Dumping on Free Trade, Optimal Antidumping Duties, and Price Undertakings: Welfare Implications in a Two-Market Equilibrium Analysis

by

Yang-Ming Chang[†] and Mian F. Raza[‡]

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Abstract: For evaluating dumping according to the GATT/WTO guidelines in comparing the prices of a product sold in home and foreign markets, we develop a two-market equilibrium model of trade that allows for endogenous quality upgrading by duopolistic firms located separately in a developed country (DC) and a less-developed country (LDC) with income differentials. The key findings and policy implications are as follows. (i) The DC firm produces a high-quality product, whereas the LDC firm produces a low-quality product which is dumped in the DC market under free trade. (ii) Dumping benefits the LDC firm at the expense of the DC firm, unless the dumping firm is charged with an antidumping (AD) duty by the DC government. (iii) The use of AD laws for imposing fines on foreign dumping is welfare increasing to the DC. (iv) It is welfare improving for the LDC to restrain its exporting firm not to dump, but to accept price undertaking (by setting the price of the low-quality product identical to that in its local market). (iv) From the perspective of "global" welfare, measured by aggregating the DC welfare and the LDC welfare, the trade damage measure of an optimal AD policy against dumping is Pareto-superior.

Keywords: dumping, free trade, antidumping duties, price undertaking, product quality, welfare
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[†]Department of Economics, Kansas State University, 319 Waters Hall, Manhattan, Kansas 66506-4001, Tel: (785)532-4573, Fax: (785) 532-6919, E-mail: ymchang@ksu.edu
[‡]Department of Economics, Kansas State University, 327 Waters Hall, Manhattan, Kansas 66506-4001; Tel: 785-532-7357; Fax: 785-532-6919; E-mail: mianfarrukhraza@ksu.edu

I. Introduction

In 2011 Whirlpool, an American manufacturer of washing machines, 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 U.S. ITC documented that Mexican manufacturers were dumping washing machines to the U.S. at about 36% to 72% below their market prices, and also South Korean manufacturers undercut the prices by 9% to 82%. The ITC findings further confirmed that such unfair trade practices by the Mexican and South Korean manufacturers materially hurt the U.S. manufacturers. Consequently, the U.S. government to impose antidumping (AD) duties on both Mexican and South Korean washers at 72% and 82%, respectively (Reuters 2012; Metal Bulletin 2014). The imposition of AD duties by the U.S. government was not limited to the washing machines. For instance, in 2014 the U.S. Commerce Department imposed AD charges against exporters of solar panels from China and Taiwan after finding that the products were sold at a low price that significantly injured the U.S. manufacturers (Reuters 2014). These cases exemplify dumping of consumption goods into a developed country (DC), where its government opts policy choices such as an antidumping duty to protect domestic manufacturers.[1]

In the frequently observed environments where LDC firms are exporters of cheap and low-quality products, there is growing concern over the large-scale dumping of these products in international markets - especially in the import-competing markets of DCs. Considering the seriousness of trade abuses by LDC firms, should LDC governments restrain their exporters not to practice dumping in international markets? What are conditions under which the governments of import-competing countries (DCs) find it welfare-improving by imposing antidumping duties to protect domestic producers? Will antidumping as a trade remedy policy necessarily be of trade protectionism? Will the Pareto superiority of free trade continue to hold in the world trading system despite the frequent observations on the global dumping of cheaper low-quality products by LDC firms? Defining "global" welfare as the aggregation of social welfare of DC and LDC trading partners, can global welfare be higher under an AD policy than under free trade? This paper attempts to provide answers to these questions by developing a two-market equilibrium

[1] It should be noted that the imposition of an AD duty is not restricted to DC, as recently some less-developed countries (LDCs) started imposing AD duties against DC firms for their unfair trade practices. For details on traditional (DCs) and new antidumping duty users (LDCs), see the systematic analysis and review by Blonigen and Prusa (2016).

analysis, which is consistent with the GATT/WTO guidelines for identifying dumping.[2]

In retrospective, there have been considerable debates about whether the use of antidumping policy constitutes a protectionist trade measure. Contributions in the literature on the economic effects of AD policy are enormous.[3] Following the GATT/WTO guideline on dumping, we present a model of product differentiation under international duopolistic competition with endogenous product-quality decisions by home and foreign firms (located in DC and LDC, respectively) to compare their equilibrium product prices in two markets. This two-market equilibrium price analysis permits us to identify economic conditions under which dumping arises, without resorting to the usual assumption of an exogenously-determined "normal value" for a dumped import in a one-market analysis. Our objectives for the analysis are twofold. One is to evaluate whether the trade abuse of dumping is *welfare-deteriorating* for an exporting country when its firm dumps a low-quality product at a price lower than the price of the product in its local market and is charged with an antidumping (AD) fine by an importing country government. The other is to evaluate whether an AD law is welfare improving for an importing country with its firm manufacturing and exporting a high-quality product. Moreover, from the perspective of global welfare, we wish to evaluate whether the trade remedy measure of imposing AD fines is Pareto-inferior as compared to worldwide free trade.

In this paper, we analyze and compare differences in the welfare implications of three different trade regimes: dumping on free trade, AD duties, and price undertakings. Our analysis allows for the endogenous decisions on the quality of products by two competing firms in international markets. In the two-way free trade between home and foreign countries (which are

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[2] The "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*."

[3] 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 Dixit (1988), Prusa (1992, 1994, 2001), Fischer (1992), Reitzes (1993), Anderson (1992, 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), Niels (2000), and Nelson (2006). For recent issues on antidumping such as the Continued Dumping and Subsidy Offset Act implemented by the U.S. government under which the revenues from AD fines are redistributed to domestic firms alleging harm see, e.g., Collie and Vandenbussche (2006), Evenett (2006) and Chang and Gayle (2006). For issues concerning antidumping measures and their various economic effects see, e.g., Vandenbuscche 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.

considered as a DC and an LDC, respectively, due to their income differentials), the DC firm is shown to be a high-quality producer due to its economic incentive to invest in R&D activities for product quality improvements. However, the LDC firm is shown to be a low-quality producer as it does not see any stimulus to participate in quality upgradation. Following the GATT/WTO guidelines, we further identify the economic conditions under which dumping arises. The key findings are summarized as follows: (i) The DC firm that manufactures and exports a high-quality finds it profitable not to dump. Nevertheless, the LDC firm that produces a low-quality product finds it profitable to dump at a price lower than the price of the product in its local market.[4] (ii) The optimal level of a quality-upgrade through costly R&D investment is the highest for the DC firm when its government imposes an AD policy on foreign dumping, but is the lowest when the LDC firm accepts a price undertaking. (iii) The DC firm makes the highest profit when its government imposes an AD policy on dumping by the LDC firm. However, the DC firm's profit is the lowest when the LDC firm accepts a price undertaking. (iv) DC consumers enjoy the highest benefit under foreign dumping but are hurt the most when their government imposes an AD policy, provided that DC-LDC income differential is sufficiently small (that is, when both markets are sufficiently similar). However, for a sufficiently large DC-LDC income differential (i.e., when both markets are sufficiently dissimilar), consumers in DC are hurt the most when the LDC firm accepts a price undertaking. (v) The overall welfare of the DC is the highest when its government imposes an AD policy, but is the lowest when the LDC firm is allowed to accept a price undertaking. (vi) The LDC firm's profit is the highest when it dumps a low-quality product in the DC market without being convicted of paying the AD duty, but the profit is the lowest when the DC government imposes an effective AD policy, provided that the DC-LDC income differential is sufficiently large. Whereas, when the income differential is sufficiently small, the LDC firm makes the lowest profit in accepting a price undertaking. (vii) Consumer surplus in the LDC is at the highest level when its exporting firm accepts a price undertaking, but is at the lowest level when the DC government imposes AD fines on dumping. (viii) The overall welfare of the LDC is the highest when its exporting firm accepts a price undertaking, but is the lowest when the LDC dumping firm is charged with AD fines by the DC

[4] Prusa (2001) empirically documents that till 1980s approximately 95% of the antidumping actions are taken by DCs against LDCs. Vandenbussche and Zanardi (2008) find that the later trend shows that LDCs are highly involved in AD actions compared to DCs. Bown (2011a, b) contends that AD actions are concentrated across traditional users (DCs) and new AD users (LDCs). A recent contribution by Blonigen and Prusa (2016) documents that based on the *size* of AD duties, DCs remain to be the largest AD policy users against the practice of dumping by firms from LDCs.

government. (ix) Global welfare, measured by aggregating the welfare of both DC and LDC altogether, is the highest when the DC government imposes an AD policy, but is the lowest when the DC government allows the dumping firm to accept a price undertaking. From the perspective of global welfare, the trade damage measure of imposing an optimal AD policy against dumping is Pareto-superior.

This paper is related to the analysis of Hansen and Neilsen (2009) which examines the GATT/WTO rules of implementing antidumping measures in a model that takes into account horizontal and vertical product differentiation. Their findings suggest that the GATT/WTO rules of allowing the domestic firm to implement AD measure, if exposed to price discrimination, are not fair. This is because the process of calculating injury is inaccurate as it does not consider quality differences in computing the margin of price-undercutting. Hansen and Neilsen (2009) indicate that product quality differences allow high-quality producers to opt protectionism, suggesting such differences in countries ability to implement AD measures to be more beneficial to the firms manufacturing high-quality products (that is, the developed world).

Our study also relates to the recent contribution of González and Viaene (2015) that analyzes issues on dumping and antidumping. The connections and differences between the two studies deserve further addresses. First, we consider the case of a full covered market where good is a necessity for consumers, while they consider a partially covered market. Second, our paper examines consumer surplus, producer surplus and social welfare of each trading country under three policy options (free trade, antidumping and price undertaking). We further analyze and compare global welfare (combined welfare of two trading nations) under the alternative trade policies. In contrast, González and Viaene (2015) pay particular attention to issues related to product quality reversal in intra-industry trade. Third, our results indicate that LDC firm produces a low-quality product and dumps the product in DC market on free trade, whereas Gonzales and Viaene suggest that the DC firm dumps its high-quality product in the LDC market. Fourth, we find that R&D investment for product quality improvement is at the highest level for the DC firm when its government imposes an AD duty on foreign dumping which, in turn, enhances the quality of its high-quality product. To the contrary, Gonzales and Viaene find that the LDC government's imposition of an AD duty on the DC's dumping firm helps the LDC firm to achieve quality reversal of its low-quality product. Finally, our paper shows that the imposition of an AD policy by DC government is welfare enhancing to the DC, as well as and

the world (both DC and LDC taken together). This result stands in stark contrast with the finding of Gonzales and Viaene. The authors show that an AD policy is welfare-enhancing to an imposing country (an LDC) at the expense of global welfare.

We organize the remainder of the paper as follows. In Section 2, we first lay out an analytical framework of vertical product differentiation to analyze international competition of duopolistic firms in DC and LDC markets. We consider three different trade regimes: free trade with the presence of dumping, an antidumping policy by an importing country suffering from dumping, and price undertaking. In Section 3, we compare firm profits, consumer surplus, and social welfare in DC and LDC under the alternative trade regimes. Section 4 contains policy implications and concluding remarks.

2. Analytical Framework

2.1 *Basic Assumptions*

To follow the GATT/WTO guidelines on dumping, we present a two-market analysis for comparing equilibrium prices of a product sold in home and foreign countries (which are considered as a DC and an LDC, respectively, due to their income differentials). We first identify economic conditions under which dumping arises. We then evaluate the resulting impacts on the social welfare of the DC and LDC under different trade regimes. For simplicity, we consider a stylized import-export model of an international duopoly in which two firms produce "like" products with vertical differentiation and compete in their domestic markets, as well as in the markets abroad. The firm located in the DC with relatively more affluent consumers in its market, will be shown to manufacture and export a high-quality product. We denote the DC firm with the subscript "*h*," representing that its product quality is high. The firm located in the LDC with relatively less affluent consumers in its market, will be shown to manufacture and export a low-quality product. We denote the LDC firm with the 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 $\lambda \in (0,1)$ for characterizing the degree of income differentials between DC and LDC. Despite income differentials, we examine the case that each firm, located in DC or LDC, not only sells a product to consumers in its

domestic market, but also exports the same product to the competing firm's market. This approach allows one to verify the emergency of dumping by comparing the equilibrium prices of each product in two different markets.

(i) LDC market

We first look at the LDC market where there is a uniform distribution of consumers over a unit line. Each consumer purchases one unit of the product, either high-quality or low-quality, which is taken to be a necessity to all citizens in the LDC.[5] 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, the indirect utility function of an LDC consumer located at point $\theta \in [0,1]$ is specified as follows:

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

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

To allow for upgradation in product quality through costly investment by the competing firms, we follow the approach in Chang and Raza (2018) and assume 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 the 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 the DC firm's strategic choice of product quality is relatively higher than the LDC firm's.[6] That is, $s_h > s_l \geq 0$. The quality-upgrade decisions of the competing firms are endogenous in our model. As in the R&D investment literature, we assume each firm's quality-upgrading expenditure takes a quadratic form: $E_i = \gamma_i s_i^2/2$, where parameter γ_i denotes the cost-effectiveness of investment by firm $i(=h,l)$.

Given consumer heterogeneity in tastes for quality $\theta \in [0,1]$ in the LDC market, the marginal consumer who is indifferent between the high-quality product and the low-quality

[5] 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).

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

product implies that $\theta(1+s_h)-p_h=\theta(1+s_l)-p_l$. The critical value of θ is calculated as $\hat{\theta}=(p_h-p_l)/(s_h-s_l)$, where $1>\hat{\theta}>0$ for $p_h>p_l>0$ and $s_h>s_l\geq 0$. It follows that demands for the low-quality and high-quality products in the LDC market are given, respectively, as

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

We shall show that the DC firm chooses to manufacture and export the high-quality product, whereas the LDC firm chooses to manufacture and export the low-quality product.

(ii) DC market

As for the DC, we use the superscript "*" to denote all the related variables. There is a uniform distribution of DC consumers over a unit line, $\theta^*\in[0,1]$, with each buying one unit of the 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. Note that there is income differential between the DC consumers and the LDC consumers, which is captured by the parameter $\lambda\in(0,1)$. The indirect utility function of a DC consumer located at point $\theta^*\in[0,1]$ is specified as follows:

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

The incorporation of the parameter λ in (4) follows directly from Tirole (1988) that consumer taste for quality is *inversely* related to the marginal utility of income. Other things being equal, the marginal utility of consumption is strictly lower for consumers in DC than in LDC. This DC-LDC income differential implies that $\lambda\theta^* q_i<\theta q_i$ for $\theta^*=\theta$ and a given level of product quality. That is, 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 with a high degree of competition. When the value of λ decreases and approaches to 0, however, the two markets become increasingly dissimilar with a low degree of competition. This suggests that the degree of market similarity/dissimilarity (λ) plays an important role in characterizing the price interaction between 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 $\lambda\theta^*(1+s_h)-p_h^*=\lambda\theta^*(1+s_l)-p_l^*$. We calculate the critical value of θ^* as $\tilde{\theta}^*=(p_h^*-p_l^*)/[\lambda(s_h-s_l)]$, where $1>\tilde{\theta}^*>0$ for $p_h^*>p_l^*>0$ and

$s_h > s_l \geq 0$. In the DC market, demands for both the low-quality and high-quality products are:

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

In the two-market framework of trade, the DC's demand for the low-quality product defines its import of the product from the LDC. Likewise, LDC's demand for the high-quality product defines its import of the product from the DC.

We proceed to analyze conditions under which there is dumping in the DC and the LDC markets by using the framework of vertical product differentiation. Three policy options we consider are: (i) free trade, (ii) the imposition of an antidumping duty, and (iii) price undertaking.

2.2 Dumping under Free Trade

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

We begin with the second stage where the two firms compete in setting prices of products sold in the DC and LDC markets by solving their respective 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} in (5). From (6), we can derive the first-order conditions (FOCs) for both firms. It can be verified that the optimal prices of the high- and low-quality products in the LDC market are:

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

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

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

The issue of concern is whether any firm sells a product in the foreign market at a price lower than the price of the product 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 that the DC firm charges in the DC and LDC markets, It follows from (7a) and (7b) that

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

which implies that

$$p_h^{FT} > p_h^{*FT}. \tag{8a}$$

The inequality in (8a) indicates that the price of the high-quality product is strictly *higher* in the LDC market than in the DC market. Thus, the DC firm as a high-quality producer finds it profitable *not* to practice dumping in the LDC market.

We then 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. It follows from (7a) and (7b) that

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

which implies that

$$p_l^{*FT} (= \lambda p_l^{FT}) < p_l^{FT}. \tag{8b}$$

The result in (8b) indicates that the price of the low-quality product is strictly *lower* in the DC market than in the LDC market. Based on the WTO/GATT guidelines, dumping arises! The LDC firm as 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 market prices from (7a) back to (3), we obtain the equilibrium demands for the high- and low-quality products in the LDC market:

$$D_h^{FT} = (1 - \hat{\theta}^{FT}) = \frac{2}{3} \text{ and } D_l^{FT} = \hat{\theta}^{FT} = \frac{1}{3}. \tag{9}$$

Substituting market prices from (7b) back to (5), we get the equilibrium demands for the high- and low-quality products in the DC market:

$$D_h^{*FT} = (1-\tilde{\theta}^{*FT}) = \frac{2}{3} \text{ and } D_l^{*FT} = \tilde{\theta}^{*FT} = \frac{1}{3}. \quad (10)$$

At stage one, the DC and LDC firms determine their optimal quality-upgrades, $\{s_h^{FT}, s_l^{FT}\}$. To find the solution, we plug the firms' prices from (7) and their demands from (9)-(10) back into the profit functions in (6). We then derive the FOCs for the DC and LDC firms with respect to s_h^{FT} and s_l^{FT}, respectively. This exercise yields

$$s_h^{FT} = \frac{4\lambda + 4}{9\gamma_h} > 0 \text{ and } s_l^{FT} = 0. \quad (11)$$

It follows that the optimal R&D expenditures on product quality improvements by the firms are:

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

These results lead to the first corollary:

COROLLARY 1. *In the framework of free trade between a DC and an LDC, the DC firm (a high-quality producer) has an economic incentive to invest in R&D activities for quality improvements. However, the LDC firm (a low-quality producer) does not find it profitable to participate in quality upgradation.*

By substituting the optimal quality-upgrades from (11) back into (7a)-(7b), we obtain the equilibrium prices of the high- and low-quality products in the LDC market:

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

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

$$p_h^{*FT} = \frac{8\lambda(1+\lambda)}{27\gamma_h} \text{ and } p_l^{*FT} = \frac{4\lambda(1+\lambda)}{27\gamma_h}. \quad (13b)$$

Making use of market demands from (9)-(10), product prices from (13a)-(13b), and the profit function in (6), we calculate the total profit for the DC firm in the two markets as

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

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

$$CS_{DC}^{FT} = \underbrace{\int_{\tilde{\theta}^{*FT}}^{1} [\lambda\theta^{*FT}(1+s_h^{FT}) - p_h^{*FT}]dF(\theta)}_{CS_h^{FT}} + \underbrace{\int_{0}^{\tilde{\theta}^{*FT}} [\theta^{FT}\lambda(1+s_l^{FT}) - p_l^{*FT}]dF(\theta)}_{CS_l^{FT}}. \quad (14b)$$

By substituting market demands, product prices and quality-upgrades from (9)-(13) into (14b), we calculate consumer surplus in the DC as

$$CS_{DC}^{FT} = \frac{\lambda(81\gamma_h - 8\lambda - 8)}{162\gamma_h}. \quad (14c)$$

Defining social welfare for the DC as the sum of consumer surplus and the total profit of the DC firm, $SW_{DC}^{FT} = CS_{DC}^{FT} + \Pi_{DC}^{FT}$, we substitute CS_{DC}^{FT} and Π_{DC}^{FT} from (14a) and (14c) into the expression. This yields

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

Now turning to the LDC, we calculate total profit from the LDC firm in the two markets by substituting demands, prices, and quality-upgrades from (9)-(13) back into (6). This yields

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

The consumer surplus measure of the LDC is: $CS_{LDC}^{FT} = CS_h^{FT} + CS_l^{FT}$, where CS_h^{FT} and CS_l^{FT} represent benefits to LDC consumers from enjoying the high- and low-quality products under free trade. That is,

$$CS_{LDC}^{FT} = \underbrace{\int_{\hat{\theta}^{FT}}^{1} [\theta^{FT}(1+s_h^{FT}) - p_h^{FT}]dF(\theta)}_{CS_h^{FT}} + \underbrace{\int_{0}^{\hat{\theta}^{FT}} [\theta^{FT}(1+s_l^{FT}) - p_l^{FT}]dF(\theta)}_{CS_l^{FT}}. \quad (15b)$$

Substituting market demands, product prices and quality-upgrades from (9)-(13) into (15b) yields consumer surplus in the LDC as

$$CS_{LDC}^{FT} = \frac{81\gamma_h - 8\lambda - 8}{162\gamma_h}. \quad (15c)$$

The social welfare of the LDC 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 follows that social welfare in the LDC is:

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

Based on the results of the above analyses, we establish the first proposition:

PROPOSITION 1. *Considering the case of free trade between a DC and an LDC where the DC firm produces a high-quality product and the LDC firm produce a low-quality product, the DC*

firm finds it profitable not to dump. Nevertheless, the LDC firm finds it profitable to dump at a price lower than the price of the product in its local market.

The results of Proposition 1 have significant implications for the WTO guidelines on identifying the circumstances under which dumping arises. Under free trade, high-quality products are not dumped. Nevertheless, low-quality products are always dumped. These results are consistent with the frequent observations regarding the large-scale dumping of cheap low-quality products by less-developed countries in international markets. The practice of dumping is a serious problem in the import-competing markets of developed countries. Our theoretical prediction is supported by some empirical findings showing that developed countries had been the target of dumping by exporting firms from LDCs under free trade. For instance, Prusa (2001) finds that till 1908s 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 DC government imposes an antidumping policy on LDC dumping.

2.3 Antidumping Policy

In section 2.2, we find that the LDC firm produces a low-quality product and practices dumping in the DC market by charging a price, p_l^{*FT}, which is strictly *lower* than the price of the product in the LDC market, p_l^{FT}. In response to dumping and following the WTO guidelines, the DC government imposes an *ad valorem* duty, *t*, up to the *dumping margin*. We consider the case in which the duty rate is 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 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 means that the DC government can elevate, through using its AD laws, the price of the low-quality product in the DC market up to level identical to p_l^{FT}, which is the free-trade price of the

product in the LDC local market. We then re-define this price level of p_l^{FT} to be p_l^{*AD}, i.e., $p_l^{FT} = p_l^{*AD}$, 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 saying that $p_l^{*FT} = (1-t) p_l^{*AD}$.

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

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

Multiply both sides of this equation by D_l^{*AD}, which denotes the quantity of the low-quality product imported by the DC under the AD regime, we have an expression for measuring 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 determined by the DC government, there is new set of demand equations for high- and low-quality products in the DC market. We derive this set of market demands in DC by replacing the free-trade price, p_l^{*FT}, in (5) with $(1-t) p_l^{*AD}$. We then have

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

Whereas, demand equations for the high- and low-quality products in the LDC market remain same (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 independently and simultaneously determine optimal levels of quality-upgrades, s_h^{AD} and s_l^{AD}, to maximize their respective profits. At stage two, the DC government imposes an antidumping duty on the LDC firm to prevent it from practicing dumping in the DC market. At stage three, the two competing firms choose their profit-maximizing prices by engaging the Bertrand competition in the DC and LDC markets. To solve for the sub-game Nash equilibrium under the AD regime, we use backward induction.

At the third stage of price competition, the DC and LDC firms determine their product

prices by solving the new profit maximization problems:

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

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

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 LDC and DC markets are:

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

Substituting prices from (17a) back into (16a)-(16b) yields the equilibrium demands for the two products in the LDC and DC markets:

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

A comparison between $\tilde{p}_l^{*AD}$ and p_l^{AD} in (17a), which are the prices of the low-quality product 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, by the DC government raises the price of the low-quality product, as compared to the product's price under free trade without the AD policy. This suggests that imposing AD fines on foreign dumping constitutes an effective policy in promoting "fair" price competition.

At the second stage of policy decision, the DC government determines an optimal AD duty that maximizes its social welfare, $SW_{DC}^{AD} = (CS_h^{AD} + CS_l^{AD}) + \Pi_{DC}^{AD} + tp_l^{*AD} D_l^{*AD}$, which is the sum of consumer surplus (from purchasing the high-quality and low-quality products), its firm's profit (net of R&D cost), and duty revenue under the AD policy. The objective of the DC government is to set an optimal *ad valorem* duty rate that maximizes the social welfare function:

$$\begin{aligned}\underset{\{t\}}{\text{Max}}\, SW_{DC}^{AD} = {} & \underbrace{\int_{\tilde{\theta}^{*AD}}^{1} [\lambda\theta^{*AD}(1+s_h^{AD}) - p_h^{*AD}]dF(\theta)}_{CS_h^{AD}} + \underbrace{\int_{0}^{\tilde{\theta}^{*AD}} [\theta^{*AD}\lambda(1+s_l^{AD}) - p_l^{*AD}]dF(\theta)}_{CS_l^{AD}} \\ & + \underbrace{[p_h^{AD} D_h^{AD} + p_h^{*AD} D_h^{*AD} - \frac{1}{2}\gamma_h (s_h^{AD})^2]}_{\Pi_{DC}^{AD}} + \underbrace{tp_l^{*AD} D_l^{*AD}}_{\text{Duty Revenue}},\end{aligned} \tag{17d}$$

where prices and demands are given in (17a)-(17b). Note that duty revenue in the last term of the welfare function is given by $tp_l^{*AD}D_l^{*AD} = (p_l^{*AD} - p_l^{*FT})D_l^{*AD}$. The FOC for the DC government implies that the optimal AD duty:[7]

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

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

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

At the third and last 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), we have

$$\frac{\partial \pi_{LDC}^{AD}}{\partial s_l^{AD}} = \gamma_l s_l^{AD} - \gamma_l s_l^{AD} - \frac{1}{9} = -\frac{1}{9} < 0, \tag{18a}$$

which implies there is a corner solution: $s_l^{AD} = 0$. Quality upgradation is thus economically unattractive to the LDC firm since its optimal 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 level of quality-upgrades s_h that maximizes its profits. Substituting prices and demands from (17f) into the profit function of the DC firm in (16c), we have the firm's profit maximization problem:

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

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 LDC firm's R&D expenditure for product quality improvement is:

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

[7] See Appendix A-1 for a detailed derivation of the optimal AD duty.

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

$$p_h^{*AD} = \frac{2\lambda(6\lambda+4)}{27\gamma_h}, \quad p_l^{*AD} = \frac{\lambda(6\lambda+4)}{9\gamma_h}, \; D_l^{*AD} = \tilde{\theta}^{*AD} = 0, \text{ and } D_h^{*AD} = 1-\tilde{\theta}^{*AD} = 1. \tag{18e}$$

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

$$p_h^{AD} = \frac{2(6\lambda+4)}{27\gamma_h}, \; p_l^{AD} = \frac{6\lambda+4}{27\gamma_h}, \; D_h^{AD} = 1-\hat{\theta}^{AD} = \frac{2}{3}, \text{ and } D_l^{AD} = \hat{\theta}^{AD} = \frac{1}{3}. \tag{18f}$$

The final step of the analysis is to calculate profits, consumer surplus, and social welfare of the DC and LDC under the AD regime. First, we calculate the DC firm's profits (Π_{DC}^{AD}) by substituting (18a) back into (16c). This yields

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

The consumer surplus of the DC is: $CS_{DC}^{AD} = CS_h^{AD} + CS_l^{AD}$, which is

$$CS_{DC}^{AD} = \underbrace{\int_{\tilde{\theta}^{*AD}}^{1} [\lambda\theta^{*AD}(1+s_h^{AD}) - p_h^{*AD}]dF(\theta)}_{CS_h^{AD}} + \underbrace{\int_{0}^{\tilde{\theta}^{*AD}} [\theta^{*AD}\lambda(1+s_l^{AD}) - p_l^{*AD}]dF(\theta)}_{CS_l^{AD}} \tag{19b}$$

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

$$CS_{DC}^{AD} = \frac{\lambda(27\gamma_h - 6\lambda - 4)}{54\gamma_h}. \tag{19c}$$

The social welfare of the DC is: $SW_{DC}^{AD} = CS_{DC}^{AD} + \Pi_{DC}^{AD} + t^{AD} p_l^{*AD} D_l^{*AD}$. Making use of the results in (19a)-(19c), we calculate the optimal social welfare for the DC:

$$SW_{DC}^{AD} = \frac{36\lambda + 18\lambda^2 + 81\lambda\gamma_h + 16}{162\gamma_h}. \tag{19d}$$

Now, 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 consumer surplus of the LDC is: $CS_{LDC}^{AD} = CS_h^{AD} + CS_l^{AD}$, that is,

$$CS_{LDC}^{AD} = \underbrace{\int_{\hat{\theta}^{AD}}^{1}[\theta(1+s_h^{AD}) - p_h^{AD}]dF(\theta)}_{CS_h^{AD}} + \underbrace{\int_{0}^{\hat{\theta}^{AD}}[\theta(1+s_l^{AD}) - p_l^{AD}]dF(\theta)}_{CS_l^{AD}}.$$

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

$$CS_{LDC}^{AD} = \frac{81\gamma_h - 12\lambda - 8}{162\gamma_h}. \tag{20b}$$

The social welfare of the LDC is: $SW_{LDC}^{AD} = CS_{LDC}^{AD} + (\pi_{LDC}^{AD} - t^{AD} p_l^{*AD} D_l^{*AD})$. Making use of (17e)-(17f) and (20a)-(20b), we calculate the optimal level of social welfare for the LDC:

$$SW_{LDC}^{AD} = \frac{1}{2}. \tag{20c}$$

The results as shown in (17f) 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 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 completely driven out of the DC market* $(i.e., \tilde{D}_l^{*AD} = 0)$.

Various studies analyzing the impact of antidumping duty through partial and general equilibrium model suggest that AD duty remarkably decreases imports (Murray and Rousslang 1989; Gallaway et al. 1999; Bloneign 2016). In addition to that, Besedeš and Prusa (2017) empirically investigate how AD duties affect US imports in terms of the timings of the antidumping actions. The study finds firms negatively affected by AD investigations tend not to return to the market even after the AD order is no longer in effect. It indicates AD actions are likely to "cause exporters to abandon the US market." Proposition 2 offers a theoretical explanation to the empirical observation that market demand for the dumped product is zero $(\tilde{D}_l^{*AD} = 0)$ in equilibrium under the AD regime.

Moreover, Prusa (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.

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 below its local market, the LDC firm may accept price undertaking as a business strategy to evade its payment of an AD fine. Under a price undertaking regime, an exporting firm has the option of setting product price identical to that in the firm's local market. That is, the LDC firm sets $p_l^{PU} = p_l^{*PU}$ in its profit maximization decision using equation (3). As such, demands of the high- and low-quality products in the DC and LDC markets are:

$$\bar{D}_h^{PU} = 1 - \frac{p_h^{PU} - p_l^{*PU}}{s_h^{PU} - s_l^{PU}},\ \bar{D}_l^{PU} = \frac{p_h^{PU} - p_l^{*PU}}{s_h^{PU} - s_l^{PU}};\ \text{and}$$

$$D_h^{*PU} = 1 - \frac{p_h^{*PU} - p_l^{*PU}}{\lambda(s_h^{PU} - s_l^{PU})},\ D_l^{*PU} = \frac{p_h^{*PU} - p_l^{*PU}}{\lambda(s_h^{PU} - s_l^{PU})}. \tag{21}$$

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

At the second stage of price competition, 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 profit maximization problem of the LDC firm 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 solve for the optimal prices of the competing products by the DC and LDC firms. 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 prices from (22c) back into (21), we calculate demands for the high- and low-quality products in the LDC and the DC markets as follows:

$$\bar{D}_l^{PU} = \hat{\theta}^{PU} = \frac{\lambda+3}{6(1+\lambda)},\ \bar{D}_h^{PU} = 1 - \hat{\theta}^{PU} = \frac{5\lambda+3}{6(1+\lambda)};\ \text{and}$$

$$D_2^{*PU} = \tilde{\theta}^{*PU} = \frac{3\lambda+1}{6(1+\lambda)},\ D_h^{*PU} = 1 - \tilde{\theta}^{*PU} = \frac{3\lambda+5}{6(1+\lambda)}. \tag{22d}$$

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

$$\underset{\{s_h^{PU}\}}{\text{Max}}\ \Pi_{DC}^{PU} = \frac{(s_h^{PU} - s_l^{PU})(9\lambda^2 + 46\lambda + 9)}{36(1+\lambda)} - \frac{1}{2}\gamma_h (s_h^{PU})^2;$$

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

Using (23a), we derive the 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 LDC market:

$$p_h^{PU} = \frac{(5\lambda+3)(9\lambda^2+46\lambda+9)}{216\gamma_h(1+\lambda)^2},\ p_l^{PU} = \frac{\lambda(9\lambda^2+46\lambda+9)}{54\gamma_h(1+\lambda)^2},\ D_h^{PU} = \frac{5\lambda+3}{6(1+\lambda)},\ D_l^{PU} = \frac{\lambda+3}{6(1+\lambda)}, \tag{23c}$$

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

$$p_h^{*PU} = \frac{\lambda(3\lambda+5)(9\lambda^2+46\lambda+9)}{216\gamma_h(1+\lambda)^2},\ p_l^{*PU} = \frac{\lambda(9\lambda^2+46\lambda+9)}{54\gamma_h(1+\lambda)^2},\ D_h^{*PU} = \frac{3\lambda+5}{6(1+\lambda)},\ D_l^{*PU} = \frac{3\lambda+1}{6(1+\lambda)}. \tag{23d}$$

Note that $p_l^{PU} = p_l^{*PU}$ in the case of a price undertaking.

A comparison of demands for the low- and high-quality 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 DC government's trade damage measure of imposing an optimal AD fine to drive the LDC firm out of the DC market, the availability of a price undertaking makes it possible for the LDC firm to have a positive market share in the DC market.* [8] *Moreover, the market share of the DC firm is higher under a price undertaking than under free trade with the presence of foreign dumping.*

Having determined the equilibrium prices and demands in the DC and LDC markets, we calculate profits, consumer surplus, and social welfare. First, making use of prices in (23c),

[8] 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.

demands in (23d), the profit function in (22a), we calculate total profit for the DC firm:

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

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

$$CS_{DC}^{PU} = \underbrace{\int_{\theta^{PU}}^{1}[\lambda\theta(1+s_h^{PU}) - p_h^{*PU}]dF(\theta)}_{CS_h^{PU}} + \underbrace{\int_{0}^{\theta^{PU}}[\lambda\theta^{PU}(1+s_l^{PU}) - p_l^{*PU}]dF(\theta)}_{CS_l^{PU}}. \tag{24b}$$

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

$$CS_{DC}^{PU} = \frac{\lambda(1296\gamma_h - 1220\lambda - 954\lambda^2 + 252\lambda^3 + 81\lambda^4 + 3888\lambda\gamma_h + 3888\lambda^2\gamma_h + 1296\lambda^3\gamma_h - 207)}{2592\gamma_h(1+\lambda)^3}. \tag{24c}$$

The social welfare of the DC is: $SW_{DC}^{PU} = CS_{DC}^{PU} + \Pi_{DC}^{PU}$. Making use of Π_h^{PU} in (24a) and CS_{DC}^{PU} in (24c), we have

$$SW_{DC}^{PU} = \frac{702\lambda + 1886\lambda^2 + 2152\lambda^3 + 1161\lambda^4 + 162\lambda^5 + 1296\lambda\gamma_h + 3888\lambda^2\gamma_h + 3888\lambda^3\gamma_h + 1296\lambda^4\gamma_h + 81}{2592\gamma_h(1+\lambda)^3}. \tag{24d}$$

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

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

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

$$CS_{LDC}^{PU} = \underbrace{\int_{\hat{\theta}}^{1}(\theta(1+s_h) - p_h)dF(\theta)}_{CS_h^{PU}} + \underbrace{\int_{0}^{\hat{\theta}}(\theta(1+s_l) - p_l)dF(\theta)}_{CS_l^{PU}}, \tag{25b}$$

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

$$CS_{LDC}^{PU} = \frac{252\lambda + 1296\gamma_h - 954\lambda^2 - 1220\lambda^3 - 207\lambda^4 + 3888\lambda\gamma_h + 3888\lambda^2\gamma_h + 1296\lambda^3\gamma_h + 81}{2592\gamma_h(1+\lambda)^3}. \tag{25c}$$

The social welfare of the LDC is: $SW_{LDC}^{PU} = CS_{LDC}^{PU} + \pi_{LDC}^{PU}$, where π_{LDC}^{PU} and CS_{LDC}^{PU} are given in (25a) and (25c). After substituting and rearranging terms, we have

$$SW_{LDC}^{PU} = \frac{540\lambda + 1296\gamma_h + 806\lambda^2 + 540\lambda^3 + 81\lambda^4 + 3888\lambda\gamma_h + 3888\lambda^2\gamma_h + 1296\lambda^3\gamma_h + 81}{2592\gamma_1(1+\lambda)^3}. \tag{25d}$$

3. Regime Comparison and Policy Recommendations

Having derived the equilibrium outcomes for three trade regimes (free trade with the presence of dumping, antidumping, and price undertaking), we proceed to compare differences among the regimes in affecting the incentives of undertaking costly R&D investments by the

competing firms in DC and LDC for product quality improvements. Moreover, we investigate how the alternative trade regimes affect profits, consumer surplus, as well as the overall welfare of each trading nation (DC or LDC).

3.1 *Effects on DC*[9]

We first look at quality-upgrades optimally chosen by the competing firms and the resulting quality levels of their products under the alternative trade regimes. It follows from the findings in (11), (18c), and (23b) that

$$s_{DC}^{AD} > s_{DC}^{FT} > s_{DC}^{PU}$$

which implies that

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

We thus have

PROPOSITION 4. *The optimal level of quality-upgrade for a product through costly R&D investment is the highest for the DC firm when its government imposes an AD policy on foreign dumping, but is the lowest when the LDC firm accepts a price undertaking.*

Proposition 4 suggests that the endogeneity of product-quality decisions chosen by the DC firm depends crucially on the type of trade policies implemented by its government. Our finding, that price undertaking reduces the economic incentive of the DC firm for product quality improvement, is consistent with the study of Vandenbuscche and Wauthy (2001) that analyzes how antidumping measures of the European Union affect product quality decisions of firms. Their finding indicates, among other things, that price undertaking leads to lower product quality in the competitive domestic industries of an importing country.

Next, we compare the profits of the DC firm under the different trade regimes. It follows from (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. *The DC firm makes the highest profit when its government imposes an AD fine against the practice of dumping by the LDC firm. However, the profit of the DC firm turns out to be the lowest when the LDC firm is allowed to accept a price undertaking.*

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

Proposition 5 suggests that the DC firm has a strong incentive to lobby its government to impose AD fines on the LDC firm that dumps its low-quality product. Further, our proposition is supported by several empirical studies documenting that AD duty increases domestic profits (Morkre and Kelly 1999; DeVault 1996; Bloneign 2016).

Based on the results in (14c), (19c), and (24c), we analyze how the DC consumers are affected by foreign dumping. In comparing CS_{DC}^{AD} and CS_{DC}^{PU}, we find that the comparison depends on the value of λ as follows:

$$CS_{DC}^{PU} > CS_{DC}^{AD} \text{ when } \lambda > \hat{\lambda}_{DC};\ CS_{DC}^{AD} > CS_{DC}^{PU} \text{ when } \lambda < \hat{\lambda}_{DC},$$

where $\hat{\lambda}_{DC}$ is the critical value of income differential that makes DC consumers indifferent between the AD regime and a price undertaking. However, the comparison between CS_{DC}^{FT} and CS_{DC}^{AD} (or CS_{DC}^{PU}) is straightforward as follows:

$$CS_{DC}^{FT} > CS_{DC}^{AD} \text{ and } CS_{DC}^{FT} > CS_{DC}^{PU}.$$

Taking together the rankings of consumer surplus in the DC market, we have two possibilities.

Case 1: When $\lambda > \hat{\lambda}_{DC}$ (i.e., when income differential is sufficiently small such that the DC and LDC markets have a high degree of similarity or competition), we have

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

Case 2: When $\lambda < \hat{\lambda}_{DC}$ (i.e., when income differential is sufficiently large such that the DC and LDC markets have a low degree of similarity or competition), we have

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

The economic implications of the results are summarized as follows:

PROPOSITION 6. *DC consumers enjoy the highest benefit under free trade in the presence of foreign dumping, regardless of the income differential between DC and LDC. However, the comparison between an AD policy and a price undertaking in their effects on DC consumers depends crucially on market similarity/dissimilarity between DC and LDC. (i) DC consumers are hurt the most by the AD policy when the income differential is sufficiently small or when the DC and LDC markets are sufficiently similar. (ii) DC consumers are hurt the most by a price undertaking when the income differential is sufficiently large or when the DC and LDC markets are sufficiently dissimilar).*

The results in Proposition 6 suggest that DC consumers are hurt the most with the implementation of antidumping duties. These results are consistent with the findings of empirical studies (see, e.g., Devault, 1996).

To see the welfare implications of the alternative trade regimes for the DC, we look at the welfare equations as shown in (14d), (19d), and (25d). It follows that

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

We, therefore, have

PROPOSITION 7. *The overall welfare of the DC is the highest when its government imposes an AD policy, but is the lowest when the LDC firm is allowed to accept a price undertaking.*

The finding in 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 findings of the study indicate 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. But 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 AD duty.

3.2 *Effects on LDC*[10]

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

[10] See Appendix A-3 for detailed derivations of the results in this section.

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

where $\hat{\lambda}_{LDC}$ is the critical value of the DC-LDC 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 profits for the LDC firm, there are two possibilities.

Case 1: When $\lambda > \hat{\lambda}_{LDC}$ (i.e., when income differential is sufficiently small such that the DC and LDC markets have a high degree of similarity or competition), we have

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

where π_{LDC}^{AD} is the LDC firm's profit only from its domestic market.

Case 2: (i.e., when income differential is sufficiently large such that the DC and LDC markets have a low degree of similarity or competition), 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. *Depending on the degree of market similarity and dissimilarity, we have:*
(i) Profit of the LDC firm is highest when it dumps a low-quality product in the DC market without being convicted of paying the AD duty, but is the lowest when the DC government imposes an effective AD policy, provided that the inter-country income differential is sufficiently large.
(ii) Profit of the LDC firm is highest when it dumps a low-quality product in the DC market without being convicted of paying the AD duty, but is the lowest when the LDC firm accepts a price undertaking, provided that the inter-country income differential is sufficiently small.

The ranking of consumer surplus in LDC under the alternative trade regimes, based on the results in (15c), (20c), and (25c), is:

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

PROPOSITION 9. *The LDC consumers enjoy the highest benefit when the LDC firm accepts a price undertaking, but the benefit is at the lowest level when the DC government imposes an*

effective AD policy on foreign dumping.

As for the ranking of social welfare under the alternative trade regimes, we have from the results in (15d), (20d), and (25d) that

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

PROPOSITION 10. *The welfare of the LDC is the highest when its exporting firm accepts a price undertaking, but is the lowest when the DC government imposes AD fines on dumping.*

Given that price undertaking allows the LDC dumping firm to keep the AD rents, it comes as no surprise that social welfare of the LDC is strictly higher under price undertaking than under the AD policy. This finding is consistent with the results of Gao and Miyagiwa (2005). The authors remark that price undertaking is a more friendly protection policy toward foreign dumping firm than the AD policy. [11]

3.3 *Effects on global welfare*

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

$$GSW^{FT} = \frac{(\lambda+1)(16\lambda+81\gamma_h+16)}{162\gamma_h}. \tag{26a}$$

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

$$GSW^{AD} = \frac{36\lambda+81\gamma_h+18\lambda^2+81\lambda\gamma_h+16}{162\gamma_h}. \tag{26b}$$

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

$$GSW^{PU} = \frac{540\lambda+648\gamma_h+806\lambda^2+540\lambda^3+81\lambda^4+1944\lambda\gamma_h+1944\lambda^2\gamma_h+648\lambda^3\gamma_h+81}{1296\gamma_h(1+\lambda)^2}. \tag{26c}$$

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

$$GW^{AD} > GW^{FT} > GW^{PU}. \tag{27}$$

[11] The finding of Proposition 10 is, in essence, supported by the study of Konings et al. (1998) that price undertaking

This ranking of global welfare in (27) permits us to state the following:

PROPOSITION 11. *Consider a simple world that is composed of a DC and an LDC in which there is free trade with the DC firm producing a -quality product and the LDC firm producing a low-quality product. Global welfare, defined by summing up the welfare of the trading nations, is the highest when the DC government imposes an AD policy against dumping by the LDC firm. However, global welfare is the lowest when the DC government allows the LDC firm to accept 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.

Using the more updated data from 1995 to 2008, Rovegno and Vandenbussche (2011) document 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 duty for the same period in the EU is more than 76%. These empirical findings have interesting welfare implications for the DC and LDC 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.

4. Concluding Remarks

In our analysis of international trade and competition in "like" products with vertical differentiation between two firms located in home country (a DC) and a foreign country (an LDC), respectively, dumping arises when there are income differences between the trading partners. Taking into account the endogenous choices of product quality, we show that the DC firm produces a high-quality product whereas the LDC firm produces a low-quality product. Moreover, the LDC firm finds it profitable to dump the low-quality product at a price lower than the product's price in its local market. This is consistent with the frequent observations on the dumping of low-quality products in many DC countries. Such a practice of dumping is in accordance with the definition of dumping on free trade as put forward by the WTO. Our analysis further shows that although dumping is profitable to foreign exporters of low-quality

products, the overall welfare of the exporting country decreases with its firms being charged with AD duties. We find that it is welfare-improving to an exporting country to restraint their exporters not to dump, but to set the price of a product identical to that in its local market.

From the perspective of an importing country with firms producing high-quality products, imposing an AD policy is an effective way to stop the practice of dumping by foreign firms that sell low-quality products. The AD policy makes it possible for the domestic firms that manufacture high-quality products to regain its market share. Under this circumstance, AD as a trade remedy policy is welfare improving and thus socially desirable.

To the best of our knowledge, this paper is among the few theoretical studies in setting up a two-market equilibrium model to characterize the dumping behavior of profit-maximizing firms exporting low-quality products from the less-developed world to markets in the developed world.[12] We find that taking an antidumping action against an LDC dumping firm by charging AD duties is welfare-improving to an importing country. Our two-market equilibrium analysis further shows that such an AD policy is welfare-enhancing from the global perspective. Given that our analysis follows the WTO/GATT guidelines for identifying dumping, imposing AD duties should not be interpreted as a protectionist measure but as a trade remedy measure. In the face of foreign dumping on free trade, the use of an optimal AD policy is shown to be globally Pareto-superior.

[12] See also the contribution by Hansen and Neilsen (2009). The authors examine antidumping issues in the presence of "reciprocal dumping." In our analysis, DC firm produces a high-quality product and does not practice dumping whereas LDC firm produces a low-quality product which is dumped in the DC market.

Mathematical Appendix

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

Under the AD regime, there is a three-stage game. At the third stage of 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:

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

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

$$SW_{DC}^{AD} = \underbrace{\int_{\theta^{*AD}}^{1}[\lambda\theta^{*AD}(1+s_h^{AD}) - p_h^{*AD}]dF(\theta)}_{CS_h^{AD}} + \underbrace{\int_{0}^{\theta^{*AD}}[\theta^{*AD}\lambda(1+s_l^{AD}) - p_l^{*AD}]dF(\theta)}_{CS_l^{AD}}$$

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

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 alternative regimes

(i) **The ranking of optimal quality-upgrades by the DC firm**

Give that the optimal quality-upgrades under the three alternative 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

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

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

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

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 profits of the DC firm

Give that the optimal profits for the DC firm under the three alternative 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 consumer surplus in the DC

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

$$CS_{DC}^{FT} = \frac{\lambda\left(-8\lambda+81\gamma_h-8\right)}{162\gamma_h},$$

$$CS_{DC}^{AD} = \frac{\lambda\left(27\gamma_h-6\lambda-4\right)}{54\gamma_h}, \text{and}$$

$$CS_{DC}^{PU} = \frac{\lambda(1296\gamma_h-1220\lambda-954\lambda^2+252\lambda^3+81\lambda^4+3888\lambda\gamma_h+3888\lambda^2\gamma_h+1296\lambda^3\gamma_h-207)}{2592\gamma_h\left(\lambda+1\right)^3},$$

it follows that

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

$$CS_{DC}^{FT} - CS_{DC}^{PU} = \frac{\lambda(-209\lambda^4-764\lambda^3+186\lambda^2+708\lambda+79)}{2592\gamma_h(\lambda+1)^3} > 0 \Rightarrow CS_{DC}^{FT} > CS_{DC}^{PU};$$

$$CS_{DC}^{PU} - CS_{DC}^{AD} = \frac{\lambda(369\lambda^4+1308\lambda^3+486\lambda^2-356\lambda-15)}{2592\gamma_h(\lambda+1)^3} \text{ which implies that}$$

$$CS_{DC}^{PU} > CS_{DC}^{AD} \text{ when } \lambda > \hat{\lambda}_{DC};\ CS_{DC}^{PU} < CS_{DC}^{AD} \text{ when } \lambda < \hat{\lambda}_{DC}.$$

We thus have two possibilities:

$CS_{DC}^{FT} > CS_{DC}^{PU} > CS_{DC}^{AD}$ when $\lambda > \hat{\lambda}_{DC}$ (i.e., when income differential is getting smaller);

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

(iii) The ranking of social welfare in the DC

Give that the optimal levels of social welfare in the DC under the three alternative regimes are:

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

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

$$SW_{DC}^{PU} = \frac{702\lambda + 1886\lambda^2 + 2152\lambda^3 + 1161\lambda^4 + 162\lambda^5 + 1296\lambda\gamma_h + 3888\lambda^2\gamma_h + 3888\lambda^3\gamma_h + 1296\lambda^4\gamma_h + 81}{2592\gamma_h(\lambda+1)^3},$$

it follows that

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

$$SW_{DC}^{FT} - SW_{DC}^{PU} = \frac{-34\lambda^5 - 393\lambda^4 - 360\lambda^3 + 162\lambda^2 + 450\lambda + 175}{2592\gamma_h(\lambda+1)^3} > 0 \Rightarrow SW_{DC}^{FT} > SW_{DC}^{PU}.$$

We thus have $SW_{DC}^{AD} > SW_{DC}^{FT} > SW_{DC}^{PU}$.

A-3 Effects on DC under the three alternative regimes

(i) The ranking of profits for the LDC firm

Give that maximum profits under the three alternative 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 consumer surplus in the DC

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

$$CS_{LDC}^{AD} = \frac{81\gamma_h - 12\lambda - 8}{162\gamma_h},\ CS_{LDC}^{FT} = \frac{-8\lambda + 81\gamma_h - 8}{162\gamma_h},$$

$$CS_{LDC}^{PU} = \frac{252\lambda + 1296\gamma_h - 954\lambda^2 - 1220\lambda^3 - 207\lambda^4 + 3888\lambda\gamma_h + 3888\lambda^2\gamma_h + 1296\lambda^3\gamma_h + 81}{2592\gamma_h(\lambda+1)^3},$$

it follows that

$$CS_{LDC}^{FT} - CS_{LDC}^{AD} = \frac{2\lambda}{81\gamma_h} > 0 \Rightarrow CS_{LDC}^{FT} > CS_{LDC}^{AD};$$

$$CS_{LDC}^{PU} - CS_{LDC}^{FT} = \frac{-79\lambda^4 - 708\lambda^3 - 186\lambda^2 + 764\lambda + 209}{2592\gamma_h(\lambda+1)^3} > 0 \Rightarrow CS_{LDC}^{PU} > CS_{LDC}^{FT}.$$

We thus have $CS_{LDC}^{PU} > CS_{LDC}^{FT} > CS_{LDC}^{AD}$.

(iv) The ranking of social welfare in the LDC

Give that the optimal levels of social welfare in the LDC under the three alternative regimes are:

$$SW_{LDC}^{FT}=\frac{8\lambda^2+8\lambda+81\gamma_h}{162\gamma_h},\ SW_{LDC}^{AD}=\frac{1}{2},$$

$$SW_{LDC}^{PU}=\frac{540\lambda+1296\gamma_h+806\lambda^2+540\lambda^3+81\lambda^4+3888\lambda\gamma_h+3888\lambda^2\gamma_h+1296\lambda^3\gamma_h+81}{2592\gamma_h(\lambda+1)^3},$$

It follows that

$$SW_{LDC}^{FT}-SW_{LDC}^{AD}=\frac{4\lambda(\lambda+1)}{81\gamma_h}\Rightarrow SW_{LDC}^{FT}>SW_{LDC}^{AD};$$

$$SW_{LDC}^{PU}-SW_{LDC}^{AD}=\frac{81\lambda^4+540\lambda^3+806\lambda^2+540\lambda+81}{2592\gamma_h(\lambda+1)^3}>0\Rightarrow SW_{LDC}^{PU}>SW_{LDC}^{AD};$$

$$SW_{LDC}^{PU}-SW_{LDC}^{FT}=\frac{-128\lambda^5-431\lambda^4-228\lambda^3+294\lambda^2+412\lambda+81}{2592\gamma_h(\lambda+1)^3}>0\Rightarrow SW_{LDC}^{PU}>SW_{LDC}^{FT}.$$

We thus have $SW_{LDC}^{PU}>SW_{LDC}^{FT}>SW_{LDC}^{AD}$.

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