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# Strategic R&D policy in a quality-differentiated industry with three exporting countries

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ABSTRACT

We examine strategic research and development (R&D) policy for quality-differentiated products in a third-market trade model. We extend the previous work by adding a third exporting country, so that the market structure is international triopoly. We show that the presence of the third exporting country affects strategic R&D policies. With three exporting countries, the lowest-quality exporting country gains from taxing domestic R&D and the middle-quality exporting country gains from subsidizing domestic R&D under both Bertrand and Cournot competition. As in the duopoly case, however, the optimal unilateral policy for the highest-quality exporting country depends on the mode of competition. Various cases of policy coordination by exporting countries are also examined.



## 1. Introduction

Subsidies on firms' research and development (R&D) activities are one of the policy instruments that have attracted the greatest deal of attention in the literature of strategic trade and industrial policy since Spencer and Brander (1983) have firstly examined its strategic use. In general, there are two types of R&D: process and product R&D. The former is aimed at reducing production costs, whereas the latter is aimed at developing new products and improving product quality of existing products. Early studies on strategic R&D policy, including Spencer and Brander (1983), focused on process R&D (Bagwell and Staiger, 1992, 1994; Miyagiwa and Ohno, 1997; Muniagurria and Singh, 1997). On the other hand, recent studies have dealt with product R&D (Jinji, 2003; Park, 2001; Zhou et al., 2002).

This shift in the research interest was partly motivated by the fact that quality differentiation gains increasingly importance in international trade. Some empirical studies confirm that in many industries goods are actually differentiated in quality. For example, using the NBER Trade Database, Hallak (2006) constructs export price indices for 3-digit sector, based on cross-country differences in export unit values of US imports in 1995 and 1996 at the 10-digit level of the Harmonized Tariff Schedule (HTS). The export price indices indicate a high variation across exporters and have a positive correlation with exporters' GDP per capita. For example, in the category of differentiated sectors, the indices of Switzerland and China are 1.64 and 0.63, respectively.[1] The average correlation between the sectoral index and GDP per capita is 0.45. Hummels and Klenow (2005) use United Nations Conference on Trade and Development (UNCTAD) Trade Analysis and Information System (TRAINS) data for 1995, covering 126 exporters to 59 markets at 6-digit level of the Harmonized System (HS) classification code. Their estimation shows that countries with twice GDP per worker tend to export 9 percent higher-quality varieties.

The existing studies on strategic policy for product R&D, such as Park (2001) and Zhou et al. (2002), focus only on the duopoly market with two rival countries. However, some casual observations in the real world suggest that in many industries for which

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[1] Indices are normalized so that Canada has a value of 1.

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quality differentiation is important, more than two major firms with possibly different nationalities compete in the global market. Consumer electronics and automobile industries are typical examples. Thus, a natural question is whether policy prescriptions regarding optimal unilateral R&D policy obtained from the analysis of two competing countries are robust to the change in the number of competing countries. In this paper, we attempt to answer this question by extending the model in the previous studies to the case of three exporting countries.

The model employed in this paper is based on that in Park (2001) and Zhou et al. (2002), which is a third-market trade model with vertically differentiated products.[2] Both of the two papers show that under Bertrand competition the government of the country that exports a high-quality (*resp*., low-quality) product has a unilateral incentive to tax (*resp*. subsidize) domestic firm's R&D. Under Cournot competition, on the other hand, the government of the high-quality (*resp*., low-quality) exporter has a unilateral incentive to subsidize (*resp*. tax) R&D.[3] Zhou et al. (2002) also examine coordinated R&D policy by the two exporting countries and show that under Bertrand competition the government of the high-quality (*resp*., low-quality) exporter should subsidize (*resp*. tax) R&D. Under Cournot competition, both governments should tax R&D. We extend the analysis by Park (2001) and Zhou et al. (2002) to the case of triopoly with three exporting countries and see how the optimal unilateral and coordinated R&D policies would be affected.[4]

The model involves a three stage game in which firms compete in two stages (quality choice and market competition) and prior to firms' decision governments set an R&D subsidy to maximize domestic welfare. We consider both price (Bertrand) and quantity (Cournot) competition at the final stage. We first examine the optimal unilateral R&D policy for each exporting country. We then consider policy coordination by two or all exporting countries. Under policy coordination, the governments of coordinating countries set their R&D subsidy to maximize their joint welfare.

The major findings of this paper are as follows. First, we find that the sign of the strategic policy (either subsidy or tax) depends on the mode of competition (either Bertrand or Cournot) only for the country that exports the highest-quality product. This result exhibits a sharp contrast to the outcome in the case of two exporting countries that, as Park (2001) and Zhou et al. (2002) show, a change in the mode of competition reverses strategic policies for both exporting countries.[5] Second, we also find that the country that exports the lowest-quality product gains from an R&D tax under both Bertrand and Cournot competition. Third, in comparison with the duopoly case, the presence of the third exporting country changes the strategic policy for the country exporting the second-highest quality product from a tax to a subsidy on R&D when firms compete in quantities at the final stage. Fourth, coordinated R&D policies by all exporting countries and by exporting countries of the high- and the middle-quality products are qualitatively similar to what Zhou et al. (2002) show in the case of two exporting countries. However, either of the exporting countries of the high- or the middle-quality products coordinates its R&D policy with the exporting country of the low-quality product, the R&D policy of the high- or the middle-quality exporter is qualitatively different from that in the duopoly case.

The rest of the paper proceeds as follows. Section 2 sets up the model. Section 3 analyzes strategic R&D policy under Bertrand and Cournot competition. Section 4 compares our results with those shown by the existing papers. Section 5 examines policy coordination by exporting countries. Section 6 concludes the paper.

## 2. The model

The model we use in this paper is an extension of the standard model of vertical differentiation with a fixed cost of quality improvement.[6] Consider that there are three exporting countries and one importing country. The exporting countries are labeled as country 1, 2, and 3. One firm is located in each exporting country. Each firm produces a quality-differentiated product and exports to the importing country. For simplicity, we assume that there is no domestic consumption in each exporting country.

As for production technology, we assume that firms face an identical cost structure. The marginal and average production costs are assumed to be constant and, for simplicity, are set equal to zero.[7] Each firm engages in product R&D to improve product quality. Let $q_i$ be quality of the product produced by firm $i$, $i = 1, 2, 3$. The cost of quality improvement for firm $i$ is given by $F^i(q_i)$. Firms are heterogeneous in their research capability. Let $\bar{q}_i$ be the highest quality for firm $i$ to be able to develop. For analytical convenience, we assume that, as long as firm $i$ develops a quality level below $\bar{q}_i$, the cost of product R&D is the same across firms. That is, we assume that the cost function of product R&D for firm $i$ is given by

$$F^i(q_i) = \begin{cases} k(q_i)^2 & \text{for } q_i \le \bar{q}_i, \\ \infty & \text{for } q_i > \bar{q}_i, \end{cases} \tag{1}$$

where $k > 0$ is a common efficiency parameter.[8] Without loss of generality, we assume that $\bar{q}_1 > \bar{q}_2 > \bar{q}_3$. That is, firm 1 has the highest research capability, followed by firm 2, and firm 3 is the lowest in the research capability. More specifically, we impose the following restrictions:

$$\bar{q}_1 = \infty; \quad \bar{q}_2 < q_H^*; \quad \bar{q}_3 < q_M^*,$$

where $q_H^*$ and $q_M^*$ denote the highest and the second highest quality levels of products, respectively, that are chosen by firms in the equilibrium of the game specified below without R&D policy. This assumption allows us to eliminate the possibility of multiple equilibria and focus on the case in which $q_1 > q_2 > q_3$ always holds.[9]

[2] Vertical differentiation naturally introduces asymmetry among firms into the study of strategic trade and industrial policy. The literature on strategic trade and industrial policy under asymmetric oligopoly includes Collie (1993, 2006), Leahy and Montagna (2001), and Long and Soubeyran (1997).

[3] Introducing managerial delegation with the relative-performance contract into the model of Zhou et al. (2002) and Wang and Wang (2011) show that the optimal unilateral R&D policy is free trade under both Bertrand and Cournor competition.

[4] The triopoly case under vertical differentiation is analyzed by Scarpa (1998) for the Bertrand competition and by Pezzino (2010) for the Cournot competition, though the focus of these two papers is on the effects of minimum quality standards. Neither paper considers R&D subsidies. International trade is also assumed away. Thus, in this paper we apply their results to the case of international trade and investigate the role of strategic R&D policy.

[5] As is well known, the sensitivity of the policy prescription to the mode of market competition has been one of the central questions in the literature of strategic trade policy. See, for example, Eaton and Grossman (1986).

[6] As for the standard model of vertical differentiation, see, e.g., Mussa and Rosen (1978), Gabszewicz and Thisse (1979, 1980), Shaked and Sutton (1982, 1983), Aoki and Prusa (1997), Aoki (2003), Motta (1993), and Toshimitsu (2003). Applications to international trade and trade policy include Herguera et al. (2000), Herguera et al. (2002), Jeanneret and Verdier (1996), Lutz (2000), Motta et al. (1997), and Toshimitsu and Jinji (2008).

[7] This is a standard assumption in the literature. See, for example, Shaked and Sutton (1982, 1983) and Ronnen (1991).

[8] Since $F(q) = k(q)^2$ is most popularly used in the literature, we use this functional form.

[9] As is well known in the literature of vertical differentiation, firms choose distinct qualities in equilibrium in both Bertrand and Cournot cases. However, under the assumption of identical cost structure, there are generally multiple equilibria, which are identical except for the identities of firms (and countries). As Park (2001) and Zhou et al. (2002) have done, one way of ruling out the possibility of multiple equilibria is to introduce a sufficient R&D cost difference among firms. However, such an approach will make it very difficult to calculate the numerical solutions under the particular functional form when there are three firms. For that reason, we do not take that approach.