DEPARTMENT OF ECONOMICS AND FINANCE

SCHOOL OF BUSINESS AND ECONOMICS

UNIVERSITY OF CANTERBURY

CHRISTCHURCH, NEW ZEALAND

Product Quality and Strategic Asymmetry in International Trade

John Gilbert
Onur A. Koska
Reza Oladi

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Department of Economics and Finance
School of Business
University of Canterbury
Private Bag 4800, Christchurch
New Zealand

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John Gilbert[1]
Onur A. Koska[2†]
Reza Oladi[3]

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Keywords: International trade; product quality; horizontal product differentiation; Cournot-Bertrand-Nash equilibrium

JEL Classifications: D43; F12

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[1] Department of Economics and Finance, Utah State University, USA
[2] Department of Economics and Finance, University of Canterbury, NEW ZEALAND
[3] Department of Applied Economics, Utah State University, USA

†Corresponding author: Onur Koska, email: onur.koska@canterbury.ac.nz

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Abstract

In a duopoly trade model with both horizontal and vertical product differentiation, we examine the endogenous choice of quantities and prices as strategic variables. We show that strategic asymmetry (such that a potential exporter commits to a quantity contract, while a local rival commits to a price contract) can be an equilibrium outcome when the relative product quality of the foreign variety is sufficiently high and trade costs are sufficiently low. A lower degree of horizontal product differentiation can make strategic asymmetry more likely. By endogenizing the quality choice, we also establish the conditions under which product quality choice gives rise to strategic asymmetry.

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1 Introduction

Empirical evidence shows that exporting firms tend to produce higher quality products, for which they charge higher prices, and that vertical product differentiation significantly contributes to the success of exporters.[1] This is true especially for exporting firms that have cost advantages in production and/or in quality investments relative to their local rivals.[2] A strong positive correlation between product quality and unit values has been reported in the empirical trade literature. Numerous studies have attempted to explain the differences

[1] We observe a high share of intra-industry trade in vertically differentiated products (e.g., 40% in the EU; see Anderson and Schmitt, 2010).

[2] See, among others, Hallak and Sivadasan (2013) for a study using Indian data; Kugler and Verhoogen (2012) for a study using Colombian data; and Manova and Zhang (2012) for a study using Chinese data.

in unit values between exporting and local firms by their product quality differences after controlling for several other factors including additional (trade/transportation) costs that exporters incur when servicing markets via international trade.[3] That said, both trade costs and product quality differences between exporters and their local rivals must have important implications for firms' preferred mode of competition, which would influence further firm-level decisions. In particular, Gilbert et al. (2020) have shown that asymmetric choices in strategic variables (price versus quantity) have important implications not only for the pattern and structure of trade, but also for firms' output and pricing decisions.

Empirical evidence does support the observation that exporting firms and their local rivals may adopt different strategies when competing in the same market: exporters may compete via sales expansion (i.e., quantity competition) while their local rivals may instead focus on price cutting (i.e., price competition). Tremblay et al. (2013) observe this phenomenon in the US small car market.[4] While Honda and Subaru focus on setting their output, Toyota (the parent of Scion) and GM (the parent of Saturn) focus on setting their prices. This observation, however, leads to several important questions. Why would foreign and local firms differ in their mode of competition in the same market? What role (if any) do trade costs and product quality differentiation play when firms decide on their mode of competition? What factors may explain exporters' and local firms' different product quality choices and how those choices may lead them to compete in the same market by adopting different strategies? These are important questions that have not been fully explored in the international trade literature, and that we address in this paper. That is, we contribute to the existing literature by developing a trade model allowing exporters and local firms to choose both their product quality and their mode of competition (their strategic variables) before competing in a differentiated product market. In doing so, we provide an intuitive explanation for the observation that in some markets, exporters and local firms differentiating

[3]See, for example, Verhoogen (2008); Kugler and Verhoogen (2012); Manova and Zhang (2012); Crozet et al. (2012); Feenstra and Romalis (2014).

[4]Such situations have been observed also in the aerospace connector industry in the US (see Tremblay et al., 2013, for details), and in the Japanese home electronics industry (see Sato, 1996, for details).

the quality of their products compete by choosing asymmetric strategies.

In particular, in a duopoly trade model with both horizontal and vertical product differentiation, we explore the endogenous choice of quantities and prices as strategic variables. We show that, consistent with empirical observations, strategic asymmetry (such that a potential exporter commits to a quantity contract, while a local rival commits to a price contract) can be observed, especially when the relative product quality of the foreign variety is sufficiently high and trade costs are sufficiently low. The reason is as follows. The local firm has to be more aggressive to substitute for its weak competitive position when the exporter's relative product quality is sufficiently high and its cost disadvantage is sufficiently low (due to low trade costs), and thus prefers to compete by setting prices. By contrast, the exporter prefers to compete by choosing quantities so as to reduce the intensity of competition and to gain more from its better competitive position. Also a lower degree of horizontal product differentiation can make strategic asymmetry more likely.

We derive these results under the assumption that the exporter produces a higher quality variety as compared to the local variety. Relaxing this assumption and extending the model to endogenous quality investments, we also delineate the conditions under which the exporter would invest in product quality more than the local firm. Our results suggest that (i) trade liberalization would increase the exporter's quality investments (which is - as will be discussed in Section 5 - consistent with the evidence presented in the recent empirical trade literature on vertically differentiated products); and that (ii) in the absence of trade costs, having higher cost efficiency in quality investments relative to the local firm is sufficient to lead an exporter to invest more in quality. In the case of positive (and non-prohibitive) trade costs, however, we derive a threshold relative cost efficiency in quality investments between the local firm and the exporter. We show that the exporter's quality investments exceed those of the local firm when the relative cost efficiency between the local firm and the exporter is above the threshold value. Also we find that the threshold relative cost efficiency is higher at higher trade costs, or in markets with low market potential.

The remainder of the paper is organized as follows. In Section 2 we introduce the model. In Section 3 and Section 4 we solve the model for the optimal choices under the assumption that the exporter's product (relative to the local variety) is of higher quality. Section 5 extends the analysis to endogenous quality investments and discusses the conditions under which a potential exporter opts for a higher product quality than a local firm. Finally, Section 6 offers some concluding remarks. For convenience, most of the proofs and technical details are relegated to the Appendix.

2 The Model

We adopt a model structure similar to Koska (2019) sans the upstream industry structure, but allowing for the endogenous choice of quantity or price as the strategic variable. Consider a country (home) with a single local firm, denoted h. Firm h may face international rivalry due to the existence of a potential exporter producing a related good, firm f, which is located outside the country. Without loss of generality, we assume that both firms' production costs are normalized to zero. Servicing the home market via export sales is costly, however, with the per-unit trade costs incurred by firm f should it enter the home market denoted t.

The demand side of the model borrows from Singh and Vives (1984), Hallak and Sivadasan (2013) and Symeonidis (2003). Consider a representative consumer maximizing:

$$U(x_h, x_f, M) = u_h x_h + u_f x_f - x_h^2/2 - x_f^2/2 - \sigma x_h x_f + M$$

with respect to the budget constraint $\sum_i p_i x_i + M \leq Y$, where Y is income, p_i denotes the price of the differentiated good $i = \{h, f\}$, and the price of a composite good M plays the role of numéraire. The degree of horizontal product differentiation is measured by $\sigma \in (0, 1)$, implying that the goods are substitutes.[5] The degree of vertical product differentiation is

[5] Each firm's market power increases as σ decreases such that if $\sigma = 0$, then each firm would have the ability to behave as a monopolist, whereas the products would be perfect substitutes when there is no vertical differentiation between the varieties and when $\sigma = 1$.

measured by u_i, $i = \{h, f\}$, such that u_i is interpreted as an index of product quality.[6] In light of the empirical evidence discussed in Section 1, the potential exporting firm is assumed to produce a high-quality product. The local firm by contrast is technologically constrained, and thus produces a low-quality product.[7] The first-order conditions of the utility maximization problem:

$$\frac{\partial U(\cdot)}{\partial x_i} : u_i - x_i - \sigma x_j - p_i = 0, \quad i \neq j \in \{h, f\}$$

yield the optimal consumption of each variety $i = \{h, f\}$ of the good, such that:

$$x_i(p_i, p_j) = \frac{(u_i - p_i - \sigma(u_j - p_j))}{(1 - \sigma^2)}, \quad i \neq j \in \{h, f\},$$

in the region $\{p \in R_+^2 : u_h - p_h - \sigma(u_f - p_f) > 0, u_f - p_f - \sigma(u_h - p_h) > 0\}$. The inverse demand functions are linear for each variety i and can be expressed as:

$$p_i(x_i, x_j) = u_i - x_i - \sigma x_j, \quad i \neq j \in \{h, f\}.$$

By assumption $u_f > u_h$. It is clear that the quantity demanded of variety i of the good is always decreasing in its own price and increasing in the price of the rival's variety.

Given the foreign market entry decision of the potential exporter, the local firm and the exporter (if it has entered the market) first simultaneously choose their strategic variables (quantities or prices), and then compete in the differentiated product market. The model is solved by backward induction.

[6] An increase in u_i increases the marginal utility of good $i = \{h, f\}$, ceteris paribus.

[7] We will relax this assumption and allow for endogenous quality investments in Section 5.

3 Product Market Competition

In the last stage of the game, the local firm and the exporter (if it has entered the market) compete in the differentiated product market. The two firms' choices of their strategic variables in the first stage determine the outcome. There are four possibilities: two symmetric outcomes such that either both firms choose to compete in quantities (Cournot) or choose to compete in prices (Bertrand); and two asymmetric outcomes such that one firm sets its price, while the other firm sets its quantity (Cournot-Bertrand).

3.1 Symmetric Cournot Strategies

Suppose that both firms have chosen to compete in quantities in the first stage. Each firm then maximizes its own profit, $\pi_i = (p_i(x_i, x_j) - c_i)x_i$, $i \neq j \in \{h, f\}$ by simultaneously choosing quantities x_i, $i \in \{h, f\}$. From the first-order conditions of the profit maximization problems, each firm's best response function is:

$$x_i(x_j) = \frac{1}{2}(u_i - \sigma x_j - c_i), \quad i \neq j \in \{h, f\}.$$

Solving $x_h^* = x_h(x_f^*)$ and $x_f^* = x_f(x_h^*)$ for x_h^* and x_f^* gives us the expressions for the optimal quantities set by each firm in equilibrium:

$$x_i^* = \frac{2(u_i - c_i) - \sigma(u_j - c_j)}{4 - \sigma^2}, \quad i \neq j \in \{h, f\}, \tag{1}$$

in the region of quality spaces where optimal quantities are positive. Note that $c_h = 0$ and $c_f = t$.

Substituting the optimal sales given in equation (1) into the inverse demand functions gives us the equilibrium price of each variety:

$$p_i^* = \frac{2u_i + (2 - \sigma^2)c_i - \sigma(u_j - c_j)}{4 - \sigma^2}, \quad i \neq j \in \{h, f\}. \tag{2}$$

Using equation (2), it is straightforward to show that $p_i^* - c_i = x_i^*$, $i \in \{h, f\}$, and thus that the equilibrium profits can be expressed as $\pi_i^* = (x_i^*)^2$, where the optimal quantities are given by equation (1).

3.2 Symmetric Bertrand Strategies

Now suppose that both firms have chosen to compete in prices in the first stage. Each firm then maximizes its own profit, $\pi_i = (p_i - c_i)x_i(p_i, p_j)$, $i \neq j \in \{h, f\}$ by simultaneously choosing prices p_i, $i \in \{h, f\}$. From the first-order conditions of the profit maximization problems, each firm's best response function is:

$$p_i(p_j) = \frac{u_i - \sigma u_j + \sigma p_j + c_i}{2}, \quad i \neq j \in \{h, f\}.$$

Solving $p_h^* = p_h(p_f^*)$ and $p_f^* = p_f(p_h^*)$ for p_h^* and p_f^* yields the expressions for the optimal prices set by each firm in equilibrium:

$$p_i^* = \frac{(2 - \sigma^2)u_i - \sigma u_j + 2c_i + \sigma c_j}{(4 - \sigma^2)}, \quad i \neq j \in \{h, f\}, \tag{3}$$

in the region of quality spaces where optimal quantities are positive, and $c_h = 0$ and $c_f = t$.

Substituting the optimal prices given in equation (3) into the demand system gives us the equilibrium sales of each variety:

$$x_i^* = \frac{(2 - \sigma^2)u_i - \sigma u_j - (2 - \sigma^2)c_i + \sigma c_j}{(4 - \sigma^2)(1 - \sigma^2)}, \quad i \neq j \in \{h, f\}. \tag{4}$$

Using equation (4), we can show that $p_i^* - c_i = (1 - \sigma^2)x_i^*$, $i \in \{h, f\}$, and thus that the equilibrium profits can be expressed as $\pi_i^* = (1 - \sigma^2)(x_i^*)^2$, where optimal quantities are given by equation (4).

3.3 Asymmetric Strategies

Finally, suppose that the two firms have chosen different strategies (firm i commits to a quantity contract, whereas firm j commits to a price contract) in the first stage. Firm i then maximizes $\pi_i = (p_i(x_i, p_j) - c_i)x_i$, $i \neq j \in \{h, f\}$ by choosing its quantity, and firm j maximizes $\pi_j = (p_j - c_j)x_j(p_j, x_i)$, $i \neq j \in \{h, f\}$ by choosing its price. Note that $p_i(x_i, p_j) = u_i - \sigma u_j - (1 - \sigma^2)x_i + \sigma p_j$ and $x_j(p_j, x_i) = u_j - \sigma x_i - p_j$. From the first-order condition of each firm's profit maximization problem, the asymmetric best response functions are:

$$x_i(p_j) = \frac{u_i - \sigma u_j + \sigma p_j - c_i}{2(1 - \sigma^2)}, \quad i \neq j \in \{h, f\},$$

$$p_j(x_i) = \frac{u_j - \sigma x_i + c_j}{2}, \quad i \neq j \in \{h, f\}.$$

Solving $x_i^* = x_i(p_j^*)$ and $p_j^* = p_j(x_i^*)$ for x_i^* and p_j^*, $i \neq j \in \{h, f\}$, yields the optimal prices and quantities set by each firm in equilibrium:

$$x_i^* = \frac{2u_i - \sigma u_j - 2c_i + \sigma c_j}{4 - 3\sigma^2}, \quad i \neq j \in \{h, f\}, \tag{5a}$$

$$p_j^* = \frac{(2 - \sigma^2)u_j - \sigma u_i + 2(1 - \sigma^2)c_j + \sigma c_i}{4 - 3\sigma^2}, \quad i \neq j \in \{h, f\}, \tag{5b}$$

in the region of quality spaces where optimal quantities are positive, and $c_h = 0$ and $c_f = t$. Note that stability of the equilibrium requires $|\partial^2\pi_i/(\partial s_i)^2| > |\partial^2\pi_i/\partial s_i \partial s_j|$, $i \neq j \in \{h, f\}$, where s_i and s_j are, respectively, each firm's strategic variable. This implies an upper bound for σ such that $\sigma \in (0, 0.781)$.

Substituting the optimal quantities and prices given by equation (5) into $x_j(p_j, x_i)$ and $p_i(x_i, p_j)$ gives x_j^* and p_i^*, $i \neq j \in \{h, f\}$, such that:

$$x_j^* = \frac{(2 - \sigma^2)u_j - \sigma u_i + \sigma c_i - (2 - \sigma^2)c_j}{4 - 3\sigma^2}, \quad i \neq j \in \{h, f\}, \tag{6a}$$

$$p_i^* = \frac{(1-\sigma^2)(2u_i - \sigma u_j + \sigma c_j) + (2-\sigma^2)c_i}{4-3\sigma^2}, \quad i \neq j \in \{h, f\}. \tag{6b}$$

Using (5b) and (6b), it follows that $(p_i^* - c_i) = (1-\sigma^2)x_i^*$ and $(p_j^* - c_j) = x_j^*$, $i \neq j \in \{h, f\}$, thus the equilibrium profits can be expressed as $\pi_i^* = (1-\sigma^2)(x_i^*)^2$ for firm i opting to compete in quantities, and as $\pi_j^* = (x_j^*)^2$ for firm j opting to compete in prices, $i \neq j \in \{h, f\}$, where optimal quantities are given by (5a) and (6a).

4 Mode of Competition

We now turn to the local firm's and the potential exporter's optimal choice of the strategic variables in the first stage. Recall that firm f (the exporter) has a cost disadvantage due to trade costs such that $c_h = 0$ and $c_f = t$. Using equations (1), (4), (5a) and (6a), we can show that given that firm h (the local firm) commits to a quantity contract, if firm f also commits to a quantity contract, then firm h earns π_h^{CC} and firm f earns π_f^{CC}, where:

$$\pi_h^{CC} = \frac{(2u_h - \sigma u_f + \sigma t)^2}{(4-\sigma^2)^2}; \quad \pi_f^{CC} = \frac{(2u_f - \sigma u_h - 2t)^2}{(4-\sigma^2)^2}. \tag{7}$$

If, however, firm f commits to a price contract, given that firm h commits to a quantity contract, then firm h earns π_h^{CB} and firm f earns π_f^{BC}, where:

$$\pi_h^{CB} = (1-\sigma^2)\frac{(2u_h - \sigma u_f + \sigma t)^2}{(4-3\sigma^2)^2}; \quad \pi_f^{BC} = \frac{((2-\sigma^2)(u_f - t) - \sigma u_h)^2}{(4-3\sigma^2)^2}. \tag{8}$$

On the other hand, given that firm h commits to a price contract, if firm f also commits to a price contract, then firm h earns π_h^{BB} and firm f earns π_f^{BB}, where:

$$\pi_h^{BB} = \frac{((2-\sigma^2)u_h - \sigma u_f + \sigma t)^2}{(4-\sigma^2)^2(1-\sigma^2)}; \quad \pi_f^{BB} = \frac{((2-\sigma^2)(u_f - t) - \sigma u_h)^2}{(4-\sigma^2)^2(1-\sigma^2)}. \tag{9}$$

Finally, if firm f commits to a quantity contract given that firm h commits to a price contract, then firm h earns π_h^{BC} and firm f earns π_f^{CB}, where

$$\pi_h^{BC} = \frac{((2-\sigma^2)u_h - \sigma u_f + \sigma t)^2}{(4-3\sigma^2)^2}; \quad \pi_f^{CB} = (1-\sigma^2)\frac{(2u_f - \sigma u_h - 2t)^2}{(4-3\sigma^2)^2}. \tag{10}$$

Note that, assuming the exporter's product quality is higher than the local firm's product quality, positive quantities imply $u_f > u_h > \sigma u_f/(2-\sigma^2)$. Using equations (7), (8), (9) and (10), it is straightforward to show that irrespective of the local firm's choice (either a quantity or a price contract): (i) Both quantity and price contracts are viable strategies for the potential exporter when $t < u_f - \sigma u_h/(2-\sigma^2)$, but a quantity contract is more profitable than a price contract; (ii) only a quantity contract earns the potential exporter positive profits when $u_f - \sigma u_h/(2-\sigma^2) < t < u_f - \sigma u_h/2$; and (iii) neither a quantity contract, nor a price contract earns the potential exporter positive profits when $t > u_f - \sigma u_h/2$. In this case instead of exporting, firm f stays out of the market. Hence we have the following result:

Lemma 1. *Irrespective of the local rival's strategic choice, a potential exporter always prefers to compete by quantities insofar as trade costs are not prohibitive, and such that market entry is profitable.*

Lemma 1 extends the standard result reported in the IO literature to a potential exporting firm in the context of international trade with vertically differentiated products. Given this result, it is sufficient to look at the local firm's optimal behavior given that firm f opts to compete in quantities. Comparing firm h's profits given by (7) and (10), we can show that there is a trade cost threshold $\tilde{t} = u_f - (16 - 12\sigma^2 + \sigma^4)u_h/4\sigma(2-\sigma^2) < u_f - \sigma u_h/2$. Note that this threshold will be binding so long as the exporter's relative product quality is sufficiently high such that $\tilde{t} > 0$. Given the exporter's commitment to a quantity contract, the local firm's best response is to commit to a price contract whenever the exporter's cost disadvantage is sufficiently small, such that $t < \tilde{t}$, or to a quantity contract when $\tilde{t} < t < u_f - \sigma u_h/2$. This leads to the following new result:

Proposition 1. *Strategic asymmetry is observed when the exporter's relative product quality is sufficiently high and trade costs are sufficiently low, such that $0 \leq t < \tilde{t}$. If, however, $\tilde{t} < t < u_f - \sigma u_h/2$, then both firms will commit to a quantity contract, and the market outcome will be Cournot duopoly.*

Proposition 1 establishes that whenever the local firm's competitive position is sufficiently weak (i.e, when the foreign variety is of sufficiently high quality relative to the local variety and the foreign firm's cost disadvantage due to trade costs is sufficiently low), it will be best for the local firm to opt for a more aggressive strategy by setting prices, whereas the exporter will always prefer to compete in quantities so as to reduce the intensity of competition. Furthermore, it should be clear that without a sufficiently large quality difference between the foreign and the local varieties, $\tilde{t}$ is negative, and thus for any non-negative (and non-prohibitive) t, the outcome will be Cournot duopoly. That is, a sufficiently large quality difference is needed for strategic asymmetry to arise in this framework. Moreover, horizontal product differentiation plays a crucial role in determining the scope for strategic asymmetry such that:

Proposition 2. *A higher degree of horizontal product differentiation (a lower σ) can make strategic asymmetry less likely.*

With a higher degree of horizontal product differentiation (a smaller σ) an even higher quality difference and a lower trade cost is required to support strategic asymmetry in equilibrium. That is, for a given u_i, $i \in \{h, f\}$, where $u_f > (16 - 12\sigma^2 + \sigma^4)u_h/4\sigma(2 - \sigma^2)$, such that $\tilde{t} > 0$, $\partial\tilde{t}/\partial\sigma > 0$ and $\partial[u_f - \sigma u_h/2]/\partial\sigma < 0$. The intuition is that market entry by a foreign rival with a higher quality product and a small trade cost disadvantage will have a stronger negative impact on the local firm's market share when the products are more closely related (i.e, when σ is higher).

5 Endogenous Product Quality

In the preceding analysis, we assume at the outset that the foreign variety is of higher quality than the local variety, such that $u_f > u_h$. We now relax this assumption and extend the analysis to endogenous quality investments so as to shed light on the conditions under which a potential exporter would opt to produce a higher quality product than a local firm.

Suppose u_i, $i = \{h, f\}$, is defined as $u_i = \underline{\mathrm{u}} + R_i$ where R_i, $i = \{h, f\}$, denotes each firm's quality investments, which we assume are undertaken simultaneously prior to firms choosing their strategic variables.[8] Quality investments are costly, as represented by a convex cost function $C_i(R_i) = \gamma_i R_i^2/2$, where $\gamma_i \geq 1$, $i = \{h, f\}$, represents cost efficiency related to quality investments.[9] Note that quality investments require (irreversible) sunk investment costs and that the marginal cost of quality investments need not be the same across the two firms, even for the same level of investments (i.e., γ_i need not be the same as γ_j, where $i \neq j \in \{h, f\}$).

Each firm (anticipating how the game would play out and solving backwards) maximizes its profits (given by equation (7) in the case of Cournot duopoly, or by equation (10) in the case of Cournot-Bertrand duopoly) with respect to quality investments in the first stage of the game. The first-order conditions yield the best response functions, which can be expressed as $R_i^k(R_j^k) = \alpha_i^k - \beta_i^k R_j^k$, $i \neq j \in \{h, f\}$, $k = \{C, M\}$, where superscript k represents the type of market competition in the last stage as is correctly anticipated by the two firms (i.e., either Cournot duopoly (C), or Cournot-Bertrand duopoly (M)).

Figure 1 illustrates the two firms' optimal quality investment decisions (R_i^{k*}, $i = \{h, f\}$, $k = \{C, M\}$), such that $R_h^{k*}(R_f^{k*}) = R_f^{k*}(R_h^{k*})$. It is straightforward to show that optimal quality investments are $R_i^{k*} = (\alpha_i^k - \beta_i^k \alpha_j^k)/(1 - \beta_i^k \beta_j^k)$, $i \neq j \in \{h, f\}$, $k = \{C, M\}$. Throughout this section, we assume that optimal quality investments are positive for both

[8] Marginal quality improvements are the same across the two firms since $\partial u_i/\partial R_i = 1$ for $i = \{h, f\}$, for simplicity.

[9] Note that $\gamma_i \geq 1$ is not a necessary but a sufficient condition such that the second-order conditions are fulfilled for any constellation of the parameter values.

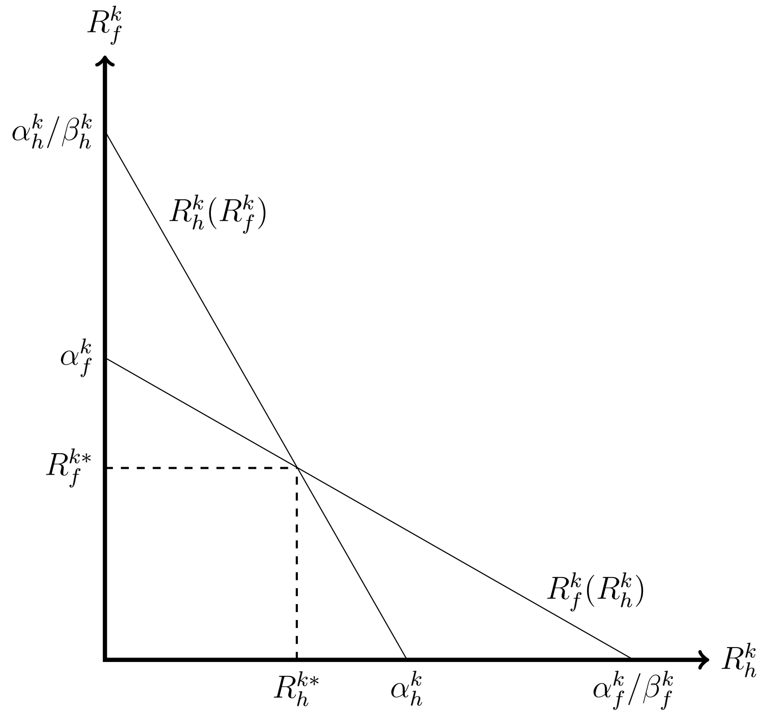

Figure 1: Best response functions: $R_i^k(R_j^k) = \alpha_i^k - \beta_i^k R_j^k$, $i \neq j \in \{h, f\}$, $k = \{C, M\}$

firms, which requires $\alpha_i^k > \beta_i^k \alpha_j^k$ and $\beta_i^k \beta_j^k < 1$, $i \neq j \in \{h, f\}$, $k = \{C, M\}$. We can now show that:

Lemma 2. *The foreign variety is of higher quality than the local variety (i.e., $R_f^{k*} > R_h^{k*}$) if (and only if) $\alpha_f^k/(1+\beta_f^k) > \alpha_h^k/(1+\beta_h^k)$, $k = \{C, M\}$.*

In the remainder of the paper, given the mode of the market competition (Cournot duopoly or Cournot-Bertrand duopoly), we will examine the conditions under which the condition stated in Lemma 2 is fulfilled, ensuring that the exporter has a higher quality product than the local firm.

In the case of Cournot duopoly, the best response functions $R_i^C(R_j^C) = \alpha_i^C - \beta_i^C R_j^C$, $i \neq j \in \{h, f\}$, are such that:

$$\alpha_h^C = \frac{4((2-\sigma)\underline{\mathrm{u}} + t\sigma)}{(4-\sigma^2)^2\gamma_h - 8}; \quad \alpha_f^C = \frac{4((2-\sigma)\underline{\mathrm{u}} - 2t)}{(4-\sigma^2)^2\gamma_f - 8};$$

$$\beta_i^C = \frac{4\sigma}{(4-\sigma^2)^2\gamma_i - 8}, \quad i = \{h, f\}. \tag{11}$$

In the case of Cournot-Bertrand duopoly (such that the exporter commits to a quantity contract, whereas the local firm commits to a price contract), the best response functions $R_i^M(R_j^M) = \alpha_i^M - \beta_i^M R_j^M$, $i \neq j \in \{h, f\}$, are such that:

$$\alpha_h^M = \frac{2(2-\sigma^2)((2-\sigma-\sigma^2)\underline{u} + t\sigma)}{(4-3\sigma^2)^2\gamma_h - 2(2-\sigma^2)^2}; \quad \beta_h^M = \frac{2(2-\sigma^2)\sigma}{(4-3\sigma^2)^2\gamma_h - 2(2-\sigma^2)^2};$$

$$\alpha_f^M = \frac{4(1-\sigma^2)((2-\sigma)\underline{u} - 2t)}{(4-3\sigma^2)^2\gamma_f - 8(1-\sigma^2)}; \quad \beta_f^M = \frac{4(1-\sigma^2)\sigma}{(4-3\sigma^2)^2\gamma_f - 8(1-\sigma^2)}. \tag{12}$$

It is clear from (11) and (12) that a decrease in trade costs decreases α_h^k and increases α_f^k, without changing β_i^k, $i = \{h, f\}$, $k = \{C, M\}$. As the optimal quality investments in equilibrium are given by $R_i^{k*} = (\alpha_i^k - \beta_i^k \alpha_j^k)/(1 - \beta_i^k \beta_j^k)$, $i \neq j \in \{h, f\}$, $k = \{C, M\}$, this leads us to the following result:

Proposition 3. *Irrespective of the mode of the market competition (Cournot or Cournot-Bertrand duopoly), trade liberalization increases the exporting firm's quality investments, while decreasing the local firm's quality investments.*

The result presented in Proposition 3 holds so long as marginal production costs do not change with quality improvements, as is the case in this model. Some earlier studies in the trade literature, such as Das and Donnenfeld (1987) and Krishna (1987), have shown that if quality improvements also increase marginal production costs, then trade volumes and product quality tend to move in opposite directions. That is, trade liberalization (decreasing trade costs and increasing trade volumes) tends to decrease exporters' product quality. Using distance as a proxy for trade costs, the empirical trade literature lends some support to this finding: for example, Bacchiega et al. (2016) find a positive correlation between distance and quality of the traded goods. In contrast, Toshimitsu (2005) shows that when quality improvements increase fixed investment costs related to product quality without changing marginal production costs, then increasing trade volumes by decreasing trade costs encourages the exporter to upgrade quality as the marginal cost of quality investments will be decreasing with an increase in quantity. Proposition 3 follows the argument by Toshimitsu (2005), and shows that this result extends also to Cournot-Bertrand duopoly. Recent studies in the empirical trade literature have also presented some robust and affirmative evidence on the positive correlation between tariff reductions and quality upgrades of the exporters; see, for example, Fan et al. (2015) and Amiti and Khandelwal (2013).

Using equation (11) and searching for parameter constellations under Cournot duopoly such that the condition given by Lemma 2 holds (so that $R_f^{C*} > R_h^{C*}$), we can now conclude that:

Proposition 4. *In the absence of trade costs, $\gamma_h > \gamma_f$ is both a necessary and a sufficient condition under which $\alpha_f^C/(1+\beta_f^C) > \alpha_h^C/(1+\beta_h^C)$, and thus $R_f^{C*} > R_h^{C*}$ under Cournot duopoly. If, however, $t > 0$, then there is a threshold value of relative cost efficiency (γ_h/γ_f), denoted $\overline{\gamma}_h^f > 1$, only above which $\alpha_f^C/(1+\beta_f^C) > \alpha_h^C/(1+\beta_h^C)$, so that $R_f^{C*} > R_h^{C*}$ under Cournot duopoly.*

Proof. See Appendix. □

While any lower cost efficiency in quality investments under Cournot duopoly would already lead the foreign firm to invest more in product quality in the absence of trade costs, a trade cost disadvantage would require greater asymmetry between the foreign and the local firm: The threshold relative cost efficiency increases with an increase in trade costs. That is, the higher is t, the higher is $\overline{\gamma}_h^f$, and thus a much lower γ_f and/or a much higher γ_h will be needed to support $R_f^{C*} > R_h^{C*}$ in equilibrium. By the same token, we can show that $\partial\overline{\gamma}_h^f/\partial\underline{u} < 0$ and $\partial\overline{\gamma}_h^f/\partial\sigma > 0$ for all non-prohibitive $t > 0$ and $\sigma \in (0, 0.781)$. That is, the threshold relative cost efficiency increases also with an increase in the degree of product substitutability (with a higher σ) and is higher when market potential (for which $\underline{u}$ can be used as a proxy) is lower. Therefore, the following result is immediate:

Corollary 1. *Given a lower cost efficiency in quality investments (as compared to the local rival's cost efficiency), a higher market share for the exporter (due to higher market potential, lower trade costs, or less product substitutability) increases the probability of the exporter investing in quality more than the local rival in the case of Cournot duopoly.*

Using equation (12) and searching for parameter constellations under Cournot-Bertrand duopoly such that the condition given by Lemma 2 holds (i.e., $R_f^{M*} > R_h^{M*}$), we can conclude that:

Proposition 5. *In the absence of trade costs, $\gamma_h > \gamma_f$ is a sufficient (but not a necessary) condition under which $\alpha_f^M/(1+\beta_f^M) > \alpha_h^M/(1+\beta_h^M)$, and thus $R_f^{M*} > R_h^{M*}$ under Cournot-Bertrand duopoly. If, however, $t > 0$, then there is a threshold value of relative cost efficiency (γ_h/γ_f), denoted $\overline{\gamma}_h^f$ (which is less than unity for sufficiently small trade costs), only above which $\alpha_f^M/(1+\beta_f^M) > \alpha_h^M/(1+\beta_h^M)$, so that $R_f^{M*} > R_h^{M*}$ under Cournot-Bertrand duopoly.*

Proof. See Appendix. □

In contrast to Cournot duopoly, in the case of Cournot-Bertrand duopoly, the exporter would invest in quality more than the local rival even for some cost efficiency disadvantage, provided that trade costs are sufficiently small. Similar to Cournot duopoly, the threshold relative cost efficiency increases with an increase in trade costs also in the case of Cournot-Bertrand duopoly. Moreover, we can show that in this case, $\partial\overline{\gamma}_h^f/\partial\underline{u} < 0$ for any non-prohibitive $t > 0$. That is, the threshold relative cost efficiency is higher when market potential is low (i.e., a small $\underline{u}$). Thus a much lower γ_f and/or a much higher γ_h will be necessary to support $R_f^{M*} > R_h^{M*}$ in equilibrium. This leads to:

Corollary 2. *A higher market share for the exporter (due to higher market potential or lower trade costs) increases the probability of the exporter investing in quality more than the local rival in the case of Cournot-Bertrand duopoly.*

Using equation (12) and searching for parameter constellations under Cournot-Bertrand duopoly such that the condition given by Lemma 2 holds (i.e., $R_f^{M*} > R_h^{M*}$), we can conclude that:

Corollary 3. *The higher the cost efficiency difference between the exporter and the local firm, the more likely will it be that firms adopt asymmetric strategies.*

This implies that in industries where exporters are more efficient in quality investments than local firms, more aggressive strategic behavior may be observed by the local firms. This seems to be consistent with the observed behavior that has motivated this study.

6 Concluding Remarks

Following Singh and Vives (1984) and Cheng (1985), the Industrial Organization (IO) literature has commonly reported that in the case of strategic substitutes, private firms would prefer to compete by choosing quantities unless there are some technological, institutional or demand asymmetries, or asymmetric set-up or contract-switching costs (as in, among others, Sato, 1996, Tremblay and Tremblay, 2011, Schroeder and Tremblay, 2015, Schroeder and Tremblay, 2016, and Chao et al., 2018). The empirical observation is, however, that firms adopt asymmetric strategies in a number of markets (e.g., the market for small cars and the aerospace connector industry in the US, and the Japanese home electronics industry). Also the evidence suggests that in some markets, exporters seem to prefer setting output, whereas their local rivals seem to prefer setting prices. In this paper, in an attempt to theoretically delineate these empirical observations, we have developed a duopoly trade model with both horizontal and vertical product differentiation. Our results are consistent with these empirical observations and have provided an intuitive explanation to the observed asymmetric strategy choice between exporters and their local rivals.

The IO literature has argued that when there are sufficient quality differences among varieties, firms may prefer price competition over quantity competition; see, for example, Häckner (2000), and the literature that follows. This literature, however, overlooks the role product quality plays in firms' asymmetric choices of strategic variables. There is a small literature on endogenous mode of competition under vertical product differentiation, but the main focus in this literature has been on the vertical relationship and bargaining over input(s) between upstream input suppliers and downstream firms; see Correa-López (2007) and the literature that follows. Also the implications of (endogenous) product quality (as an important and empirically significant factor) for the preferred mode of competition have not been well established in the context of a trade model. While there are some studies in the trade literature looking into endogenous mode of competition in the context of strategic trade policy, the implications of vertical product differentiation have not been explored in those papers; e.g., see Maggi (1996) and the literature that follows. In this paper, we have shown that both trade costs and product quality are crucial for strategic asymmetry between exporting firms and their local rivals. Our results suggest that strategic asymmetry can be observed, especially when the relative product quality of the foreign variety is sufficiently high and trade costs are sufficiently low. The local firm will have a weak competitive position when both its relative product quality and the exporter's cost disadvantage due to trade costs are sufficiently low. To remedy this, the local firm chooses a more aggressive strategy and competes by setting prices, whereas the exporter gains more from less intense competition, and thus prefers to compete by choosing quantities.

By endogenizing the choice of quality, we have also shown that a lower cost efficiency in quality investments is sufficient for the exporter to invest in quality more than the local firm, especially in the absence of trade costs. When there are positive trade costs, then there is a threshold relative cost efficiency between the local firm and the exporter above which the exporter will invest in quality more than the local firm. This threshold increases with trade costs. In particular, our results suggest that lower trade costs not only encourage the exporter to upgrade quality, but also increase the probability of the exporter investing in quality more than the local rival, and therefore make strategic asymmetry more likely.

Our analysis can be extended in several ways. For instance, following Maggi (1996), strategic trade policy discussions as in Brander and Spencer (1985) and Eaton and Grossman (1985) can be incorporated in our model which may shed light on commercial policies. By the same token, transportation costs can be made endogenous as in Ishikawa and Tarui (2018), and/or potential exporters can be given the choice first between becoming a multinational and serving the host market via FDI or via exports.

Appendix

A.1 Proof of Proposition 4

Using equation (11), we can write $\alpha_f^C/(1+\beta_f^C)$ and $\alpha_h^C/(1+\beta_h^C)$ and we can show that $\partial(\alpha_i^C/(1+\beta_i^C))/\partial\gamma_i < 0$, $i = h, f$. Normalizing $\gamma_f = 1$ and denoting γ_h by γ_h^f, we can solve for $\overline{\gamma}_h^f$ such that $\alpha_f^C/(1+\beta_f^C) = \alpha_h^C/(1+\beta_h^C)$. It is now clear that, for any $\gamma_h^f > \overline{\gamma}_h^f$, $\alpha_f^C/(1+\beta_f^C) > \alpha_h^C/(1+\beta_h^C)$, and thus $R_f^{C*} > R_h^{C*}$. Differentiating $\overline{\gamma}_h^f$ with respect to t shows that $\partial\overline{\gamma}_h^f/\partial t > 0$, $\forall\ \sigma \in (0, 0.781)$, i.e., the stability condition.

Evaluating $\overline{\gamma}_h^f$ at $t = 0$ leads to $\overline{\gamma}_h^f|_{t=0} = 1$. We can now conclude that, in the absence of trade costs (i.e., $t = 0$), for any $\gamma_h^f > \overline{\gamma}_h^f = 1$, $\alpha_f^C/(1+\beta_f^C) > \alpha_h^C/(1+\beta_h^C)$, and thus $R_f^{C*} > R_h^{C*}$. This completes the first part of Proposition 4. As for the last part, it is now straightforward to show that, given $\overline{\gamma}_h^f|_{t=0} = 1$ and $\overline{\gamma}_h^f$ increases in t, for any positive and non-prohibitive trade cost $t > 0$, $\overline{\gamma}_h^f > 1$ and it is required that $\gamma_h^f > \overline{\gamma}_h^f > 1$, so that $\alpha_f^C/(1+\beta_f^C) > \alpha_h^C/(1+\beta_h^C)$, and thus $R_f^{C*} > R_h^{C*}$. This completes the proof of Proposition 4.

A.2 Proof of Proposition 5

Similar to Appendix A.1, using equation (12), we can write $\alpha_f^M/(1+\beta_f^M)$ and $\alpha_h^M/(1+\beta_h^M)$ and we can show that $\partial(\alpha_i^M/(1+\beta_i^M))/\partial\gamma_i < 0$, $i = h, f$. Normalizing $\gamma_f = 1$ and denoting γ_h by γ_h^f, we can solve for $\overline{\gamma}_h^f$ such that $\alpha_f^M/(1+\beta_f^M) = \alpha_h^M/(1+\beta_h^M)$. It is now clear that, for any $\gamma_h^f > \overline{\gamma}_h^f$, $\alpha_f^M/(1+\beta_f^M) > \alpha_h^M/(1+\beta_h^M)$, and thus $R_f^{M*} > R_h^{M*}$. Differentiating $\overline{\gamma}_h^f$ with respect to t shows that $\partial\overline{\gamma}_h^f/\partial t > 0$ for all $\sigma \in (0, 0.781)$.

Evaluating $\overline{\gamma}_h^f$ at $t = 0$ leads to $\overline{\gamma}_h^f|_{t=0} = (2+\sigma)(2-\sigma^2)/2(2-\sigma)(1+\sigma)$ which is less than unity $\forall\ \sigma \in (0, 0.781)$. We can now conclude that, in the absence of trade costs (i.e., $t = 0$), $\forall\ \gamma_h^f > \overline{\gamma}_h^f$, $\alpha_f^M/(1+\beta_f^M) > \alpha_h^M/(1+\beta_h^M)$, and thus $R_f^{M*} > R_h^{M*}$. Given that $\overline{\gamma}_h^f < 1$ $\forall\ \sigma \in (0, 0.781)$, $\gamma_h^f > 1$ is not a necessary but a sufficient condition under which (in the absence of trade costs) $R_f^{M*} > R_h^{M*}$. This completes the first part of Proposition 5. As for the last part, it is now straightforward to show that, given $\overline{\gamma}_h^f|_{t=0} < 1$ and $\overline{\gamma}_h^f$ increases in t, there is a threshold value of positive and non-prohibitive t at which $\overline{\gamma}_h^f = 1$. This threshold t increases in σ within the range $(0, 0.781)$. Below this threshold, $\overline{\gamma}_h^f < 1$, and above this threshold, $\overline{\gamma}_h^f > 1$. In either case, as in the case of $t = 0$, also for positive and non-prohibitive t, $\gamma_h^f > \overline{\gamma}_h^f$ is required for $\alpha_f^M/(1+\beta_f^M) > \alpha_h^M/(1+\beta_h^M)$, so that $R_f^{M*} > R_h^{M*}$. This completes the proof of Proposition 5.

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