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Import competition, product quality reversal, and welfare[☆]

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HIGHLIGHTS

- An import tariff policy does not lead to product quality reversal.
- A quality-based R&D subsidy encourages R&D investment and quality upgrade.
- Identify conditions when a quality-upgrading R&D subsidy leads to quality reversal.
- R&D subsidy policy may maximize consumer surplus, domestic profit and welfare

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ABSTRACT

We investigate product quality in an import-competing country using the framework of vertical product differentiation. Comparison of three polices suggests that the quality-based R&D subsidy brings quality-reversal, leading to a win-win-win equilibrium in consumer surplus, domestic profit and social welfare.

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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 policy makers 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

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1 See, e.g., Das and Donnenfeld (1987), Flam and Helpman (1987), Krishna (1987), Reitzes (1992), Motta et al. (1997), Herguera et al. (2002), Zhou et al. (2002), Moraga-González 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; Andaluz, 2000).

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quality-upgrading equation for each firm. This approach permits us to derive reduced-form solutions for optimal 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.

2. The model

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 $\hat{\theta} = \frac{p_f - p_d}{s_f - s_d}$, 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:

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

[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.

2.2. Three policy options

(i) 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] :

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

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

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:

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

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:

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

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

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

[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.

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:

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

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]

(ii) 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.

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

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

It is easy to verify that the optimal prices are:

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

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

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

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

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

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

Solving for the optimal quality upgrades yields

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

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

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

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:

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

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

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

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.*

(iii) 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 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:

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

Solving for the optimal prices yields

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

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

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

[6] Lenway et al. (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.

[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.

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

$$\underset{\{s_f\}}{\text{Max}}\,\pi_f^{Q-R\&D} = \frac{4(s_f - s_d)}{9} - \frac{1}{2}\gamma_f s_f^2 \text{ and}$$
$$\underset{\{s_d\}}{\text{Max}}\,\pi_d^{Q-R\&D} = \frac{(s_f - s_d)}{9} - \frac{1}{2}\gamma_d(1-\mu)s_d^2 + \alpha s_d.$$

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:

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

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.*

[8] Some 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 et al. (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, Czarnitzki 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.

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

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

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

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]

[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 $CS_d^{Q-R\&D} = [99\gamma_f + (162\gamma_f\gamma_d - 16\gamma_d)(1-\mu)]/[324\gamma_f\gamma_d(1-\mu)]$.

[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.

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.

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