_{\hat{\theta}}^{a+1}(\theta(1+s_h) - p_h)dF(\theta)}_{CS_h^{PU} \text{ in LDC}}, \quad (25b)$$

Substituting the results from (23c)-(23d) into (25b), after rearranging terms, we have:

$$CS_{LDC}^{PU} = \frac{252\lambda + 1296\gamma_h - 954\lambda^2 - 1220\lambda^3 - 207\lambda^4 + 3888\lambda\gamma_h + 3888\lambda^2\gamma_h + 1296\lambda^3\gamma_h + 81}{2592\gamma_h(1+\lambda)^3} + \frac{a(324 + 2520\lambda + 5280\lambda^2 + 3624\lambda^3 + 540\lambda^4 + 324a + 2592\gamma_h)}{2592\gamma_h(1+\lambda)^3} + \frac{a\lambda(2304a + 3960a\lambda + 2304a\lambda^2 + 324a\lambda^3 + 7776\gamma_h + 7776\lambda\gamma_h + 2592\lambda^2\gamma_h)}{2592\gamma_h(1+\lambda)^3}. \quad (25c)$$

The LDC's social welfare is: $SW_{LDC}^{PU} = CS_{LDC}^{PU} + \pi_{LDC}^{PU}$, where π_{LDC}^{PU} and CS_{LDC}^{PU} are given in (25a) and (25c). It follows that

$$SW_{LDC}^{PU} = \frac{540\lambda + 1296\gamma_h + 806\lambda^2 + 540\lambda^3 + 81\lambda^4 + 3888\lambda\gamma_h + 3888\lambda^2\gamma_h + 1296\lambda^3\gamma_h + 81}{2592\gamma_h(1+\lambda)^3} + \frac{a(324 + 2520\lambda + 5280\lambda^2 + 3624\lambda^3 + 540\lambda^4 + 324a + 2592\gamma_h)}{2592\gamma_h(1+\lambda)^3} + \frac{a\lambda(2304a + 3960a\lambda + 2304a\lambda^2 + 324a\lambda^3 + 7776\gamma_h + 7776\lambda\gamma_h + 2592\lambda^2\gamma_h)}{2592\gamma_h(1+\lambda)^3}. \quad (25d)$$

Having derived the equilibrium outcomes of the three different trade regimes, our next step of the analysis is to see how the regimes affect DC and LDC differently.

2.3. Regime Comparisons and Policy Recommendations

In this section, we compare various effects on R&D investments and the product quality decisions by the competing DC and LDC firms across the trade regimes. We then compare the resulting effects on firm profits, consumer surplus, and social welfare of the trading nations (i.e., DC vs. DC).

2.3.1 *Effects on DC*[26]

In terms of quality-upgrades chosen by the DC and LDC firms and the quality levels of their products, we have from the results in (11), (18c), and (23b) that

$s_{DC}^{AD} > s_{DC}^{FT} > s_{DC}^{PU}$ which implies that $q_{DC}^{AD} > q_{DC}^{FT} > q_{DC}^{PU}$.

[26] See Appendix A-2 for detailed derivations of the results in this section.

We thus have:

PROPOSITION 4. *In the model of trade in quality-differentiated products between a DC and an LDC, the optimal quality-upgrade through costly R&D investment is the highest for the DC firm when its government imposes AD duties, but is the lowest when the LDC firm accepts a price-undertaking.*

Proposition 4 suggests that product quality optimally chosen by a DC firm depends crucially on the type of trade policies that its government implements. Our finding that price undertaking reduces the incentive of a DC firm for quality improvement is consistent with the study of Vandenbuscche and Wauthy(2001). The authors investigate how the European Union's antidumping measures affect the product quality choices of firms and find, among other things, that price undertaking affects product quality negatively in the domestic industries of an importing-competing country.

Next, we compare the DC firm's profits. It follows from the results in (14a), (19a), and (24a) that

$$\Pi_{DC}^{AD} > \Pi_{DC}^{FT} > \Pi_{DC}^{PU}.$$

This ranking of profits leads to the following proposition:

PROPOSITION 5. *DC firm's profit is highest when its government imposes AD duties. However, the DC firm's profit is the lowest when the LDC firm accepts a price-undertaking.*

Proposition 5 suggests that DC firms that produce high-quality products have a strong incentive to lobby their government to impose AD duties on the dumping of low-quality products by LDC firms. This finding lends strong support to several empirical studies documenting that AD duty increases domestic profits (Morkre and Kelly 1999; DeVault 1996; Bloneign 2016).

To see how DC consumers are affected by LDC dumping, we look at the results in (14c), (19c), and (24c). Comparing the surplus of DC consumers across the three trade regimes yields

$$CS_{DC}^{AD} > CS_{DC}^{FT} > CS_{DC}^{PU}.$$

This ranking has interesting policy implications, as summarized in the following proposition:

PROPOSITION 6. *DC consumers enjoy the highest surplus when their government imposes duties against dumping, as compared to the other two trade regimes. Nevertheless, DC consumers are hurt the most when the LDC firm accepts a price-undertaking.*

Proposition 6 suggests that, relative to free trade equilibrium in which foreign dumping of low-quality products takes place, DC consumers are better off by purchasing more high-quality products under an AD policy. This finding appears to be consistent with the findings of empirical studies (see, e.g., Devault, 1996).

To see the welfare implications of the three different regimes for DC, we look at the equilibrium levels of social welfare, as shown in (14d), (19d), and (25d). It follows that

$$SW_{DC}^{AD} > SW_{DC}^{FT} > SW_{DC}^{PU}.$$

We thus can state the following proposition:

PROPOSITION 7. *DC's social welfare is the highest when its government implements an AD policy, but is the lowest when the LDC firm accepts a price-undertaking.*

Proposition 7 is consistent with that study of Pauwels and Springael (2002) that compares differences in welfare implications between the European AD policy and a price-undertaking. The authors contend that, from the welfare-enhancing perspective, the European Union is better off with an AD policy rather than accepting a price undertaking. Moreover, this result holds, regardless of whether there is Bertrand or Cornout competition.

The acceptance of price undertakings by foreign firms as a settlement strategy plays a vital role in affecting the termination of antidumping cases in the European Economic Community (EEC). Member countries of the EEC frequently allow foreign firms to accept price undertakings, but the number of price undertakings accepted has varied considerably over time. Tharakan (1991) indicates that, out of 249 affirmative case decisions for the period 1980–1987, as high as 72% were terminated by the acceptance of undertakings in the EEC.Zanardi (2006) remark that out of 578 affirmative AD actions for the EEC between 1981 and 2001, as high as 40.6% of these cases were terminated by price undertakings.However, for the period from 1995 to 2008, Rovegno and Vandenbussche (2011) demonstrate that the use of price undertakings in the European Union has decreased steadily in favor of imposing AD duties.

2.3.2 *Effects on LDC*[27]

We now examine how the different trade regimes affect the profits of the LDC firm that sells a low-quality product. Following the results in (15a), (20a), and (25a), we have

$$\pi_{LDC}^{PU} > \pi_{LDC}^{AD} \text{ when } \lambda > \hat{\lambda}_{LDC} \text{ and } \pi_{LDC}^{AD} > \pi_{LDC}^{PU} \text{ when } \lambda < \hat{\lambda}_{LDC},$$

where $\hat{\lambda}_{LDC}$ is the critical value of the inter-country income differential that makes the LDC firm indifferent between the AD regime and a price undertaking. The comparison between π_{LDC}^{FT} and π_{LDC}^{AD} (or π_{LDC}^{PU}) is straightforward:

$$\pi_{LDC}^{FT} > \pi_{LDC}^{AD} \text{ and } \pi_{LDC}^{FT} > \pi_{LDC}^{PU}.$$

Taking together the rankings of firm profits, as shown above, we have two possibilities.

Case 1: When $\lambda > \hat{\lambda}_{LDC}$ (i.e., when income differential is smaller such that the DC and LDC markets are more competitive), we have

[27] See Appendix A-2 for detailed derivations of the results in this section.

$$\pi_{LDC}^{FT} > \pi_{LDC}^{PU} > \pi_{LDC}^{AD},$$

where π_{LDC}^{AD} is the LDC's firm profit from its domestic market (due to zero market share in DC).

Case 2: When $\lambda < \hat{\lambda}_{LDC}$ (i.e., when income differential is more substantial such that the DC and LDC markets are less competitive), we have

$$\pi_{LDC}^{FT} > \pi_{LDC}^{AD} > \pi_{LDC}^{PU}.$$

It is easy to verify that π_{LDC}^{PU} in Case 2 is lower than that in Case 1. We, thus, have

PROPOSITION 8. *LDC's firm profit is the highest by dumping its low-quality product into the DC market under free trade, regardless of the degree of competition between the DC and LDC markets. However, the comparison between an AD policy and a price-undertaking depends on the degree of international market competition. When the DC and LDC markets are more (less) competitive, the LDC firm's profit is higher (lower) under a price-undertaking than under an AD policy.*

As for the surplus of LDC consumers under the alternative trade regimes, we compare the results in (15c), (20c), and (25c) and find that

$$CS_{LDC}^{AD} > CS_{LDC}^{FT}.$$

However, the comparisons between CS_{LDC}^{PU} and CS_{LDC}^{FT} (or CS_{LDC}^{AD}) cannot be determined unambiguously. We thus have:

PROPOSITION 9. *LDC consumers are better off when the DC government imposes AD duties than when there is free trade.*

The economic intuition is as follows. Under an AD policy, gains in LDC's consumer surplus by consuming an imported good with a relatively upgraded quality (resulting from DC's

R&D investment in quality enhancement) exceed the losses that consumers encounter in consumer surplus through consuming the low-quality product with an increased price.

To compare the equilibrium levels of social welfare across the trade regimes, we have from the results in (15d), (20d), and (25d) that

$$SW_{LDC}^{PU} > SW_{LDC}^{FT} > SW_{LDC}^{AD}.$$

This ranking has the following welfare implications:

PROPOSITION 10. *LDC's social welfare is the highest when its exporting firm accepts a price-undertaking, but is the lowest when the firm practices dumping and pays AD duties.*

Given that price undertaking allows a foreign dumping firm to keep some of the AD rents, it comes as no surprise that an LDC's social welfare is higher under price undertaking than under the AD regime. This finding is consistent with the results of Gao and Miyagiwa (2005).The authors indicate that the price undertaking option is a more friendly protection policy toward foreign dumper than the AD policy.

2.3.3 *Effects on global welfare*

It is instructive to investigate how alternative trade regimes affect the world or global welfare, defined by aggregating the social welfare of DC and LDC trading partners. Under free trade in the presence of dumping**,** global welfare is: $GW^{FT} = SW_{DC}^{FT} + SW_{LDC}^{FT}$, where SW_{DC}^{FT} and SW_{LDC}^{FT} are, respectively, given in (14d) and (15d). It follows that

$$GW^{FT} = \frac{(1+\lambda)[(16\lambda + 81\gamma_h + 16) + a(48 + 48\lambda + 162\gamma_h + 36a + 36a\lambda)]}{162\gamma_h}. \quad (26a)$$

Under the AD regime, global welfare is: $GW^{AD} = SW_{DC}^{AD} + SW_{LDC}^{AD}$, where SW_{DC}^{AD} and SW_{LDC}^{AD} are, respectively, given in (19d) and (20d). It follows that

$$GW^{AD} = \frac{36\lambda + 81\gamma_h + 18\lambda^2 + 81\lambda\gamma_h + 16}{162\gamma_h} + \frac{a(48 + 162a\lambda^2 + 168\lambda + 162\gamma_h + 144\lambda^2 + 162a\lambda + 36a + 162\lambda\gamma_h)}{162\gamma_h}. \quad (26b)$$

Under a price-undertaking, global welfare is: $GW^{PU} = SW_{DC}^{PU} + SW_{LDC}^{PU}$, where SW_{DC}^{PU} and SW_{LDC}^{PU} are, respectively, given in (24d) and (25d). It follows that

$$\begin{aligned} GW^{PU} = &\frac{540\lambda + 648\gamma_h + 806\lambda^2 + 540\lambda^3 + 81\lambda^4 + 1944\lambda\gamma_h + 1944\lambda^2\gamma_h + 648\lambda^3\gamma_h + 81}{1296\gamma_h(1+\lambda)^2} \\ &+ \frac{a(162 + 162a + 1296\gamma_h + 3888\lambda\gamma_h + 3888\lambda^2\gamma_h + 1296\lambda^3\gamma_h)}{1296\gamma_h(1+\lambda)^2} \\ &+ \frac{a\lambda(1152a + 1980a\lambda + 1152a\lambda^2 + 162a\lambda^3 + 1368 + 3084\lambda + 1368\lambda^2 + 162\lambda^3)}{1296\gamma_h(1+\lambda)^2}. \end{aligned} \quad (26c)$$

A comparison of global welfare in(26a), (26b), and (26c) reveals that

$$GW^{AD} > GW^{FT} > GW^{PU}.$$

This ranking of global welfare permits us to state the following:

PROPOSITION 11. *In the model of two-way trade between a DC and an LDC in quality-differentiated products,* global *welfare is the* <u>*highest*</u> *when the DC government imposes an optimal AD policy against LDC dumping. However, global welfare is the lowest when the LDC firm accepts a price-undertaking.*

From the perspective of global welfare, our two-market equilibrium analysis with the endogeneity of product quality by DC and LDC firms implies the Pareto superiority of the AD policy on dumping. Further, the result in Proposition 11 is supported by the analysis of Anderson, Schmitt, and Thisse(1995) that imposing an AD duty on foreign dumping affects global welfare positively.

Rovegno and Vandenbussche (2011) use data from 1995 to 2008 and find that the use of price undertakings in the European Union has decreased steadily in favor of AD duty.Similarly, Rovegno and Vandenbussche (2011) find that the average use of AD duties for the same period in the EU is more than 76%. These empirical findings have interesting welfare implications for DCs and LDCs taken together. As suggested by the finding of Proposition 11, moving toward the use of optimal AD charges on foreign dumping as a trade damage measure is essentially welfare-improving from the global (i.e., WTO) perspective.

2.4. Concluding Remarks

In this paper, we present a simple model of international trade and competition in quality-differentiated products between two firms located separately in a DC and an LDC. We show that dumping arises when the DC and LDC markets have different degrees of competition (due to income differences between the trading nations). Explicitly allowing for the endogenous decisions of product quality, we find that the DC firm produces a high-quality product, whereas the LDC firm produces a low-quality product. Under free trade, the LDC firm dumps its low-quality product on the DC market at a price lower than the product's price in its local market. This result helps to explain frequent observations concerning the dumping of low-quality and cheaper products by LDC firms into DC countries. This suggests that dumping is evidence of low product quality. Our analysis demonstrates that although dumping is profitable to exporters of low-quality products from an LDC, the country's overall welfare decreases when its exporters are charged with AD duties. We further show that an LDC is better off by restraining its exporters not to practice dumping, but to accept price undertakings.

To the best of our knowledge, the present paper is among the few theoretical studies that adopt a two-market equilibrium model to characterize the dumping decisions of international firms, which export low-quality products from the less-developed world to markets in the developed world. From the perspective of DCs with their firms producing high-quality products, the use of AD duties is effective in dealing with foreign dumping. An AD policy allows for domestic firms to regain their market shares. Moreover, AD protection as a trade remedy policy for a DC improves its overall welfare and is thus socially desirable. The equilibrium analysis indicates that such an AD policy improves world welfare. Following the WTO/GATT guidelines to identify the price-discriminating behavior of dumping low-quality products, the positive welfare effect of using AD duties indicates that such a policy is not a protectionist measure. Instead, an AD policy is an effective measure of remedy to unfair trade practices. In the face of foreign dumping under free trade, the trade remedy measure of imposing AD duties is Pareto optimal from the global trade perspective and hence is fundamentally WTO-consistent.

Chapter 3 - Import Tariffs vs. Antidumping Duties: A Comparative Analysis with Welfare Implications

3.1. Introduction

States use various protection measures (e.g., tariffs and antidumping duties) to restrain imports or to alleviate trade injury resulting from foreign competition which, in turn, helps to maximize their economic interests. To illustrate, the United States and South Africa traded white meat and dark meat as chicken eaters in the U.S. prefer white meat and South Africans prefer dark meat. In 1999, the South African Board of Tariffs and Trade (BTT) initiated an antidumping case against the U.S. exporters for their dumping practices. Later, the BTT decided with antidumping (AD) duties ranging from 209% to 357% on chicken exports which significantly reduced U.S. chicken exports to South Africa and caused the U.S. poultry exports to fell by 80% (Watson 2015).Alternatively, national governments use tariffs as a protection tool. For instance, recently the U.S. President Donald Trump imposed import tariffs as high as 25% and 10% on steel and aluminum imports from the European Union, Canada, and Mexico. These tariffs aim to address dumping along with trade protection by supporting U.S. steel and aluminum manufacturers. It comes as no surprise that a national government has protection measures when facing problems with imports and the resulting trade damage to domestic industries.

Given import tariffs and AD duties as alternative policy options, the issue is whether one policy is preferred over the other. Some researchers contend that imposing safeguard tariffs is a better choice than using AD duties. Mankiw and Swagel (2005) contend that the primary objective of U.S. antidumping law is to protect domestic firms from predatory pricing and provide the firms time to become competitive again. However, the use of AD duties by the U.S.

government may not be able to achieve its objective but may instead affect both domestic producers and consumers negatively. Mankiw and Swagel (2005) further indicate that the best strategy to avoid harm is to reform existing AD law and to promote import tariffs (i.e., safeguard tariffs). Nonetheless, the U.S. government shows no interest in AD reforms and opposes any proposition of reforms both under the domestic and international law (Watson 2015). From the perspective of adopting protection measures by trading nations, however, one observes that reliance on import tariffs has shown a declining trend, whereas the use of AD duties has been on the rise (especially in developing countries).[28]

The above discussions about the choice between a tariff policy and an AD duty in a contemporary setting shed light on its significance and make it an important issue to investigate. Besides, the politico/economic repercussion motivated us to move beyond the arguments and investigate the issue by digging deep down into tariffs vs. AD duties to see which policy yields the best outcome in terms of domestic profits, consumer benefits, and social welfare. There is a plethora of scholarly work done on import tariffs and AD duties in separate settings that analyzes the economic implications of each policy. Starting with AD duty, researchers have theoretically and empirically examined this policy choice and came across with mixed findings. For instance, Marsh (1998) suggests that AD laws positively affect domestic firms' pursuit of AD protection. However, Prussa (2005) indicates that AD duty generates more harm to international trade and

[28]Prusa (2001) documents that until the 1980sabout 95% of the AD disputes are initiated by DCs against LDCs. Vandenbussche and Zanardi (2008) find that the later trend shows that LDCs are also highly involved in AD actions. Bown (2011a, b) indicates that AD actions are concentrated across traditional users (DCs) and new AD users (LDCs). Bown (2013) remarks that most of the new AD disputes launched by LDCs have targeted imports from other LDCs.

does not achieve the real purpose of AD laws.[29] From a different perspective, researchers query the effectiveness of import tariffs as a policy option. For example, Baldwin and Green (1988) remark that imposing import tariffs as a protection measure is not of much help to enhance domestic output. In contrast, Brander and Spencer (1992) demonstrate the effects of tariffs in protecting domestic firms from long-term damage when markets are characterized by imperfect competition.[30]

It seems that relatively little research has been done to compare differences in welfare implications between import tariffs and antidumping duties within a unified framework of trade. The study of Dinlersoz and Dogan (2010) is an exception. The authors further indicate the difficulties in comparing the alternative protection measures in a consolidated approach. Practically, the imposition of a tariff is to maximize import revenue or domestic welfare, while the use of an AD duty is to elevate the price of a dumped product, which is lower than that of its local price (i.e., dumping margin). To deal with this challenging problem of comparing the two policy options, we develop a two-market equilibrium model of trade in quality-differentiated products. We first show that dumping arises under free trade when there is an income differential between two trading nations (e.g., DC and LDC). We then consider two policy options, tariffs or AD duties, and conduct a comparative analysis to demonstrate their differences in economic effects and welfare implications. Specifically, our model allows for product quality choices of

[29]For contributions on examining antidumping issues see, e.g., Lahiri and Sheen (1990), Webb (1992), Tharakan(1999), Prusa (2001, 2002), Wooton and Zanardi (2002), Aggarwal (2004), Zanardi (2004), Blonigen (2006), Chang and Gayle (2006).

[30]For contributions on analyzing on the economic effects of tariffs see, e.g., Bhagwati and Ramaswami (1963), Bhagwati and Kemp (1969), Leith (1971), Alam (1988), Bond (1990), Blonigen (2002), and Johnson (2013). Besides investigating tariffs, scholars have examined tariffs in comparison to quotas. See, e.g., Bhagwati (1968), Rodriguez (1974), Pelcovits (1976), Takacs (1978), Cassing and Hillman (1985), Krishna (1987), Rotemberg and Saloner (1989), Reitzes (1991), Anderson and Neary (2002), and Anderson (2002).

two competing firms located separately in a developed country (DC) and a less-developed country (LDC), which are characterized by an income differential or a different degree of market competition.[31]

We summarize the key findings as follows. First, we show that DC firm produces a high-quality product and does not practice dumping, whereas the LDC firm produces a low-quality product that is “dumped” into the DC market. Second, in the case of imposing an AD policy by the DC government for trade remedies, the optimal duty rate is at a level high enough to drive the LDC firm out of the DC market. Third, the use of AD duties by the DC government encourages its firm to undertake more R&D investment for quality improvement than a tariff policy. Fourth, In the case of imposing import tariffs under the protectionist regime, the optimal tariff set by the LDC government is higher than that set by the DC government. Fifth, DC's firm profit is higher under an AD policy than under a tariff policy. DC's consumer surplus and domestic welfare are higher (lower) under an AD policy than under a tariff policy when the degree of competition between the DC and LDC markets is sufficiently high (low). As for impacts on the LDC, we find that LDC's firm profit is higher when the DC government adopts a tariff policy than when it imposes an AD policy. LDC consumers are better off under an AD policy than a tariff policy. However, LDC's welfare is higher under a tariff policy than under an AD policy.

In comparing the two policy tools, our model of trade in quality-differentiated products has implications for world welfare, defined by aggregating the welfare of both DC and LDC. We find that world welfare is higher when the DC government imposes an AD policy on LDC

[31] Our analytical framework is fundamentally similar to a North-South trade model where one firm in the North (a developed country) competes with one firm in the South (a less developed country) in both the northern and southern markets. That is, we use DC-LDC trade and North-South trade interchangeably.

dumping than when there is a tariff war, under the condition that the degree of competition between the DC and LDC markets is sufficiently high. Otherwise, world welfare is higher under a tariff policy than under an AD policy.

This paper complements the contribution of Dinlersoz and Dogan (2010) in comparing the two policy tools in a unified approach. Dinlersoz and Dogan (2010)show, among other things, that the choice between an AD duty and a tariff depends on the elasticity of demand for imports. The authors find that the government opts for an AD duty when import demand elasticity is low since it hurts the foreign firm the most. When import demand elasticity is high, the government finds it better off by imposing tariffs. It should be mentioned that the present study departs from Dinlersoz and Dogan (2010) in some important aspects. First, Dinlersoz and Dogan (2010) adopt an oligopoly framework with firms producing a homogeneous product. We employ a vertical differentiation framework to show product quality choices of the competing firms before engaging in price competition in international markets. Dinlersoz and Dogan (2010) assume that one dominant foreign firm competes with few domestic firms where consumers in the domestic market have a choice to consume both domestic and foreign goods; however domestic firms are not exporters (i.e., no import-competition in the foreign market). We consider duopolistic competition between a DC firm and an LDC firm, and their products are available to consumers in both markets through trade. Third, Dinlersoz and Dogan (2010) compare tariffs and AD duties by assuming the existence of dumping. We show that dumping arises endogenously due to product differentiation and a different degree of competition in DC and LDC markets.

The remainder of the paper is organized as follows. In Section 2, we present a two-market framework of international trade in final goods with vertical product differentiation to analyze duopolistic competition in DC and LDC markets. Showing that dumping takes place under free trade, we then evaluate an antidumping policy and compare it with an import tariff policy. In Section 3, we discuss how the different protection policies affect firm profits, consumer surplus, and social welfare in DC and LDC differently. Section 4 concludes.

3.2. The Analytical Framework

3.2.1 *Basic assumptions*

To develop a unified framework for comparing the two protection measures, we consider a two-market equilibrium model of trade in which dumping practice arises endogenously due to differences in the degree of market competition between two trading countries. The model allows for comparing the prices of a product sold in both the domestic and foreign countries (which are treated as DC and LDC, respectively, due to an income differential). In the presence of dumping, we analyze and compare equilibrium outcomes between two trade policies: import tariffs and anti-dumping (AD) duties. One may wonder why it is necessary to compare tariffs to AD duties as a policy choice. The key reason for the policy comparison is due to their inherent differences in market price effects and welfare consequences. For instance, the use of tariffs is to enhance the revenue or welfare of an importing country, while the use of an AD policy is to eliminate the dumping margin through price restoration. Given the differences between the two protection measures, once we identify the conditions under which there is dumping under free trade, we then investigate how import tariffs and AD duties affect firm profits, consumer surplus, and social welfare of DC and LDC.

We consider an import-export model of international duopoly where firms produce "like" products with a quality difference and compete in both DC and LDC markets. The firm located in DC, where consumers are relatively more affluent, will be shown to manufacture and export a high-quality product. For notational convenience, we denote variables for the DC firm with the subscript "h," representing that its product quality is high. The firm located in LDC, where consumers are relatively less affluent, will be shown to manufacture and export a low-quality product. Similarly, for notational convenience, we denote variables for the LDC firm with the subscript "l," representing that its product quality is low. We shall show that an income differential between DC and LDC markets has a role in explaining the occurrence of dumping in the DC market under free trade.

3.2.1.1 *LDC market*

In the LDC market, consumers are uniformly distributed over a unit line, $\theta \in [0,1]$, and each consumer purchases one unit of a product, which is taken to be a necessity.[32] Let p_h and p_l be the prices of the high- and low-quality products sold in the LDC market. Following the literature on vertical product differentiation, we specify the indirect utility function of an LDC consumer located at point θ as follows:

$$V_{LDC}(\theta) = \begin{cases} \theta q_h - p_h & \text{if buys the high-quality product at price } p_h; \\ \theta q_l - p_l & \text{if buys the low-quality product at price } p_l. \end{cases} \tag{1}$$

where q_i represents the quality level of a product by firm $i(=h,l)$.

Following Chang and Raza (2018), we take into account the endogenous decisions of product quality improvement by the firms and assume that

$$q_i = 1 + s_i, \tag{2}$$

where $s_i (\geq 0)$ denotes "quality-upgrade" resulting from firm i's R&D investment. This approach includes the case when the firms are not interested in quality-upgrades $(s_h = s_l = 0)$. The

[32]That is, we consider the case of a full covered market. This consideration is consistent with the literature that uses a vertical product differentiation framework (see, e.g., Cremer and Thisse, 1994; Crampes and Hollander, 1995; Wauthy, 1996; Ecchia and Lambertini, 1997; Andaluz, 2000; Chang and Raza 2018).

expression in (2) implies that product quality is normalized to one $(q_h = q_l = 1)$ in the absence of quality upgradation. Empirical studies suggest that the strategic choice of product quality by the DC firm is relatively higher than that of the LDC firm's (i.e., $q_h > q_l \geq 0$).[33] In other words, the result that $q_h > q_l \geq 0$ is due to their respective quality-upgrade choices (i.e., $s_h > s_l \geq 0$). The quality upgrade decisions of the firms are endogenous in our model. As in the R&D investment literature, we consider that each firm's quality-upgrading expenditure takes a quadratic form: $E_i = \gamma_i s_i^2 / 2$, where the parameter $\gamma_i (> 0)$ denotes the cost-effectiveness of R&D investment by firm $i (= h, l)$.

In the LDC market with consumer heterogeneity in tastes for quality $\theta \in [0,1]$, the marginal consumer who is indifferent between the high-quality product and the low-quality product implies that $\theta(1+s_h) - p_h = \theta(1+s_l) - p_l$. We calculate the critical value of θ as $\hat{\theta} = p_h - p_l / s_h - s_l$, where $1 > \hat{\theta} > 0$ for $p_h > p_l > 0$ and $s_h > s_l \geq 0$. Demands for the low- and high-quality products in the LDC market are then given, respectively, as

$$D_l(p_h, p_l) = \frac{p_h - p_l}{s_h - s_l} \text{ and } D_h(p_h, p_l) = 1 - \theta = 1 - \frac{p_h - p_l}{s_h - s_l}. \tag{3}$$

Here, market demand for the high-quality product, $D_h(p_h, p_l)$, defines the LDC import.

3.2.1.2 *DC market*

In the DC market, we use the superscript "$*$" to denote all the related variables. We assume that DC consumers are distributed uniformly over a unit line, $\theta^* \in [0,1]$, with each buying one unit of the product, which is a necessity. We represent prices of high- and low-

[33]See, e.g., Amiti and Khandelwal (2013).

quality products by p_h^* and p_l^*, , respectively. We use the parameter λ, where $\lambda \in (0,1)$, to reflect the degree of an income differential between DC and LDC. The indirect utility function of a consumer located at a point $\theta^* \in [0,1]$ in the DC market is specified as

$$V_{DC}(\theta^*) = \begin{cases} \lambda\theta^* q_h - p_h^* \text{ if consumer buys the high-quality product at } p_h^*; \\ \lambda\theta^* q_l - p_l^* \text{ if consumer buys the low-quality product at } p_l^*. \end{cases} \quad (4)$$

The incorporation of the parameter λ into the preference function in (4) follows directly from Tirole (1988) that consumer taste for quality is *inversely* related to the marginal utility of income. That is, other things being equal, the marginal utility of consumption is strictly *lower* for consumers in DC than LDC's consumers. Given (3) and (4), this implies that $\lambda\theta^* q_i < \theta q_i$ for $\theta^* = \theta$ and a given level of product quality. The parameter $\lambda \in (0,1)$ reflects the degree of market similarity or dissimilarity between DC and LDC. When the value of λ increases and approaches 1, the DC and the LDC markets resemble each other in that there is a high degree of competition. However, when the value of λ decreases and approaches to 0, the two markets become increasingly dissimilar with a low degree of competition. We shall show that the degree of similarity or dissimilarity (λ) has a crucial role in characterizing the market interaction between the DC and LDC firms.

Given the quality upgradation equations for the competing firms $(q_i = 1 + s_i$ for $i = h, l)$, the marginal consumer in the DC market is such that $\lambda\theta^*(1+s_h) - p_h^* = \lambda\theta^*(1+s_l) - p_l^*$. The critical value of θ^*, denoted by $\tilde{\theta}^*$, is calculated as $\tilde{\theta}^* = (p_h^* - p_l^*)/[\lambda(s_h - s_l)]$, noting that $1 > \tilde{\theta}^* > 0$ for $p_h^* > p_l^* > 0$ and $s_h > s_l \geq 0$. In the DC market, demands for the low- and high-quality products are then given, respectively, as

$$D_l^*(p_h^*, p_l^*) = \tilde{\theta}^* = \frac{p_h^* - p_l^*}{\lambda(s_h - s_l)} \text{ and } D_h^*(p_h^*, p_l^*) = 1 - \tilde{\theta}^* = 1 - \frac{p_h^* - p_l^*}{\lambda(s_h - s_l)}. \tag{5}$$

Here, market demand for the low-quality product, $D_l^*(p_h^*, p_l^*)$, defines the DC import.

Based on consumer preferences and demands for the quality-differentiated products, we proceed to examine the profit-maximization decisions of the DC and LDC firms for identifying the firm type practicing dumping. We then analyze how the dumping equilibrium under free trade is affected by each of the trade remedy policies: an AD duty and a tariff.

3.2.2 *Free trade (under which dumping takes place)*

Under free trade, each country can access the market of a trading partner's duty-free. We consider a two-stage game. At stage one, DC and LDC firms choose quality upgrades that maximize their respective profits. At stage two, the firms set their profit-maximizing prices in both the DC and LDC markets by engaging in Bertrand competition. To derive the sub-game perfect Nash equilibrium for the two-stage game, we use backward induction.

We begin with the second stage of the game at which the firms set their prices in the DC and LDC markets by solving the following profit maximization problems:

$$\underset{\{p_h^{*FT},\ p_h^{FT}\}}{\text{Max}} \ \Pi_{DC}^{FT} = p_h^{*FT} D_h^{*FT}(p_h^{*FT}, p_l^{*FT}) + p_h^{FT} D_h^{FT}(p_h^{FT}, p_l^{FT}) - \frac{1}{2}\gamma_h (s_h^{FT})^2, \tag{6a}$$

$$\underset{\{p_l^{FT},\, p_l^{*FT}\}}{\text{Max}} \ \pi_{LDC}^{FT} = p_l^{FT} D_l(p_h^{FT}, p_l^{FT}) + p_l^{*FT} D_l^{*FT}(p_h^{*FT}, p_l^{*FT}) - \frac{1}{2}\gamma_l (s_l^{FT})^2, \tag{6b}$$

where product demands in the DC and LDC markets,denoted as $\{ D_h^{*FT}, D_h^{FT}, D_l^{FT}, \text{ and } D_l^{*FT} \}$, are taken from (3) and (5) with the superscript "*FT*" representing the case of free trade.The first-order conditions (FOCs) for the DC and LDC firms imply that their optimal prices are:

$$p_h^{*FT} = \frac{2\lambda(s_h^{FT} - s_l^{FT})}{3},\ p_l^{*FT} = \frac{\lambda(s_h^{FT} - s_l^{FT})}{3},\ p_h^{FT} = \frac{2(s_h^{FT} - s_l^{FT})}{3}, \text{and } p_l^{FT} = \frac{(s_h^{FT} - s_l^{FT})}{3}. \tag{6c}$$

The issue of concern is whether any firm sells a product in the foreign market at a price lower than the product's price in its domestic market. In this case, dumping arises.

We first compare p_h^{*FT} and p_h^{FT}, the equilibrium prices of the high-quality product that the DC firm charges in both markets, It follows from (6c) that

$$\frac{p_h^{*FT}}{p_h^{FT}} = \frac{\left[\dfrac{2\lambda(s_h^{FT} - s_l^{FT})}{3}\right]}{\left[\dfrac{2(s_h^{FT} - s_l^{FT})}{3}\right]} = \lambda < 1,$$

which implies that

$$p_h^{FT} > p_h^{*FT}. \tag{7a}$$

The result in (7a) indicates that the equilibrium price of the high-quality product is *higher* in the LDC market than in the DC market. Based on the WTO/GATT guidelines, the DC firm does not practice dumping.

Next, we compare p_l^{*FT} and p_l^{FT}, the prices of the low-quality product that the LDC firm charges in the DC and LDC markets, respectively. It follows from (6c) that

$$\frac{p_l^{*FT}}{p_l^{FT}} = \frac{\left[\dfrac{\lambda(s_h^{FT} - s_l^{FT})}{3}\right]}{\left[\dfrac{(s_h^{FT} - s_l^{FT})}{3}\right]} = \lambda < 1,$$

which implies that

$$p_l^{*FT} (= \lambda p_l^{FT}) < p_l^{FT}. \tag{7b}$$

The result in (7b) indicates that the price of the low-quality product is *lower* in the DC market than in the LDC market. Based on the WTO/GATT guidelines, dumping arises! The LDC firm, a low-quality producer, takes advantage of free trade and wallows in trade abuse activity of practicing dumping in the DC market under free trade.

To calculate market demands (or shares) of the two products for the DC and LDC firms, we substitute prices from (6c) back into (3) and (5) to obtain the following:

$$D_h^{*FT} = (1-\tilde{\theta}^{*FT}) = \frac{2}{3},\ D_l^{*FT} = \tilde{\theta}^{*FT} = \frac{1}{3},\ D_h^{FT} = (1-\hat{\theta}^{FT}) = \frac{2}{3}, \text{and } D_l^{FT} = \hat{\theta}^{FT} = \frac{1}{3}. \tag{8}$$

At the first stage of the game, the DC and LDC firms determine quality upgrades, $\{s_h^{FT}, s_l^{FT}\}$, to maximize their respective profits. Substituting demands from (8) back into the profit functions in (6a) and (6b), we derive the FOCs for the firms and solve for the optimal quality-upgrades. This exercise yields

$$s_h^{FT} = \frac{4\lambda + 4}{9\gamma_h} > 0 \text{ and } s_l^{FT} = 0. \tag{9a}$$

It follows from (9a) that R&D expenditures for quality improvements are:

$$E_h^{FT} = \frac{1}{2}\gamma_h (s_h^{FT})^2 = \frac{8(1+\lambda)^2}{81\gamma_h} \text{ and } E_l^{FT} = 0. \tag{9b}$$

These results lead to the first corollary:

COROLLARY 1. *In a two-way free trade between a DC and an LDC we consider, the DC firm has an economic incentive to undertake costly R&D investment for product quality improvements. As such, the DC firm manufactures and exports a high-quality product. However, the LDC firm is not interested in quality upgrades such that it manufactures and exports a low-quality product.*

To calculate the equilibrium prices set by the DC and LDC firms, we substitute (9a) back into the price equations in (6c). This yields

$$p_h^{*FT} = \frac{8\lambda(1+\lambda)}{27\gamma_h},\ p_l^{*FT} = \frac{4\lambda(1+\lambda)}{27\gamma_h},\ p_h^{FT} = \frac{8(1+\lambda)}{27\gamma_h}, \text{ and } p_l^{FT} = \frac{4(1+\lambda)}{27\gamma_h}. \tag{9c}$$

Making use of (9a)-(9c), we compute profit, consumer surplus, and welfare of the DC market:

$$\Pi_{DC}^{FT}=\frac{8(1+\lambda)^2}{81\gamma_h},\ CS_{DC}^{FT}=\frac{\lambda(81\gamma_h-8\lambda-8)}{162\gamma_h},\text{ and } SW_{DC}^{FT}=\frac{24\lambda+8\lambda^2+81\lambda\gamma_h+16}{162\gamma_h}. \tag{10a}$$

We further compute profit, consumer surplus, and welfare of the LDC market:

$$\pi_{LDC}^{FT}=\frac{4(1+\lambda)^2}{81\gamma_h}, CS_{LDC}^{FT}=\frac{81\gamma_h-8\lambda-8}{162\gamma_h},\text{ and } SW_{LDC}^{FT}=\frac{8\lambda^2+8\lambda+81\gamma_h}{162\gamma_h}. \tag{10b}$$

The findings of the analyses permit us to establish the first proposition:

PROPOSITION 1. *Under free trade between a DC and an LDC where DC firm produces a high-quality product and LDC firm produces a low-quality product, the DC firm chooses not to dump. Nevertheless, the LDC firm practices dumping by charging at a lower price for its product in the DC market than the product's price in its local market.*

The result Proposition 1 has significant implications in the light of WTO guidelines that help us to identify the circumstances under which dumping arises. Under free trade, high-quality products are not dumped. Instead, low-quality products are always dumped. These results support the empirical studies suggesting that LDC firms dump low-quality products in DC markets. For instance, Neufeld (2001) shows that antidumping duties as a trade remedy rose to 42% from 38% as a response to the LDC dumping during the 1994-1999 period. This finding prompts one to examine the response of the DC government and the resulting implications both in the domestic and global markets.

The above analysis suggests that an LDC firm manufacturing and exporting a low-quality product has an incentive to practice dumping in the DC market under the free trade scenario. As a consequence, the rival DC firm faces economic damage due to dumping on free trade. In response to the damage, the DC firm files a petition to its government against the LDC firm's trade abuse (i.e., unfair price) for addressing its concerns. After the legal investigation and identification, if the LDC firm is found guilty, then the DC government can opt among various tools (i.e., antidumping duties or import tariffs) to assist the domestic firm. Here, in this paper, we investigate the issue concerning which policy tool helps to obtain the defined objective to prevail the "fair" price of an imported product in its domestic market.

3.2.3 *Antidumping regime*

We have shown in Section 2.2 that, under free trade, the LDC firm dumps its low-quality product in the DC market at a price lower than its local price since $p_l^{*FT} < p_l^{FT}$ (see equation 9c). In response to dumping, the DC government may choose to impose an *ad valorem* duty, *t*, up to the dumping margin. We consider the case where the government sets the duty rate to be identical to the dumping margin. That is,

$$t = \frac{p_l^{FT} - p_l^{*FT}}{p_l^{FT}},$$

which is the price difference between p_l^{FT} and p_l^{*FT} as a proportion of the LDC local price p_l^{FT}. It follows that $p_l^{FT} - p_l^{*FT} = tp_l^{FT}$, which can be re-written as:

$$p_l^{FT} = \frac{1}{(1-t)} p_l^{*FT}.$$

This result implies that the DC government can elevate, through its AD laws, the price of the low-quality product in the DC market up to the level of p_l^{FT}, which is the free-trade price of the product in the LDC local market. We thus re-define this price level p_l^{FT} to be p_l^{*AD}, i.e., $p_l^{*AD} = p_l^{FT}$, where p_l^{*AD} denotes the price of the low-quality product in the DC market after the *ad valorem* duty, *t*, is imposed. It follows that

$$p_l^{*AD} = (\frac{1}{1-t}) p_l^{*FT}$$

which is equivalent to

$$p_l^{*FT} = (1-t) p_l^{*AD}.$$

Given that p_l^{*AD} is set identical to the LDC local price p_l^{FT} under the AD regime, the equation that $p_l^{FT} - p_l^{*FT} = tp_l^{FT}$ can be re-written as:

$$p_l^{*AD} - p_l^{*FT} = tp_l^{*AD}.$$

Multiplying both sides of this equation by D_l^{*AD}, which denotes the quantity of the low-quality product imported by DC under the AD regime, we have the following expression to measure the total amount of *duty revenue*:

$$(p_l^{*AD} - p_l^{*FT})D_l^{*AD} = tp_l^{*AD}D_l^{*AD}.$$

Under the AD regime with an *ad valorem* duty, which remains to be optimally determined by the DC government, there is a new set of demand equations for low- and high-quality products in the DC market. We derive this new set of market demands in DC by replacing the free-trade price, p_l^{*FT}, in (5) with $(1-t)p_l^{*AD}$. This yields

$$D_l^{*AD}(p_h^{*AD}, p_l^{*AD}) = \tilde{\theta}^{*AD} = \frac{p_h^{*AD} - (1-t)p_l^{*AD}}{\lambda(s_h^{AD} - s_l^{AD})};\ D_h^{*AD}(p_h^{*AD}, p_l^{*AD}) = 1 - \tilde{\theta}^{*AD} = 1 - \frac{p_h^{*AD} - (1-t)p_l^{*AD}}{\lambda(s_h^{AD} - s_l^{AD})}. \quad (11a)$$

Whereas demand equations for the low- and high-quality products in the LDC market remain the same(see equation 5). That is,

$$D_l^{AD}(p_h^{AD}, p_l^{AD}) = \hat{\theta}^{AD} = \frac{p_h^{AD} - p_l^{AD}}{s_h^{AD} - s_l^{AD}};\ D_h^{AD}(p_h^{AD}, p_l^{AD}) = 1 - \hat{\theta}^{AD} = 1 - \frac{p_h^{AD} - p_l^{AD}}{s_h^{AD} - s_l^{AD}}. \quad (11b)$$

For the two-market equilibrium solution under the AD regime, we consider a three-stage game. At stage one, the DC and LDC firms independently and simultaneously determine quality-upgrades that maximize their respective profits. At stage two, the DC government imposes an antidumping duty that maximizes domestic welfare. At stage three, the competing firms determine their profit-maximizing prices in the DC and LDC markets by engaging in Bertrand competition. To solve for the sub-game Nash equilibrium, we use backward induction.

At the third and last stage of the game, the DC and LDC firms compete in setting product prices as per the following profit maximization problems:

$$\underset{\{p_h^{*AD},\, p_h^{AD}\}}{\text{Max}}\ \Pi_{DC}^{AD} = p_h^{*AD} D_h^{*AD}(p_h^{*AD}, p_l^{*AD}) + p_h^{AD} D_h^{AD}(p_h^{AD}, p_l^{AD}) - \frac{1}{2}\gamma_h (s_h^{AD})^2;$$

$$\underset{\{p_l^{AD},\, p_l^{*AD}\}}{\text{Max}}\ \pi_{LDC}^{AD} = p_l^{AD} D_l^{AD}(p_h^{AD}, p_l^{AD}) + p_l^{*AD} D_l^{*AD}(p_h^{*AD}, p_l^{*AD}) - \frac{1}{2}\gamma_l (s_l^{AD})^2, \qquad (12a)$$

where the market demands, D_h^{*AD}, D_h^{AD}, D_l^{AD}, and D_l^{*AD}, are given in (11a) and (11b). The FOCs for the firms imply that the prices of the products in the DC and LDC markets are:

$$p_h^{*AD} = \frac{2\lambda(s_h^{AD} - s_l^{AD})}{3},\ p_l^{*AD} = \frac{\lambda(s_h^{AD} - s_l^{AD})}{3(1-t)},\ p_h^{AD} = \frac{2(s_h^{AD} - s_l^{AD})}{3}, \text{ and } p_l^{AD} = \frac{(s_h^{AD} - s_l^{AD})}{3}. \quad (12b)$$

Substituting the prices from (12b) back into (11) yields demands facing the DC and LDC firms:

$$D_h^{*AD} = 1 - \tilde{\theta}^{*AD} = \frac{2-t}{3(1-t)},\ D_h^{AD} = 1 - \hat{\theta} = \frac{2}{3},\ D_l^{AD} = \hat{\theta} = \frac{1}{3}, \text{ and } D_l^{*AD} = \tilde{\theta}^{*AD} = \frac{2t-1}{3t-3}. \qquad (12c)$$

To see how the AD policy affects prices of the low-quality products sold in both the DC and LDC markets, we have from (12b) that

$$\frac{p_l^{*AD}}{p_l^{AD}} = \frac{\left[\dfrac{\lambda(s_h^{AD} - s_l^{AD})}{3(1-t)}\right]}{\left[\dfrac{(s_h^{AD} - s_l^{AD})}{3}\right]} = \frac{\lambda}{1-t},$$

which implies that

$$p_l^{*AD}\left(= \frac{\lambda p_l^{AD}}{1-t}\right) > p_l^{*FT}(= \lambda p_l^{FT}). \qquad (12d)$$

Imposing the AD duty, based on the dumping margin, raises the price of the low-quality product in the DC market. This result implies that the DC government achieves its goal of having a “fair price” in the domestic market.

At the second stage of the game, the DC government determines an optimal AD duty rate that maximizes domestic welfare. This welfare is the sum of consumer surplus (from purchasing the high-quality and low-quality products), the DC firm's profit (net of R&D cost), and duty revenue under the AD regime. Given the prices and demands in (12b)-(12c), the DC government solves the following welfare maximization problem:

$$\underset{\{t\}}{\text{Max}}\ SW_{DC}^{AD} = \underbrace{\int_{\tilde{\theta}^*}^{1}[\lambda\theta^{*AD}(1+s_h^{AD}) - p_h^{*AD}]dF(\theta)}_{CS_h^{AD}} + \underbrace{\int_{0}^{\tilde{\theta}^*}[\theta^{*AD}\lambda(1+s_l^{AD}) - p_l^{*AD}]dF(\theta)}_{CS_l^{AD}}$$
$$+\underbrace{[p_h^{AD}D_h^{AD} + p_h^{*AD}D_h^{*AD} - \frac{\gamma_h(s_h^{AD})^2}{2}]}_{\Pi_{DC}^{AD}} + \underbrace{tp_l^{*AD}D_l^{*AD}}_{\text{Duty Revenue}}$$

The FOC for the government implies that the optimal AD duty rate is:

$$t^{AD} = \frac{2}{3}. \tag{13a}$$

Substituting t^{AD} from (13a) back into (12b)-(12c), we calculate product prices and demands in the DC and LDC markets:

$$p_h^{*AD} = \frac{2\lambda(s_h - s_l)}{3},\ p_l^{*AD} = \frac{\lambda(s_h - s_l)}{3},\ p_h^{AD} = \frac{2(s_h - s_l)}{3},\ p_l^{AD} = \frac{(s_h - s_l)}{3};$$

$$D_h^{*AD} = 1 - \tilde{\theta}^{*AD} = 1,\ D_l^{*AD} = \tilde{\theta}^{*AD} = 0,\ D_h^{AD} = 1 - \hat{\theta} = \frac{2}{3},\ D_l^{AD} = \hat{\theta} = \frac{1}{3}. \tag{13b}$$

At the third and last stage of the game, the LDC and DC firms determine their quality upgrades that maximize individual profits. Based on the profit maximization problems in (12a) where the prices and demands are given in (13b), we derive the FOCs for the firms which lead to the following results:

$$s_h^{AD} = \frac{6\lambda + 4}{9\gamma_h} > 0 \text{ and } s_l^{AD} = 0. \tag{13c}$$

This implies that quality improvement is economically unattractive to the LDC firm since its R&D expenditure is zero $(E_l^{AD} = \gamma_l s_l^2/2 = 0)$. This finding is consistent with the observations that low-quality product firms in LDCs may have no incentives to undertake costly R&D for quality improvements. On the other hand, the DC firm chooses an optimal quality-upgrade and incurs an R&D expenditure for product quality improvement:

$$E_h^{AD} = \frac{2(3\lambda+2)^2}{81\gamma_h} > 0. \tag{13d}$$

Substituting the optimal quality upgrades from (13c) back into (13b), we calculate the optimal prices and demands for the DC and LDC firms:

$$p_h^{*AD} = \frac{2\lambda(6\lambda+4)}{27\gamma_h},\ p_l^{*AD} = \frac{\lambda(6\lambda+4)}{9\gamma_h},\ p_h^{AD} = \frac{2(6\lambda+4)}{27\gamma_h},\ p_l^{AD} = \frac{6\lambda+4}{27\gamma_h};$$

$$D_h^{*AD} = 1-\tilde{\theta}^* = 1,\ D_l^{*AD} = \tilde{\theta}^{*AD} = 0,\ D_h^{AD} = 1-\hat{\theta}^{AD} = \frac{2}{3}, \text{and } D_l^{AD} = \hat{\theta}^{AD} = \frac{1}{3}. \tag{14}$$

Next, we calculate firm profits, consumer surplus, and welfare of both countries. Substituting (13c) and (14) back into (12a) yields the optimal profits for the DC and LDC firms:

$$\Pi_{DC}^{AD} = \frac{2(3\lambda+2)^2}{81\gamma_h} \text{ and } \pi_{LDC}^{AD} = \frac{6\lambda+4}{81\gamma_h}. \tag{15a}$$

The consumer surplus measures of the two countries are given, respectively, as:

$$\begin{aligned} CS_{DC}^{AD} &= \underbrace{\int_{\tilde{\theta}^*}^1 [\lambda\theta^{*AD}(1+s_h^{AD}) - p_h^{*AD}]dF(\theta^*)}_{CS_h^{AD} \text{ in DC}} + \underbrace{\int_0^{\tilde{\theta}^*} [\theta^*\lambda(1+s_l^{AD}) - p_l^{*AD}]dF(\theta^*)}_{CS_l^{AD} \text{ in DC}}; \\ CS_{LDC}^{AD} &= \underbrace{\int_{\hat{\theta}}^1 [\theta(1+s_h^{AD}) - p_h^{AD}]dF(\theta)}_{CS_h^{AD} \text{ in LDC}} + \underbrace{\int_0^{\hat{\theta}} [\theta(1+s_l^{AD}) - p_l^{AD}]dF(\theta)}_{CS_l^{AD} \text{ in LDC}}. \end{aligned} \tag{15b}$$

Making use of (13c) and (14), we calculate the equilibrium levels of consumer surplus:

$$CS_{DC}^{AD} = \frac{\lambda(27\gamma_h - 6\lambda - 4)}{54\gamma_h} \text{ and } CS_{LDC}^{AD} = \frac{81\gamma_h - 12\lambda - 8}{162\gamma_h}. \tag{15c}$$

The welfare functions of the DC and the LDC are defined, respectively, as:

$$SW_{DC}^{AD} = CS_{DC}^{AD} + \Pi_{DC}^{AD} + t^{AD} p_l^{*AD} D_l^{*AD} \text{ and } SW_{LDC}^{AD} = CS_{LDC}^{AD} + \pi_{LDC}^{AD} - t^{AD} p_l^{*AD} D_l^{*AD}, \tag{15d}$$

where t^{AD} is given in (13a), firm profits are given in (15a), and consumer surplus measures are given in (15c).We first calculate the total amount of duty revenues, $t^{AD} p_l^{*AD} D_l^{*AD}$, and then substitute all the related terms from (15a)-(15c) into (15d) to obtain the maximum levels of welfare for the two countries:

$$SW_{DC}^{AD} = \frac{36\lambda + 18\lambda^2 + 81\lambda\gamma_h + 16}{162\gamma_h} \text{ and } SW_{LDC}^{AD} = \frac{1}{2}. \tag{15e}$$

It is instructive to note the results in (14) that $D_l^{*AD} = \tilde{\theta}^{*AD} = 0$ and $D_h^{*AD} = 1 - \tilde{\theta}^{*AD} = 1$. We summarize their economic implications in the following proposition:

PROPOSITION 2. *In the two-market equilibrium model of trade where the LDC firm dumps its low-quality product in the DC market (at a price below the price of the product in the LDC market), the best response of the DC government is to optimally set an AD duty rate such that the LDC firm is driven out of the DC market* (*i.e.*, $\tilde{D}_l^{*AD} = 0$).

The finding of Proposition 2 is consistent with both theoretical and empirical studies that investigate the impact of AD duties. For example, Murray and Rousslang (1989) show theoretically that the use of AD duties causes a remarkable reduction in imports. Likewise, several empirical studies on the impacts of AD duties on U.S. imports indicate that foreign dumping firms are significantly hurt by such policy and are less likely to trade with the United States. In addition to that, studies suggest that antidumping duty causes trade diversion, and have different consequences (variation occurs in short-term to long-term consequences. (Besedes and Prusa 2017; Prusa 1997; Choi 2017).

3.2.4 *Tariff regime*

Under a tariff regime, each country imposes an optimal tariff for restraining import from its trading partner. We consider a three-stage game. At stage one, DC and LDC firms choose optimal quality-upgrades and R&D investments that maximize their respective profits. At stage two, the DC government imposes a tariff (t_{DC}) on its import of a low-quality product supplied by the LDC firm. In the meanwhile, the LDC government levies a tariff (t_{LDC}) on its import of a high-quality product supplied by the DC firm. At stage three, the competing firms set optimal prices for their products sold in both the DC and LDC markets by engaging in Bertrand competition. We solve the three-stage game using backward induction.

At the third stage of the game, the DC and LDC firms solve the following profit maximization problems:

$$\underset{\{p_h^{*T}, p_h^T\}}{\text{Max}}\ \Pi_{DC}^T = p_h^{*T} D_h^{*T}(p_h^{*T}, p_l^{*T}) + (p_h^T - t_{LDC}) D_h^T(p_h^T, p_l^T) - \frac{1}{2}\gamma_h (s_h^T)^2;$$

$$\underset{\{p_l^T, p_l^{*T}\}}{\text{Max}}\ \pi_{LDC}^T = p_l^T D_l^T(p_h^T, p_l^T) + (p_l^{*T} - t_{DC}) D_l^{*T}(p_h^{*T}, p_l^{*T}) - \frac{1}{2}\gamma_l (s_l^T)^2, \tag{16a}$$

where market demands are given by (3)-(5) with a superscript "*T*" representing variables under the tariff regime. The FOCs for the firms imply that the product prices in the DC and LDC markets are:

$$p_h^{*T} = \frac{t_{DC} + 2\lambda(s_h^T - s_l^T)}{3},\ p_l^{*T} = \frac{2t_{DC} + \lambda(s_h^T - s_l^T)}{3},$$

$$p_h^T = \frac{2(s_h^T - s_l^T + t_{LDC})}{3},\ p_l^T = \frac{s_h^T - s_l^T + t_{LDC}}{3}. \tag{16b}$$

Substituting the prices from (16b) back into the demand equations (see equations 3-5) yields $D_h^{*T} = \dfrac{t_{DC} + 2\lambda(s_h^T - s_l^T)}{3\lambda(s_h^T - s_l^T)}$, $D_l^{*T} = \dfrac{\lambda(s_h^T - s_l^T) - t_{DC}}{3\lambda(s_h^T - s_l^T)}$,

$$D_h^T = \frac{2(s_h^T - s_l^T) - t_{LDC}}{3(s_h^T - s_l^T)},\ D_l^T = \frac{(s_h^T - s_l^T) + t_{LDC}}{3(s_h^T - s_l^T)}. \quad (16c)$$

At the second stage of the game, the DC and LDC governments independently determine their tariffs by solving the following welfare maximization problems:

$$\underset{\{t_{DC}\}}{\text{Max}}\ SW_{DC}^T = CS_{DC}^T + \Pi_{DC}^T + t_{DC} D_l^{*T} \text{ and } \underset{\{t_{LDC}\}}{\text{Max}}\ SW_{LDC}^T = CS_{LDC}^T + \pi_{LDC}^T + t_{LDC} D_h^T. \quad (16d)$$

Note that the consumer surplus terms in (16d) are:

$$CS_{DC}^T = \underbrace{\int_{\tilde{\theta}}^1 [\lambda\theta(1+s_h^T) - p_h^{*T}]dF(\theta)}_{CS_h^T \text{ in DC}} + \underbrace{\int_0^{\tilde{\theta}} [\lambda\theta(1+s_l^T) - p_l^{*T}]dF(\theta)}_{CS_l^T \text{ in DC}};$$

$$CS_{LDC}^T = \underbrace{\int_{\tilde{\theta}}^1 [\theta(1+s_h^T) - p_h^T]dF(\theta)}_{CS_h^T \text{ in LDC}} + \underbrace{\int_0^{\tilde{\theta}} [\theta(1+s_l^T) - p_l^T]dF(\theta)}_{CS_l^T \text{ in LDC}}. \quad (16e)$$

Making use of (16a)-(16e), we derive the FOCs for the DC and LDC governments and calculate the optimal tariffs. This exercise yields

$$t_{DC} = \lambda(s_h^T - s_l^T) \text{ and } t_{LDC} = s_h^T - s_l^T. \quad (16f)$$

We then plug the optimal tariffs in (16f)back into (16b)-(16c)to obtain product prices and demands for the firms:

$$p_h^{*T} = \lambda(s_h^T - s_l^T),\ p_l^{*T} = \lambda(s_h^T - s_l^T),\ p_h^T = \frac{4(s_h^T - s_l^T)}{3},\ p_l^T = \frac{2(s^T - s_l^T)}{3};$$

$$D_l^{*T} = 0,\ D_h^T = \frac{1}{3},\ D_l^T = \frac{2}{3}. \quad (17a)$$

At the first stage of the game, the DC and LDC firms determine quality-upgrades, $\{s_h^T, s_l^T\}$, that maximize their respective profits. By substituting the prices and demands from (17a) back into the profit functions in (16a), we derive the FOCs for the DC and LDC firms:

$$\frac{\partial \Pi_{DC}^T}{\partial s_h^T} = (\lambda - \gamma_h s_h^T + \frac{1}{9}) = 0 \text{ and } \frac{\partial \pi_{LDC}^T}{\partial s_l^T} = (\gamma_l s_l^T - \gamma_l s_l^T - \frac{4}{9}) = 0.$$

Solving for the optimal quality-upgrades chosen by the DC and LDC firms yields

$$s_h^T = \frac{9\lambda + 1}{9\gamma_h} \text{ and } s_l^T = 0.$$

(17b)Equation (17b) implies that the LDC firm does not have an incentive for quality-upgrades since its R&D expenditure is zero $(E_l^T = \gamma_l (s_l^T)^2/2 = 0)$. This may explain why firms in many developing countries show no interest in costly R&D investments for quality enhancement.

On the other hand, the DC firm finds it profitable to undertake R&D since

$$ED_h^T = \frac{\gamma_h (s_h^T)^2}{2} = \frac{(9\lambda + 1)^2}{162\gamma_h} > 0. \tag{17c}$$

We thus have

PROPOSITION 3. *The imposition of an import tariff by the DC government on the foreign dumped product by an LDC firm, which manufactures and exports a low-quality product, does* <u>*not*</u> *affect the LDC firm's incentive in undertaking R&D investment for product quality upgradation*.

The result in Proposition 3 is consistent with several studies that empirically test how import tariffs affect quality reversal. For example, Feenstra (1988) investigates imports of Japanese compact trucks and finds that there is no sustained quality upgradation despite the increased tariffs. In analyzing trade policy and quality upgradation in developing economies, Moraga-González and Viaene (2005) find that import tariffs help to reap foreign rents but do not help for quality reversal.[34]

[34]Lenway, Morck, and Yeung (1996) examine the effect of protectionism on innovation in American Steel Industry. Though the study did not specifically focus on the tariffs as a protectionism policy, it does suggest that protectionism in steel industry discourage innovation that eventually lead the firms to exit.

The next step of the analysis is to determine optimum tariffs set by the DC and LDC governments. To do so, we substitute the firms' quality-upgrades, $\{s_h^T, s_l^T\}$, from (17b) back into (16f). This yields

$$t_{DC}^T = \frac{\lambda(9\lambda+1)}{9\gamma_h} \text{ and } t_{LDC}^T = \frac{(9\lambda+1)}{9\gamma_h}. \tag{17d}$$

Since $0 < \lambda < 1$, it follows from (17d) that

$$t_{LDC}^T > t_{DC}^T.$$

We thus have the following proposition:

PROPOSITION 4: *In a tariff game under the protectionist regime, where the DC firm exports a high-quality product and the LDC firm exports a low-quality product, the optimal tariff imposed by the LDC government is strictly higher than that imposed by the DC government.*

By substituting the optimal quality-upgrades from (17b) back into (17a), we calculate the equilibrium prices and demands of the high-quality product in the DC and LDC markets:

$$p_h^{*T} = \frac{\lambda(9\lambda+1)}{9\gamma_h},\ p_h^T = \frac{4(9\lambda+1)}{27\gamma_h};\ D_h^{*T} = (1-\tilde{\theta}) = 1,\ D_h^T = \tilde{\theta} = \frac{1}{3}. \tag{18a}$$

As for the equilibrium prices and demands of the low-quality product in the DC and LDC markets, we have

$$p_l^{*T} = \frac{\lambda(9\lambda+1)}{9\gamma_h},\ p_l^T = \frac{2(9\lambda+1)}{27\gamma_h},\ D_l^{*T} = \tilde{\theta} = 0,\ D_l^T = \hat{\theta} = \frac{2}{3}. \tag{18b}$$

Making use of (17b), (17d), (18a), and (18b), we calculate profits (see equation 16a) for the DC and LDC firms:

$$\Pi_{DC}^T = \frac{(9\lambda+1)^2}{162\gamma_h} \text{ and } \pi_{LDC}^T = \frac{4(9\lambda+1)}{81\gamma_h}. \tag{18c}$$

Moreover, we calculate the equilibrium levels of consumer surplus, $\{CS^T_{DC}, CS^T_{LDC}\}$, for DC and LDC by substituting (17b) and (18b) into the consumer surplus measures in (16e). This yields

$$CS^T_{LDC} = \frac{81\gamma_h - 99\lambda - 11}{162\gamma_h} \text{ and } CS^T_{DC} = \frac{-18\lambda^2 + 7\lambda + 9\gamma_h + 1}{18\gamma_h}. \tag{18d}$$

To compute welfare for each country, we use the functions in (16d). That is, $SW^T_{DC} = CS^T_{DC} + \Pi^T_{DC} + t_{DC} D^{*T}_l$ and $SW^T_{LDC} = CS^T_{LDC} + \pi^T_{LDC} + t_{LDC} D^T_h$, where tariff rates are given in (17d), consumer surplus measures are in (18d), and firm profits are in (18d). After calculating and rearranging terms, we have

$$SW^T_{DC} = \frac{-81\lambda^2 + 81\lambda + 81\gamma_h + 10}{162\gamma_h} \text{ and } SW^T_{LDC} = \frac{9\lambda + 27\gamma_h + 1}{54\gamma_h}. \tag{18e}$$

3.3. Tariffs vs. AD Duties: Policy Recommendations

Having derived the equilibrium outcomes under an AD policy and a tariff policy, we proceed to analyze differences in implications between the two policies (in terms of quality upgrades, product prices and demands, consumer surplus, firm profits, and social welfare). We include free-trade equilibrium results (with the presence of LDC dumping) for references. In Sections 3.1 and 3.2, we look at effects on the trading nations, DC and LDC, respectively. In Section 3.3, we discuss differences in implications from the global perspective of welfare.

3.3.1*Effects on DC*

We first compare the optimal levels of quality-upgrades and the DC firm's product quality under alternative trade regimes. An examination of (9a), (13c), and (17b) reveals that

$$s^{AD}_h > s^T_h > s^{FT}_h \Rightarrow q^{AD}_h > q^T_h > q^{FT}_h \text{ if } \lambda > 0.6;$$

$$s^{AD}_h > s^{FT}_h > s^T_h \Rightarrow q^{AD}_h > q^{FT}_h > q^T_h \text{ if } \lambda < 0.6.$$

From the results in (9b), (13d), and (17c), it follows that the optimal R&D investments for quality improvement by the DC firm are ranked as follows:

$$E_{DC}^{AD} > E_{DC}^{T} > E_{DC}^{FT} \text{ if } \lambda > 0.6;\; E_{DC}^{AD} > E_{DC}^{FT} > E_{DC}^{T} \text{ if } \lambda < 0.6.$$

We thus have

PROPOSITION 5.*The imposition of an AD policy by the DC government against LDC dumping leads the DC firm to invest more for product quality upgradation than a tariff policy. Consequently, the DC firm's product quality is relatively higher under the AD policy than under the tariff policy.*

As for the price of the high-quality product in the DC market, we have from (9c),(14), and (17a) that

$$p_h^{*T} > p_h^{*AD} > p_h^{*FT} \text{ if } \lambda > \frac{1}{3};\; p_h^{*AD} > p_h^{*T} > p_h^{*FT} \text{ if } \lambda < \frac{1}{3}.$$

Using the results in (8), (14), and (18a), we compare DC's demands for the high-quality product. It follows that

$$D_h^{*T} = D_h^{*AD} > D_h^{*FT}.$$

For comparing the prices of the low-quality product in the DC market, we have from (9c), (14), and (18b) that

$$p_l^{*AD} > p_l^{*T} > p_l^{*FT}.$$

As for DC's demands for the low-quality product, we have from (8), (14), and (18b) that

$$D_l^{*FT} = \frac{1}{3} > D_l^{*AD} = D_l^{*T} = 0.$$

Next, we look at firm profits, consumer surplus, and social welfare under the two protection policies against the LDC dumping under free trade. First, a comparison of the DC firm's profits in (15a)and (18c) reveals that

$$\Pi_{DC}^{AD} > \Pi_{DC}^{T}.$$

While, comparing profits across the three regimes through (10a),(15a), and (18c) yields

$$\Pi_{DC}^{AD} > \Pi_{DC}^{T} > \Pi_{DC}^{FT} \text{ if } \lambda > 0.6;\ \Pi_{DC}^{AD} > \Pi_{DC}^{FT} > \Pi_{DC}^{T} \text{ if } \lambda < 0.6.$$

We thus have the following proposition:

PROPOSITION 6. *DC's firm profit is higher when its government implements an AD policy than when its government implements a tariff policy.*

This proposition suggests that, compared to imposing import tariffs, imposing AD duties by the DC government against dumping benefits domestic industries. This may explain why the use of AD duties continues to be the policy option by DC countries when it comes to protecting domestic industries.

Concerning differences in impacts on consumer benefits, we have from (10a), (15b), and (18d) that the ranking of consumer surplus depends on the degree of international market competition. That is,

$$CS_{DC}^{T} > CS_{DC}^{FT} > CS_{DC}^{AD} \text{ if } \lambda < 0.7;$$

$$CS_{DC}^{FT} > CS_{DC}^{AD} > CS_{DC}^{T} \text{ if } \lambda > 0.7.$$

Finally, we look at differences in implications for social welfare. It follows from (10a) ,(15e), and (18e) that

$$SW_{DC}^{T} > SW_{DC}^{AD} > SW_{DC}^{FT} \text{ if } \lambda < 0.7;$$

$$SW_{DC}^{AD} > SW_{DC}^{FT} > SW_{DC}^{T} \text{ if } \lambda > 0.7.$$

We thus have:

PROPOSITION 7. *Consumer surplus and overall welfare in DC are higher under an AD policy than under a tariff policy when* λ *is critically high (i.e., when the DC-LDC income differential is* *smaller or when the DC and LDC markets are more similar and competitive). Otherwise, consumer surplus and overall welfare are relatively lower under an AD policy.*

The results in Propositions 6 and 7 have interesting policy implications. When the degree of competition between DC and LDC markets is sufficiently high, the process for filing an AD petition in DC is likely to be relatively easy. The economic reason is that firm profits, consumer benefits, and overall welfare (including duty revenue collected by an importing country government) in DC are all higher with an AD duty than with a tariff.

3.3.2 *Effects on LDC*

We now turn to the LDC market. The equilibrium prices of the low-quality product charged by the LDC firm (see equations 14 and 18b) under the two protection measures indicate that

$$p_l^T > p_l^{AD} \text{ if } \lambda > \frac{1}{6};\ p_l^{AD} > p_l^T \text{ if } \lambda < \frac{1}{6}.$$

Considering also the product prices under free trade, we have from (9c),(14), and (18b) that

$$p_l^T > p_l^{AD} > p_l^{FT} \text{ if } \lambda > \frac{1}{6};\ p_l^{AD} > p_l^T > p_l^{FT} \text{ if } \lambda < \frac{1}{6}.$$

With respect to LDC's demands for the low-quality product under the two protection measures, we have

$$D_l^T > D_l^{AD}.$$

Considering also the market demands under free trade, we have from (8), (14), and (18b) that

$$D_l^T > D_l^{AD} = D_l^{FT}.$$

In contrast, the price of the high-quality product that the DC firm charges in the LDC market is higher under a tariff policy than under an Ad policy. That is,

$$p_h^T > p_h^{AD}.$$

It comes as no surprise that the price of the high-quality product in the LDC market is the lowest under free trade.

$$p_h^T > p_h^{AD} > p_h^{FT}.$$

This ranking comes from comparing the results in (9c), (14), and (18a).

As for LDC's demands for the high-quality product under the alternative trade regimes, we have from (8), (14), and (18b) that

$$D_h^{FT} = D_h^{AD} > D_h^T.$$

Next, we look at LDC's firm profits, consumer surplus, and social welfare. Profits of the LDC firm, when the DC government adopts the protection regimes, are recorded in (15a) and (18c). It follows that

$$\pi_{LDC}^T > \pi_{LDC}^{AD}.$$

Considering also the LDC firm's profits free trade (see equation 10b), we have:

$$\pi_{LDC}^T > \pi_{LDC}^{FT} > \pi_{LDC}^{AD}.$$

These results to the following:

PROPOSITION 8. *LDC's firm profit is higher when the DC government implements a tariff policy than when it implements an AD policy.*

Concerning differences in impacts on consumer benefits between the two protection measures, we have from (15c) and (18d) that

$$CS_{LDC}^{AD} > CS_{LDC}^T.$$

Including the equilibrium level of consumer surplus under free trade (see equation 10b), the ranking is:

$$CS_{LDC}^{FT} > CS_{LDC}^{AD} > CS_{LDC}^T.$$

To see differences in implications for social welfare between the two protection measures, we have from (15e) and (18e) that

$$SW_{LDC}^{T} > SW_{LDC}^{AD}.$$

Including the equilibrium level of social welfare under free trade (see equation 10b), the ranking of welfare is:

$$SW_{LDC}^{T} > SW_{LDC}^{FT} > SW_{LDC}^{AD}.$$

We, therefore, have

PROPOSITION 9. *LDC consumers are better off under an AD policy than under a tariff policy. Nevertheless, LDC's overall welfare is higher under a tariff policy than under an AD policy.*

3.3.3 *Implications for global welfare*

Finally, we investigate differences in implications between the two protection measures from the perspective of global welfare. To do so, we calculate global welfare, denoted as *GW*, by aggregating the welfare of both DC and LDC under the alternative regimes (i.e., $GW^{j} = SW_{DC}^{j} + SW_{LDC}^{j}$ for $j = FT, AD, T$).

Making use of the results in (10b), (15e) and (18e), we have

$$GW^{FT} = \frac{(\lambda+1)(16\lambda+81\gamma_h+16)}{162\gamma_h},\ GW^{AD} = \frac{36\lambda+81\gamma_h+18\lambda^2+81\lambda\gamma_h+16}{162\gamma_h},$$

$$GW^{T} = \frac{-81\lambda^2+108\lambda+162\gamma_h+13}{162\gamma_h}.$$

An examination of the equilibrium levels of global welfare reveals that there are two possibilities:

(i) $GW^{AD} > GW^{FT} > GW^{T}$ if $\lambda > 0.8$;

(ii) $GW^{T} > GW^{AD} > GW^{FT}$ if $\lambda < 0.8$.

We thus have

PROPOSITION 10.*World welfare is higher when the DC government adopts an AD policy (against LDC dumping) than when the government adopts a tariff policy, provided that* λ *is critically high (i.e., when the DC and LDC markets are similar and competitive).Otherwise, world welfare is higher under a tariff policy than under an AD policy. Regardless of the degree of international market competition, AD policy is Pareto superior to free trade (under which LDC dumping arises).*

3.4. Concluding Remarks

In this paper, we analyze differences in welfare implications between two protection measures: import tariffs and antidumping duties, within a unified model of trade. Our two-market equilibrium model of trade allows for preference heterogeneity in consumer choices and the endogenous decisions of product quality by international duopolistic located in a DC and an LDC, respectively. We show that the LDC firm sells a low-quality product that is dumped into the DC market. We consider the two policy tools. In comparing AD duties to import tariffs, we find that the former is more likely to drive the LDC firm out from the DC market completely, while the latter does not affect the LDC firm's incentive for product quality upgradation. Imposing AD duties by the DC government encourages its firm to undertake more R&D investment for product quality upgradation than that under import tariffs. This result suggests that AD is a better policy option for increasing the domestic firm's product quality. Likewise, DC's firm profit is higher, with its government choosing an AD policy over an import tariff policy. AS for effects on DC consumers and domestic welfare, both are higher under the AD policy than under the tariff policy when the DC-LDC income differential is smaller (i.e., their markets are similar). However, it yields opposite results when the DC and LDC markets are dissimilar, or the degree of market competition is low.

In the context of an LDC firm that produces and exports a low-quality product, its profit is higher when an importing country (DC government) imposes tariffs than when there is an AD duty. For consumer surplus in the LDC, it is higher with the AD duty than with an import tariff, whereas for social welfare the converse is true.

The two-market equilibrium analysis of trade in quality-differentiated products has welfare implications for world trade. We show that world welfare is higher with DC government imposing an AD duty against LDC dumping than when there is a tariff policy, when the DC-LDC income differential is smaller or when the degree of market competition is high. In contrast, world welfare is higher under a tariff policy than under an AD policy when the DC-LDC income differential is greater or when the degree of market competition is lower.

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Appendix A - Appendix of Chapter 2

A-1. ***The determination of an optimal AD duty***

Under the AD regime, there is a three-stage game. At the third stage where there is price competition, the DC and LDC firms determine their product prices by solving the profit maximization problems. The FOCs for the DC firm are:

$$\frac{\partial \Pi_{DC}^{AD}}{\partial p_h^{*AD}} = (2p_h^{*AD} - p_l^{*AD} + tp_l^{*AD} - \lambda s_h^{AD} + \lambda s_l^{AD}) = 0 \text{ and } \frac{\partial \Pi_{DC}^{AD}}{\partial p_h^{AD}} = p_l^{AD} - 2p_h^{AD} + s_h^{AD} - s_l^{AD} = 0. \quad \text{(a.1)}$$

Moreover, the FOCs for the LDC firm are:

$$\frac{\partial \pi_{LDC}^{AD}}{\partial p_l^{*}} = (p_h^{*AD} - 2p_l^{*AD} + 2tp_l^{*AD}) = 0 \text{ and } \frac{\partial \pi_{LDC}^{AD}}{\partial p_l^{AD}} = \frac{p_h^{AD} - 2p_l^{AD}}{s_h^{AD} - s_l^{AD}} = 0. \quad \text{(a.2)}$$

Simultaneously taking into account the four-equation system in (a.1) and (a.2), we solve for the equilibrium prices of the high- and low-quality products in the DC and LDC markets as follows:

$$p_h^{*AD} = \frac{2\lambda(s_h^{AD} - s_l^{AD})}{3},\ p_h^{AD} = \frac{2(s_h^{AD} - s_l^{AD})}{3},\ p_l^{*AD} = \frac{\lambda(s_h^{AD} - s_l^{AD})}{3(1-t)},\ \text{and}\ p_l^{AD} = \frac{s_h^{AD} - s_l^{AD}}{3}.$$

We then calculate market demands for the two products in the DC and LDC markets:

$$D_l^{AD} = \theta^{AD} = \frac{1}{3},\ D_h^{AD} = 1 - \theta^{AD} = \frac{2}{3},\ D_l^{*AD} = \theta^{*AD} = \frac{2t-1}{3(t-1)}, \text{and}\ D_h^{*AD} = 1 - \theta^{*AD} = \frac{t-2}{3(t-1)}.$$

To solve for an optimal AD duty set by the DC government, we substitute prices and demands into the social welfare function of the DC:

$$SW_{DC}^{AD} = \underbrace{CS_l^{AD} + CS_h^{AD}}_{\text{Consumer surplus}} + \underbrace{\Pi_{DC}^{AD}}_{\text{Producer surplus}} + \underbrace{(p_l^{*AD} - p_l^{*FT})D_l^{*AD}}_{\text{Duty revenue}},$$

where the last term measures the total amount of duty revenue. It follows that

$$SW_{DC}^{AD} = \underbrace{\int_a^{\tilde{\theta}^{*AD}} [\theta^{*AD}\lambda(1+s_l^{AD}) - p_l^{*AD}]dF(\theta)}_{CS_l^{AD} \text{ in DC}} + \underbrace{\int_{\tilde{\theta}^{*AD}}^{a+1} [\lambda\theta^{*AD}(1+s_h^{AD}) - p_h^{*AD}]dF(\theta)}_{CS_h^{AD} \text{ in DC}}$$

$$+ \underbrace{[p_h^{AD}D_h^{AD} + p_h^{*AD}D_h^{*AD} - \frac{1}{2}\gamma_h(s_h^{AD})^2]}_{\Pi_{DC}^{AD}} + \underbrace{(p_l^{*AD} - p_l^{*FT})D_l^{*AD}}_{\text{Duty Revenue}}.$$

The FOC for the DC government is:

$$\frac{\partial SW_{DC}^{AD}}{\partial t} = \frac{\lambda(s_h^{AD} - s_l^{AD})(3a - 3t - 3at + 2)}{9(t-1)^3} = 0,$$

which implies that the optimal AD duty is: $t^{AD} = \dfrac{a+2}{a+3}$.

A-2 Effects on DC under the alternative trade regimes

(i) **The ranking of DC firm's optimal quality-upgrades**

Given that the optimal quality-upgrades under the three different regimes are:

$$s_h^{FT} = \frac{4\lambda + 4}{9\gamma_h}, \; s_h^{AD} = \frac{6\lambda + 4}{9\gamma_h}, \text{ and } s_h^{PU} = \frac{46\lambda + 9\lambda^2 + 9}{36\gamma_h + 36\lambda\gamma_h}.$$

It follows that

$$s_h^{AD} - s_h^{FT} = \frac{2\lambda}{9\gamma_h} > 0 \Rightarrow q_h^{AD} > q_h^{FT};$$

$$s_h^{AD} - s_h^{PU} = \frac{15\lambda^2 - 6\lambda + 7}{36\gamma_h(\lambda+1)} > 0 \Rightarrow q_h^{AD} > q_h^{PU};$$

$$s_h^{FT} - s_h^{PU} = \frac{7(\lambda-1)^2}{36\gamma_h(\lambda+1)} > 0 \Rightarrow q_h^{FT} > q_h^{PU}.$$

We thus have: $s_h^{AD} > s_h^{FT} > s_h^{PU} \Rightarrow q_h^{AD} > q_h^{FT} > q_h^{PU}$.

(ii) The ranking of DC firm's profits

Given that the optimal profits for the DC firm under the three different regimes are:

$$\Pi_{DC}^{AD} = \frac{2(3\lambda+2)^2}{81\gamma_h}, \; \Pi_{DC}^{FT} = \frac{8(\lambda+1)^2}{81\gamma_h}, \; \Pi_{DC}^{PU} = \frac{(9\lambda^2 + 46\lambda + 9)^2}{2592\gamma_h(\lambda+1)^2}.$$

it follows that

$$\Pi_{DC}^{AD} - \Pi_{DC}^{FT} = \frac{2\lambda(5\lambda+4)}{81\gamma_h} > 0 \Rightarrow \Pi_{DC}^{AD} > \Pi_{DC}^{FT};$$

$$\Pi_{DC}^{FT} - \Pi_{DC}^{PU} = \frac{7(\lambda-1)^2(25\lambda^2 + 78\lambda + 25)}{2592\gamma_h(\lambda+1)^2} > 0 \Rightarrow \Pi_{DC}^{FT} > \Pi_{DC}^{PU};$$

$$\Pi_{DC}^{AD} - \Pi_{DC}^{PU} = \frac{495\lambda^4 + 1092\lambda^3 + 90\lambda^2 + 452\lambda + 175}{2592\gamma_h(\lambda+1)^2} > 0 \Rightarrow \Pi_{DC}^{AD} > \Pi_{DC}^{PU}.$$

We thus have: $\Pi_{DC}^{AD} > \Pi_{DC}^{FT} > \Pi_{DC}^{PU}$.

(iii) The ranking of DC's consumer surplus

Given the equilibrium levels of consumer surplus in (14c), (19c), and (24c), we have

$$CS_{DC}^{FT} - CS_{DC}^{AD} = \frac{\lambda(5\lambda+2) - a\lambda(24+48\lambda+63a\lambda+36a)}{81\gamma_h};$$

$$\begin{aligned}&CS_{DC}^{FT} - CS_{DC}^{PU}\\ &= \frac{\lambda(1-\lambda)(209\lambda^3+973\lambda^2+787\lambda+79)}{2592\gamma_h(\lambda+1)^3}\\ &\quad + \frac{a\lambda(1-\lambda)(-252a\lambda^3-252a\lambda^2+252a\lambda+252a-444\lambda^3-996\lambda^2-324\lambda+228)}{2592\gamma_h(\lambda+1)^3}.\end{aligned}$$

To make a comparison, we need to determine restrictions on the parameter a for utility $V_{DC}(\theta^*) = \lambda\theta^* q_l - p_l^*$ to be strictly positive under any of the trade regimes. Note that $\theta^* \in [a, a+1]$, where $a > 0$. The utility of a DC consumer located at point a is:

$$V_{DC}(a) = \lambda\theta^* q_l - p_l^* = \lambda a(q_l) - p_l^* = \lambda a(1+s_l) - p_l^* = \lambda a(1+0) - p_l^* > 0.$$

Under free trade, $V_{DC}(a) = \lambda a - p_l^{*FT} = \lambda a - \frac{\lambda(4\lambda+4)}{27\gamma_h} > 0$ which implies that $a > \frac{4\lambda+4}{27\gamma_h}$.

Under AD, $V_{DC}(a) = \lambda a - p_l^{*AD} = \lambda a - \frac{\lambda(6\lambda+4)}{9\gamma_h} > 0$ which implies that $a > \frac{6\lambda+4}{9\gamma_h}$.

Under PU, $V_{DC}(a) = \lambda a - p_l^{*PU} = \lambda a - \frac{\lambda(9\lambda^2+46\lambda+9)}{54\gamma_h(1+\lambda)^2} > 0$ which implies that $a > \frac{(9\lambda^2+46\lambda+9)}{54\gamma_h(1+\lambda)^2}$.

For $V_{DC}(a) > 0$ under any of the trade regimes, the constrained condition is: $a > \frac{6\lambda+4}{9\gamma_h}$. We assume that this condition holds. Substituting this condition into the expression $(CS_{DC}^{FT} - CS_{DC}^{AD})$, as shown above, we find that $CS_{DC}^{FT} - CS_{DC}^{AD} < 0$ which implies that $CS_{DC}^{AD} > CS_{DC}^{FT}$. Substituting the constrained condition that $a > (6\lambda+4)/9\gamma_h$ into the expression $(CS_{DC}^{FT} - CS_{DC}^{PU})$, we find that $CS_{DC}^{FT} > CS_{DC}^{PU}$. We thus have: $CS_{DC}^{AD} > CS_{DC}^{FT} > CS_{DC}^{PU}$.

(iv) The ranking of DC's social welfare

Given the optimal levels of DC welfare under the three regimes in (14d), (19d), and (24d), we have

$$SW_{DC}^{AD} - SW_{DC}^{FT} = \frac{\lambda(5\lambda+6)}{81\gamma_h} + \frac{a\lambda(24+48\lambda+63a\lambda+36a)}{81\gamma_h} \Rightarrow SW_{DC}^{AD} > SW_{DC}^{FT};$$

$$\begin{aligned} &SW_{DC}^{FT} - SW_{DC}^{PU} \\ &= \frac{(1-\lambda)(34\lambda^4+427\lambda^3+787\lambda^2+625\lambda+175)}{2592\gamma_h(\lambda+1)^3} \\ &\quad + \frac{a(1-\lambda)(-252a\lambda^4-252a\lambda^3+252a\lambda^2+252a\lambda-444\lambda^4-996\lambda^3-324\lambda^2+228\lambda)}{2592\gamma_h(\lambda+1)^3}. \end{aligned}$$

Evaluating the above expression under the constrained condition that $a > (6\lambda+4)/9\gamma_h$, we find that $(SW_{DC}^{FT} - SW_{DC}^{PU}) > 0$ which implies that $SW_{DC}^{FT} > SW_{DC}^{PU}$. We thus have: $SW_{DC}^{AD} > SW_{DC}^{FT} > SW_{DC}^{PU}$.

A-3 Effects on DC under the three alternative trade regimes

(i) The ranking of LDC firm's profits

Given that maximum profits under the three different regimes are:

$$\pi_{LDC}^{FT} = \frac{(4\lambda+4)(\lambda+1)}{81\gamma_h},\ \pi_{LDC}^{AD} = \frac{6\lambda+4}{81\gamma_h}, \text{ and } \pi_{LDC}^{PU} = \frac{\lambda(9\lambda^2+46\lambda+9)}{81\gamma_h(\lambda+1)^2}.$$

it follows that

$$\pi_{LDC}^{FT} - \pi_{LDC}^{AD} = \frac{2\lambda(2\lambda+1)}{81\gamma_h} > 0 \Rightarrow \pi_{LDC}^{FT} > \pi_{LDC}^{AD};$$

$$\pi_{LDC}^{FT} - \pi_{LDC}^{PU} = \frac{(\lambda-1)^2(4\lambda^2+15\lambda+4)}{81\gamma_h(\lambda+1)^2} > 0 \Rightarrow \pi_{LDC}^{FT} > \pi_{LDC}^{PU};$$

$$\pi_{LDC}^{PU} - \pi_{LDC}^{AD} = -\frac{-3\lambda^3-30\lambda^2+5\lambda+4}{81\gamma_h(\lambda+1)^2}.$$

We thus have two possibilities:

(1) $\pi_{LDC}^{FT} > \pi_{LDC}^{PU} > \pi_{LDC}^{AD}$ when $\lambda > \hat{\lambda}_{LDC}$ (i.e., when income differential is getting smaller) and

(2) $\pi_{LDC}^{FT} > \pi_{LDC}^{AD} > \pi_{LDC}^{PU}$ when $\lambda < \hat{\lambda}_{LDC}$ (i.e., when income differential is getting greater).

(ii) The ranking of LDC's consumer surplus

Given the equilibrium levels of consumer surplus in (15c), (20b), and (25c), we have

$$CS_{LDC}^{FT} - CS_{LDC}^{AD} = \frac{-\lambda(9a^2 + 12a - 2)}{81\gamma_h};$$

$$CS_{LDC}^{PU} - CS_{LDC}^{AD}$$
$$= \frac{(-15\lambda^4 - 516\lambda^3 + 6\lambda^2 + 828\lambda + 209)}{2592\gamma_h(\lambda+1)^3}$$
$$- \frac{a(540a\lambda^4 + 864a\lambda^3 + 360a\lambda^2 + 288a\lambda + 252a + 612\lambda^4 + 600\lambda^3 + 480\lambda^2 + 936\lambda + 444)}{2592\gamma_h(\lambda+1)^3};$$

$$CS_{LDC}^{PU} - CS_{LDC}^{FT}$$
$$= \frac{(1-\lambda)(79\lambda^3 + 787\lambda^2 + 973\lambda + 209)}{2592\gamma_h(\lambda+1)^3}$$
$$+ \frac{(1-\lambda)(252a^2\lambda^3 + 252a^2\lambda^2 - 252a^2\lambda - 252a^2 + 228a\lambda^3 - 324a\lambda^2 - 996a\lambda - 444a)}{2592\gamma_h(\lambda+1)^3}.$$

Evaluating the above expressions under the constrained condition that $a > (6\lambda + 4)/9\gamma_h$, we have, $(CS_{LDC}^{FT} - CS_{LDC}^{AD}) < 0$ which implies that $CS_{LDC}^{AD} > CS_{LDC}^{FT}$. However, the comparison between CS_{LDC}^{PU} and CS_{LDC}^{AD} or that between CS_{LDC}^{PU} and CS_{LDC}^{FT} cannot be determined unambiguously. So, the only unambiguous ranking of LDC's consumer surplus is: $CS_{LDC}^{AD} > CS_{LDC}^{FT}$.

We present an alternative proof for the result that $CS_{LDC}^{AD} > CS_{LDC}^{FT}$ in the following. Under free trade, the equilibrium prices, demands, and R&D investments in product quality improvement by the DC and LDC firms are shown in (11), (12a), and (13). The LDC's consumer surplus under free trade contains two components: $CS_{LDC}^{FT} = CS_l^{FT} + CS_h^{FT}$, where

$$CS_l^{FT} = \int_a^{\hat\theta}[\theta(1+s_l) - p_l]dF(\theta) = (1+s_l)\int_a^{\hat\theta}\theta d\theta - p_l\int_a^{\hat\theta}d\theta = (1+s_l)\frac{1}{2}[(\hat\theta)^2 - a^2] - p_l(\hat\theta - a) \text{ and}$$

$$CS_h^{FT} = \int_{\hat\theta}^{a+1}[\theta(1+s_h) - p_h]dF(\theta) = (1+s_h)\int_{\hat\theta}^{a+1}\theta d\theta - p_h\int_{\hat\theta}^{a+1}d\theta = (1+s_h)\frac{1}{2}[(a+1)^2 - (\hat\theta)^2] - p_h[(a+1) - \hat\theta].$$

Plugging the results from (11), (12a), and (13) into the above expressions, we obtain the following:

$$CS_l^{FT} = (1+0)\frac{1}{2}\left[(\frac{1}{3})^2 - a^2\right] - \frac{4(\lambda+1)}{27\gamma_h}\left(\frac{1}{3} - a\right) = \frac{(3a-1)(8\lambda - 9\gamma_h - 27a\gamma_h + 8)}{162\gamma_h} \text{ and}$$

$$CS_h^{FT} = (1 + \frac{4(\lambda+1)}{9\gamma_h})\frac{1}{2}\left[(a+1)^2 - (\frac{1}{3})^2\right] - \frac{8(\lambda+1)}{27\gamma_h}\left[(a+1) - \frac{1}{3}\right] = \frac{(3a+2)(4a+12\gamma_h+4a\lambda+9a\gamma_1)}{54\gamma_h}.$$

We thus have the result that

$$CS_{LDC}^{FT} = CS_l^{FT} + CS_h^{FT} = \frac{48a - 8\lambda + 81\gamma_h + 48a\lambda + 162a\gamma_h + 36a^2\lambda + 36a^2 - 8}{162\gamma_h}.$$

Whereas under an AD policy, the optimal duty is shown in (17e), R&D investments in product quality improvement by the DC and LDC firms are shown in (18a) and (18c), and the equilibrium prices and demands are shown in (17f), (18e), and (18f). The LDC's consumer surplus under the AD policy contains two components: $CS_{LDC}^{AD} = CS_l^{AD} + CS_h^{AD}$, where

$$CS_l^{AD} = \int_a^{\hat{\theta}}[\theta(1+s_l) - p_l]dF(\theta) = (1+s_l)\int_a^{\hat{\theta}}\theta d\theta - p_l\int_a^{\hat{\theta}}d\theta = (1+s_2)\frac{1}{2}\left[(\hat{\theta})^2 - a^2\right] - p_2(\hat{\theta} - a);$$

$$CS_h^{AD} = \int_{\hat{\theta}}^{a+1}[\theta(1+s_h) - p_h]dF(\theta) = (1+s_h)\int_{\hat{\theta}}^{a+1}\theta d\theta - p_h\int_{\hat{\theta}}^{a+1}d\theta = (1+s_h)\frac{1}{2}\left[(a+1)^2 - (\hat{\theta})^2\right] - p_h[(a+1) - \hat{\theta}].$$

Plugging the equilibrium results under an AD policy into the above expressions, we have:

$$CS_l^{AD} == (1+0)\frac{1}{2}\left[(\frac{1}{3})^2 - a^2\right] - \frac{2(3\lambda+2)}{27\gamma_h}\left(\frac{1}{3} - a\right) = \frac{(3a-1)(12\lambda - 9\gamma_h - 27a\gamma_h + 8)}{162\gamma_h} \text{ and}$$

$$CS_h^{AD} = (1 + \frac{2(3\lambda+2)}{9\gamma_h})\frac{1}{2}\left[(a+1)^2 - (\frac{1}{3})^2\right] - \frac{2(3\lambda+2)}{27\gamma_h}\left((a+1) - \frac{1}{3}\right) = \frac{(3a+2)(4a+12\gamma_h+6a\lambda+9a\gamma_h)}{54\gamma_h}.$$

It follows that

$$CS_{LDC}^{AD} = CS_l^{AD} + CS_h^{AD} = \frac{48a - 12\lambda + 81\gamma_h + 72a\lambda + 162a\gamma_h + 54a^2\lambda + 36a^2 - 8}{162\gamma_h}.$$

Next, we look at the difference in surplus that LDC consumers obtain through consuming the high-quality product and the low-quality product, separately, between the two alternative regimes. We have:

$$\Delta CS_h = CS_h^{AD} - CS_h^{FT} = \frac{(3a+2)(4a+12\gamma_h+6a\lambda+9a\gamma_h)}{54\gamma_h} - \frac{(3a+2)(4a+12\gamma_h+4a\lambda+9a\gamma_h)}{54\gamma_h} = \frac{a\lambda(3a+2)}{27\gamma_h}$$

which implies that $CS_h^{AD} > CS_h^{FT}$ and

$$\Delta CS_l = CS_l^{AD} - CS_l^{FT} = \frac{(3a-1)(12\lambda-9\gamma_h-27a\gamma_h+8)}{162\gamma_h} - \frac{(3a-1)(8\lambda-9\gamma_h-27a\gamma_h+8)}{162\gamma_h} = \frac{2\lambda(3a-1)}{81\gamma_h}$$

which suggests that $CS_l^{AD} > CS_l^{FT}$. These results indicate that, under an AD regime, gains in surplus (ΔCS_h) to LDC consumers by enjoying the high-quality product with enhanced quality (due to DC firm's R&D investment in quality upgradation) exceed the losses in consumer surplus (ΔCS_l) that LDC consumers encounter when consuming the low-quality product at an increased price. Thus, compared to the result under free trade, LDC's consumer surplus is higher under an AD policy than under free trade.

(iv) The ranking of LDC's social welfare

Given the optimal levels of LDC welfare under the three regimes in (15d), (20c), and (25d), we have:

$$SW_{LDC}^{FT} - SW_{LDC}^{AD} = \frac{\lambda(4\lambda+4)}{81\gamma_h} - \frac{a\lambda(9a+12)}{81\gamma_h};$$

$$\begin{aligned} &SW_{LDC}^{PU} - SW_{LDC}^{FT} \\ &= \frac{(1-\lambda)(128\lambda^4+559\lambda^3+787\lambda^2+293\lambda+81)}{2592\gamma_h(\lambda+1)^3} \\ &\quad + \frac{a(1-\lambda)(252a\lambda^3+252a\lambda^2-252a\lambda-252a+228\lambda^3-324\lambda^2-996\lambda-444)}{2592\gamma_h(\lambda+1)^3}. \end{aligned}$$

Evaluating the above expressions for $a > (6\lambda+4)/9\gamma_h$, we find that $SW_{LDC}^{FT} - SW_{LDC}^{PU} > 0$ and $SW_{LDC}^{PU} - SW_{LDC}^{FT} > 0$. It follows that $SW_{LDC}^{PU} > SW_{LDC}^{FT} > SW_{LDC}^{AD}$.

(v) The ranking of global welfare

Given the optimal levels of global welfare as shown in(26a), (26b), and (26c), we have:

$$GW^{AD} - GW^{FT} = \frac{\lambda(36a+\lambda+48a\lambda+63a^2\lambda+45a^2+2)}{81\gamma_h} > 0;$$

$$GW^{FT} - GW^{PU} = \frac{(1-\lambda)^2(47\lambda^2+66\lambda+47)}{1296\gamma_h(1+\lambda)^2}$$

$$+\frac{a(1-\lambda)^2(126a\lambda^2+252a\lambda+126a+222\lambda^2+612\lambda+222)}{1296\gamma_h(1+\lambda)^2} > 0.$$

It follows that $GW^{AD} > GW^{FT} > GW^{PU}$.

Appendix B - Appendix of Chapter 3

A-1. ***The determination of an optimal AD duty***

Under the antidumping policy, we consider a three-stage game and solve for the sub-game Nash equilibrium using backward induction. At stage three, DC and LDC firms determine the optimal prices of their products in the DC and LDC markets by engaging in Bertrand competition. The FOCs for the DC firm are:

$$\frac{\partial \Pi_{DC}^{AD}}{\partial p_h^{*AD}} = (2p_h^{*AD} - p_l^{*AD} + tp_l^{*AD} - \lambda s_h^{AD} + \lambda s_l^{AD}) = 0,\ \frac{\partial \Pi_{DC}^{AD}}{\partial p_h^{AD}} = p_l^{AD} - 2p_h^{AD} + s_h^{AD} - s_l^{AD} = 0,$$

and the FOCs for the LDC firm are:

$$\frac{\partial \pi_{LDC}^{AD}}{\partial p_l^{*AD}} = (p_h^{*AD} - 2p_l^{*AD} + 2tp_l^{*AD}) = 0,\ \frac{\partial \pi_{LDC}^{AD}}{\partial p_l^{AD}} = \frac{p_h^{AD} - 2p_l^{AD}}{s_h^{AD} - s_l^{AD}} = 0.$$

Solving for the prices of high- and low-quality product, we have

$$p_h^{*AD} = \frac{2\lambda(s_h^{AD} - s_l^{AD})}{3},\ p_h^{AD} = \frac{2(s_h^{AD} - s_l^{AD})}{3},\ p_l^{*AD} = \frac{\lambda(s_h^{AD} - s_l^{AD})}{3(1-t)},\ \text{and}\ p_l^{AD} = \frac{s_h^{AD} - s_l^{AD}}{3}.$$

Substituting these prices into demands for the two products yields

$$D_h^{*AD} = \frac{2-t}{3(1-t)},\ D_h^{AD} = \frac{2}{3},\ D_l^{*AD} = \frac{2t-1}{3(t-1)},\ \text{and}\ D_l^{AD} = \frac{1}{3}.$$

To solve for an optimal AD duty set by the DC government, we substitute prices and demands into the social welfare function of the DC:

$$SW_{DC}^{AD} = \underbrace{CS_h^{AD} + CS_l^{AD}}_{\text{Consumer surplus}} + \underbrace{\Pi_{DC}^{AD}}_{\text{Producer surplus}} + \underbrace{(p_l^{*AD} - p_l^{*FT})D_l^{*AD}}_{\text{Duty revenue}},$$

where the last term measures the total amount of duty revenue. It follows that

$$SW_{DC}^{AD} = \underbrace{\int_{\tilde{\theta}^{*AD}}^{1}[\lambda\theta^{*AD}(1+s_h^{AD}) - p_h^{*AD}]dF(\theta)}_{CS_h^{AD}} + \underbrace{\int_0^{\tilde{\theta}^{*AD}}[\theta^{*AD}\lambda(1+s_l^{AD}) - p_l^{*AD}]dF(\theta)}_{CS_l^{AD}}$$

$$+\underbrace{[p_h^{AD}D_h^{AD} + p_h^{*AD}D_h^{*AD} - \frac{1}{2}\gamma_h(s_h^{AD})^2]}_{\Pi_{DC}^{AD}} + \underbrace{(p_l^{*AD} - p_l^{*FT})D_l^{*AD}}_{\text{Duty Revenue}}.$$

The FOC for the DC government is:

$$\frac{\partial SW_{DC}^{AD}}{\partial t} = \frac{\lambda(s_h^{AD} - s_l^{AD})(3t-2)}{9(t-1)^3} = 0,$$

which implies that the optimal AD duty is: $t^{AD} = 2/3$.

A-2 Effects on DC under the three different trade regimes

(i) **The ranking of DC firm's optimal quality-upgrades**

Given that the optimal quality-upgrades under the three alternative regimes are: $s_h^{FT} = (4\lambda+4)/9\gamma_h$, $s_h^{AD} = (6\lambda+4)/9\gamma_h$, and $s_h^{T} = (9\lambda+1)/9\gamma_h$, we have

$$s_h^{AD} - s_h^{FT} = \frac{2\lambda}{9\gamma_h} > 0 \Rightarrow q_h^{AD} > q_h^{FT};\ s_h^{AD} - s_h^{T} = \frac{1-\lambda}{3\gamma_h} > 0 \Rightarrow q_h^{AD} > q_h^{T};$$

$$s_h^{T} - s_h^{FT} = \frac{5\lambda-3}{9\gamma_h} > 0 \text{ if } \lambda > 0.60.$$

It follows that there are two possibilities:

$$s_h^{AD} > s_h^{T} > s_h^{FT} \Rightarrow q_h^{AD} > q_h^{T} > q_h^{FT} \text{ if } \lambda > 0.60.$$

$$s_h^{AD} > s_h^{T} > s_h^{FT} \Rightarrow q_h^{AD} > q_h^{FT} > q_h^{T} \text{ if } \lambda < 0.60.$$

R&D expenditures are: $E_h^{AD} = 2(3\lambda+2)^2/81\gamma_h$, $E_{DC}^{T} = (9\lambda+1)^2/162\gamma_h$, $E_h^{FT} = 8(1+\lambda)^2/81\gamma_h$. We have: $E_{DC}^{AD} - E_{DC}^{T} = \dfrac{5(-3\lambda^2+2\lambda+1)}{54\gamma_h} > 0$; $E_{DC}^{T} - E_{DC}^{FT} = \dfrac{-(-65\lambda^2+14\lambda+15)}{162\gamma_h}$ >0 if λ >0.6.

It follows that there are two possibilities:

$$E_{DC}^{AD} > E_{DC}^{T} > E_{DC}^{FT} \text{ if } \lambda > 0.6;\ E_{DC}^{AD} > E_{DC}^{FT} > E_{DC}^{T} \text{ if } \lambda < 0.6.$$

(ii) The ranking of DC firm's prices of the high-quality product

The equilibrium prices of the high-quality product in three alternative regimes are:

$$p_h^{*FT} = \frac{8\lambda(1+\lambda)}{27\gamma_h},\ p_h^{*AD} = \frac{2\lambda(6\lambda+4)}{27\gamma_h}, \text{and } p_h^{*T} = \frac{\lambda(9\lambda+1)}{9\gamma_h},$$

which imply that

$$p_h^{*AD} - p_h^{*T} = \frac{5\lambda(1-3\lambda)}{27\gamma_h} \Rightarrow p_h^{*T} > p_h^{*AD} \text{ if } \lambda > \frac{1}{3} \text{ and } p_h^{*T} < p_h^{*AD} \text{ if } \lambda < \frac{1}{3};$$

$$p_h^{*AD} - p_h^{*FT} = \frac{4\lambda^2}{27\gamma_h} > 0 \Rightarrow p_h^{*AD} > p_h^{*FT};$$

$$p_h^{*T} - p_h^{*FT} = \frac{\lambda(19\lambda-5)}{27\gamma_h} > 0 \text{ if } \lambda > \frac{5}{19};\ p_h^{*T} < p_h^{*FT} \text{ if } \lambda < \frac{5}{19}.$$

It follows that

$$p_h^{*T} > p_h^{*AD} > p_h^{*FT} \text{ if } \lambda > \frac{1}{3};\ p_h^{*AD} > p_h^{*T} > p_h^{*FT} \text{ if } \lambda < \frac{1}{3}.$$

(iii) The ranking of LDC firm's prices of the low-quality product

The optimal prices of the low-quality product in three alternative regimes are: $\tilde{p}_l^{*AD} = \lambda(6\lambda+4)/9\gamma_h$, $p_l^{*T} = \lambda(9\lambda+1)/9\gamma_h$, $p_l^{*FT} = 4\lambda(1+\lambda)/27\gamma_h$. It follows that

$$\tilde{p}_l^{*AD} - p_l^{*T} = \frac{\lambda(1-\lambda)}{3\gamma_h} > 0;\ p_l^{*T} - p_l^{*FT} = \frac{\lambda(1-\lambda)}{3\gamma_h} > 0. \text{ We thus have: } p_l^{*AD} > p_l^{*T} > p_l^{*FT}.$$

(iv) The ranking of demands for the high-quality product in the DC market

The equilibrium level of market demands of high-quality product in the DC market under three alternative regimes are: $D_h^{*AD} = 1-\tilde{\theta}^* = 1$, $D_h^{*T} = (1-\tilde{\theta}) = 1$, and $D_h^{*FT} = (1-\hat{\theta}^*) = 2/3$. Thus, the ranking is:

$$D_h^{*T} = D_h^{*AD} > D_h^{*FT}.$$

(v) The ranking of demands for the low-quality product in the DC market

The equilibrium demands for the low-quality product in the DC market under three alternative regimes are: $\tilde{D}_l^{*AD} = \tilde{\theta}^* = 0$, $D_l^{*T} = \tilde{\theta} = 0$, and $D_l^{*FT} = \hat{\theta}^* = 1/3$. Thus, the ranking is: $D_l^{*FT} > D_l^{*T} = D_l^{*AD}$.

(vi) The ranking of DC firm's profits

Given that the optimal profits for the DC firm under the three alternative regimes are: $\Pi_{DC}^{FT} = 8(1+\lambda)^2/81\gamma_h$, $\Pi_{DC}^{AD} = 2(3\lambda+2)^2/81\gamma_h$, $\Pi_{DC}^{T} = (9\lambda+1)^2/162\gamma_h$. It follows that

$$\Pi_{DC}^{AD} - \Pi_{DC}^{T} = \frac{5(-3\lambda^2+2\lambda+1)}{54\gamma_h} > 0 \Rightarrow \Pi_{DC}^{AD} > \Pi_{DC}^{T};$$

$$\Pi_{DC}^{AD} - \Pi_{DC}^{FT} = \frac{2\lambda(5\lambda+4)}{81\gamma_h} > 0 \Rightarrow \Pi_{DC}^{AD} > \Pi_{DC}^{FT};$$

$$\Pi_{DC}^{T} - \Pi_{DC}^{FT} = \frac{(65\lambda^2 - 14\lambda - 5)}{162\gamma_h} > 0 \text{ if } \lambda > \frac{3}{5};\ \Pi_{DC}^{T} < \Pi_{DC}^{FT} \text{ if } \lambda < \frac{3}{5}.$$

We thus have: $\Pi_{DC}^{AD} > \Pi_{DC}^{T} > \Pi_{DC}^{FT}$ if $\lambda > 0.6$; $\Pi_{DC}^{AD} > \Pi_{DC}^{FT} > \Pi_{DC}^{T}$ if $\lambda < 0.6$.

(vii) The ranking of DC's consumer surplus

Given that the optimal profits for the DC firm under the three alternative regimes are: $CS_{DC}^{AD} = \frac{\lambda(27\gamma_h - 6\lambda - 4)}{54\gamma_h}$, $CS_{DC}^{T} = \frac{-18\lambda^2 + 7\lambda + 9\gamma_h + 1}{18\gamma_h}$, and $CS_{DC}^{FT} = \frac{\lambda(81\gamma_h - 8\lambda - 8)}{162\gamma_h}$, it follows that

$$CS_{DC}^{FT} - CS_{DC}^{AD} = \frac{\lambda(5\lambda+2)}{81\gamma_h} > 0 \Rightarrow CS_{DC}^{FT} > CS_{DC}^{AD};$$

$$CS_{DC}^{T} - CS_{DC}^{AD} = \frac{\lambda(25\lambda + 27\gamma_h - 27\lambda\gamma_h - 4)}{54\gamma_h} > 0 \text{ if } \lambda < \hat{\lambda};\ CS_{DC}^{T} < CS_{DC}^{AD} \text{ if } \lambda > \hat{\lambda}.$$

We thus have two possibilities:

$$CS_{DC}^{T} > CS_{DC}^{FT} > CS_{DC}^{AD} \text{ if } \lambda < \hat{\lambda};\ CS_{DC}^{FT} > CS_{DC}^{AD} > CS_{DC}^{T} \text{ if } \lambda > \hat{\lambda}.$$

(viii) The ranking of DC's social welfare

Given that DC's welfare in the three regimes are:

$$SW_{DC}^{FT} = \frac{24\lambda + 8\lambda^2 + 81\lambda\gamma_h + 16}{162\gamma_h},\ SW_{DC}^{AD} = \frac{36\lambda + 18\lambda^2 + 81\lambda\gamma_h + 16}{162\gamma_h},$$

$$SW_{DC}^{T} = \frac{-81\lambda^2 + 81\lambda + 81\gamma_h + 10}{162\gamma_h}.$$

It follows that

$$SW_{DC}^{AD} - SW_{DC}^{FT} = \frac{\lambda(5\lambda+6)}{81\gamma_h} > 0 \Rightarrow SW_{DC}^{AD} > SW_{DC}^{FT};$$

$$SW_{DC}^{AD} - SW_{DC}^{T} = \frac{33\lambda^2 - 27\gamma_h - 15\lambda + 27\lambda\gamma_h + 2}{54\gamma_h}.$$

$$\Rightarrow SW_{DC}^{AD} > SW_{DC}^{T} \text{ if } \lambda > 0.7;\ SW_{DC}^{T} > SW_{DC}^{AD} \text{ if } \lambda < 0.7;$$

$$SW_{DC}^{FT} - SW_{DC}^{T} = \frac{89\lambda^2 - 81\gamma_h - 57\lambda + 81\lambda\gamma_h + 6}{162\gamma_h}$$

$$\Rightarrow SW_{DC}^{FT} > SW_{DC}^{T} \text{ if } \lambda > 0.7;\ SW_{DC}^{T} > SW_{DC}^{FT} \text{ if } \lambda < 0.7.$$

We thus have two possibilities:

$$SW_{DC}^{T} > SW_{DC}^{AD} > SW_{DC}^{FT} \text{ if } \lambda < 0.7;\ SW_{DC}^{AD} > SW_{DC}^{FT} > SW_{DC}^{T} \text{ if } \lambda > 0.7.$$

A-3 Effects on LDC under the three alternative regimes

(i) The ranking of prices for the high-quality product in the LDC market

The optimal prices of the high-quality product in three alternative regimes are:

$$p_h^{T} = \frac{4(9\lambda+1)}{27\gamma_h},\ p_h^{AD} = \frac{2(6\lambda+4)}{27\gamma_h},\ p_h^{FT} = \frac{8(1+\lambda)}{27\gamma_h},$$

It follows that

$$p_h^{T} - p_h^{AD} = \frac{4(6\lambda-1)}{27\gamma_h} > 0 \Rightarrow p_h^{T} > p_h^{AD};\ p_h^{AD} - p_h^{FT} = \frac{4\lambda}{27\gamma_h} > 0 \Rightarrow p_h^{AD} > p_h^{FT}.$$

We thus have:

$$p_h^{T} > p_h^{AD} > p_h^{FT}.$$

(ii) The ranking of prices for the low-quality product prices in LDC market

The optimal prices of the low-quality product in the three alternative regimes are:

$$p_l^{T} = \frac{2(9\lambda+1)}{27\gamma_h},\ p_l^{AD} = \frac{6\lambda+4}{27\gamma_h},\ p_l^{FT} = \frac{4(1+\lambda)}{27\gamma_h}.$$

It follows that

$$p_l^{AD} - p_l^{FT} = \frac{2\lambda}{27\gamma_h} > 0 \Rightarrow p_l^{AD} > p_l^{FT};\ p_l^{FT} - p_l^{T} = \frac{2(1-7\lambda)}{27\gamma_h} \Rightarrow p_l^{FT} < p_l^{T};$$

$$p_l^{AD} - p_l^{T} = \frac{2(1-6\lambda)}{27\gamma_h} \Rightarrow p_l^{T} > p_l^{AD} \text{ if } \lambda > \frac{1}{6};\ p_l^{AD} > p_l^{T} \text{ if } \lambda < \frac{1}{6}.$$

We thus have:

$$p_l^{T} > p_l^{AD} > p_l^{FT} \text{ if } \lambda > \frac{1}{6};\ p_l^{AD} > p_l^{T} > p_l^{FT} \text{ if } \lambda < \frac{1}{6}.$$

(iii) The ranking of demands for the low-quality product in the LDC market

Given that the optimal levels of market demands in the LDC market under the three alternative regimes are: $D_l^{FT} = \frac{1}{3}$, $D_l^{AD} = \frac{1}{3}$, $D_l^{T} = \frac{1}{6}$. Thus, we can rank the market demands as: $D_l^{T} > D_l^{AD} = D_l^{FT}$.

(iv) The ranking of demands for the high-quality product in the DC market

Given that the optimal levels of market demands in the DC market under the three alternative regimes are:

$D_h^{FT} = \frac{2}{3}$, $D_h^{AD} = \frac{2}{3}$, $D_h^{T} = \frac{1}{3}$. We thus have: $D_h^{AD} = D_h^{FT} > D_h^{T}$.

(v) The ranking of LDC's firm profit

Given that maximum profits under the three alternative regimes are: $\pi_{LDC}^{FT} = \frac{4(1+\lambda)^2}{81\gamma_h}$,

$\pi_{LDC}^{AD} = \frac{6\lambda+4}{81\gamma_h}$, and $\pi_{LDC}^{T} = \frac{4(9\lambda+1)}{81\gamma_h}$, it follows that

$$\pi_{LDC}^{T} - \pi_{LDC}^{AD} = \frac{10\lambda}{27\gamma_h} > 0 \Rightarrow \pi_{LDC}^{T} > \pi_{LDC}^{AD}; \pi_{LDC}^{FT} - \pi_{LDC}^{AD} = \frac{2\lambda(2\lambda+1)}{81\gamma_h} > 0 \Rightarrow \pi_{LDC}^{FT} > \pi_{LDC}^{AD}.$$

Thus, $\pi_{LDC}^{T} > \pi_{LDC}^{FT} > \pi_{LDC}^{AD}$.

(vi) The ranking of DC's consumer surplus

Given that the optimal profits for the DC firm under the three alternative regimes are:

$$CS_{LDC}^{FT} = \frac{81\gamma_h - 8\lambda - 8}{162\gamma_h},\ CS_{LDC}^{AD} = \frac{81\gamma_h - 12\lambda - 8}{162\gamma_h},\ CS_{LDC}^{T} = \frac{81\gamma_h - 99\lambda - 11}{162\gamma_h};$$

It follows that

$$CS_{LDC}^{FT} - CS_{LDC}^{T} = \frac{91\lambda+3}{162\gamma_h} > 0 \Rightarrow CS_{LDC}^{FT} > CS_{LDC}^{T}; CS_{LDC}^{FT} - CS_{LDC}^{AD} = \frac{4\lambda}{162\gamma_h} > 0 \Rightarrow CS_{LDC}^{FT} > CS_{LDC}^{AD};$$

$$CS_{LDC}^{AD} - CS_{LDC}^{T} = \frac{29\lambda+1}{54\gamma_h} > 0 \Rightarrow CS_{LDC}^{AD} > CS_{LDC}^{T}.$$

We thus have:

$$CS_{LDC}^{FT} > CS_{LDC}^{AD} > CS_{LDC}^{T}.$$

(vii) The ranking of LDC's social welfare

The optimal levels of social welfare in the LDC under the three alternative regimes are: $SW_{LDC}^{FT} = \frac{8\lambda^2 + 8\lambda + 81\gamma_h}{162\gamma_h}$, $SW_{LDC}^{AD} = \frac{1}{2}$, and $SW_{LDC}^{T} = \frac{9\lambda + 27\gamma_h + 1}{54\gamma_h}$. It follows that

$$SW_{LDC}^{FT} - SW_{LDC}^{AD} = \frac{4\lambda(\lambda+1)}{162\gamma_h} > 0 \Rightarrow SW_{LDC}^{FT} > SW_{LDC}^{AD};$$

$$SW_{LDC}^{FT} - SW_{LDC}^{T} = \frac{8\lambda^2 - 19\lambda - 3}{162\gamma_h} > 0 \Rightarrow SW_{LDC}^{FT} > SW_{LDC}^{T};$$

$$SW_{LDC}^{T} - SW_{LDC}^{AD} = \frac{9\lambda + 1}{54\gamma_h} > 0 \Rightarrow SW_{LDC}^{T} > SW_{LDC}^{AD}.$$

We thus have:

$$SW_{LDC}^{T} > SW_{LDC}^{FT} > SW_{LDC}^{AD}.$$

A-4 Effects on global welfare

We have global welfare, denoted as *GW*, by aggregating the social welfare of DC and LDC under three regimes (i.e., $GW = SW_{DC} + SW_{LDC}$):

$$GW^{FT} = \frac{(\lambda+1)(16\lambda + 81\gamma_h + 16)}{162\gamma_h},\ GW^{AD} = \frac{36\lambda + 81\gamma_h + 18\lambda^2 + 81\lambda\gamma_h + 16}{162\gamma_h},$$

$$GW^{T} = \frac{-81\lambda^2 + 108\lambda + 162\gamma_h + 13}{162\gamma_h}.$$

It follows that

$$GW^{AD} - GW^{FT} = \frac{\lambda(\lambda+2)}{81\gamma_h} > 0 \Rightarrow GW^{AD} > GW^{FT};$$

$$GW^{T} - GW^{FT} = \frac{-97\lambda^2 + 81\gamma_h + 76\lambda - 81\lambda\gamma_h - 3}{162\gamma_h}$$

$$\Rightarrow GW^{T} > GW^{FT} \text{ if } \lambda < \hat{\lambda};\ GW^{FT} > GW^{T} \text{ if } \lambda > \hat{\lambda};$$

$$GW^{AD} - GW^{T} = \frac{33\lambda^2 - 27\gamma_h - 24\lambda + 27\lambda\gamma_h + 1}{54\gamma_h}$$

$$\Rightarrow GW^{AD} > GW^{T} \text{ if } \lambda > \hat{\lambda}\,; GW^{T} > GW^{AD} \text{ if } \lambda < \hat{\lambda}\,.$$

Hence, we have two possibilities for the ranking of global welfare:

$$GW^{AD} > GW^{FT} > GW^{T} \text{ if } \lambda > \hat{\lambda};$$

$$GW^{T} > GW^{AD} > GW^{FT} \text{ if } \lambda < \hat{\lambda}.$$