International competition in vertically differentiated markets with innovation and imitation: Impacts of trade policy*

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Abstract

We analyze the domestic welfare implications of trade policies in a less developed or transition country whose firm competes with the firm from a developed country in the domestic market. The important characteristic of such competition is vertical product differentiation, where the quality choices represent strategic decisions of the firms. Compared to the previous literature, we introduce leadership, and possibility of imitation and learning by the domestic firm. We identify conditions under which the phenomenon of so called *quality reversal* takes place.

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1 Introduction

Contrary to the prediction of the standard international trade theory, it is often the case that firms from countries on rather different stages of development compete in the same market (Schott 2004). The products produced by firms from developed countries (DCs) are usually associated with variety of higher quality than the ones produced by firms from less developed countries (LDCs).[1] Firms' choices of qualities are, however, endogenous and may be influenced by some governmental policies. For instance, a policy maker designing a trade policy for such oligopolistic market may affect the corresponding firms' choice of qualities. Thus, she may, therefore, need to take into account the strategic behavior of competing firms, and in particular, their choices of qualities. Recent trade literature has already started to explore strategic trade policies in markets with vertically differentiated products. A striking phenomenon in such markets is *quality reversal*, which occurs when the trade policy reverses the equilibrium ranking of qualities. The existing literature, however, does not address two important aspects of quality choice in the context of DC and LDC: leadership and imitation. In reality the firms from developed countries are usually technological leaders undertaking R&D or investments, in order to innovate their products of higher quality and different design, or to invent better production processes, while LDC firms tend to imitate these product and processes. To support these endeavors, the governments of LDC (or former LDCs like Japan) used to endorse a whole spectrum of "non-conventional" polices from the arsenal of trade and industrial policy. For instance, as noted by Rodrik (2001), governments in the Republic of Korea and Taiwan freely resorted to unorthodox strategies and protected the home markets to raise profits by implementing various industrial and protectionist trade policies, and encouraged their firms to reverse-engineer foreign patented products.

Our paper aims to fill the above mentioned gap in the literature by introducing leadership and imitation into the vertical differential model of international trade. We are particularly interested under which conditions the optimal trade policy leads in this setup to quality reversal.

Early studies of strategic trade policy focused on markets with either perfectly substitutable or horizontally differentiated products; see Brander (1995) for a survey. However, in recent years the attention of trade economists has been shifted towards vertically differentiated markets. One of the first

[1]In industries like automobiles, electronics, computer hardware and cosmetics, the products from Japan, USA and Europe are associated with higher qualities than products from East Asia (Ghosh and Das 2001). See also Greenway, Hine and Milner (1994), and Clark and Stanley (1999) for empirical findings.

theoretical studies capturing the difference between firms from DCs and LDCs by vertical differentiation is Ghosh and Das (2001). The authors compare competition in the LDC market, DC market, and a third country market, using a two-stage game. In the first stage, the countries set their trade policies in the form of export taxes (or subsides) and import tariffs. In the second stage, the firms compete in prices. The authors assume that the qualities of the products are given exogenously. They show that in the policy equilibrium, the LDC firm may not be able to survive in the DC market whereas the DC firm always maintains a market share in the LDC market.

Zhou, Spencer and Vertinsky (2000, 2002) introduce endogenous choices of qualities. They capture the difference between the DC firm and the LDC firm by different costs innovation (investment in quality) and assume that the firms compete in a third country market. To model the endogenous choices of qualities, the authors construct a three-stage game adding a middle stage, at which the firms decide on their qualities. As opposed to Ghosh and Das (2001), the policy instruments available to the countries (DC and LDC) are taxes and subsidies on the investment in quality. The authors show that a unilateral policy involves investment tax by the DC and investment subsidy by the LDC. On the other hand, a jointly optimal policy involves the reverse, in order to soften the price competition.

Herguera, Kujal and Petrakis (2002) are the first who analyze the phenomenon of quality reversal. Much like Zhou, Spencer and Vertinsky (2002), they consider a model with endogenous choice of quality but in a domestic market setup, where the competition takes place in one of the firm's home market. The authors analyze policy instruments in the form of *ex-ante* and *ex-post tariffs* depending on whether the trade policy is chosen before or after firms' quality decisions. Herguera et al. (2002) do not distinguish between DC and LDC firms and consider the firms (one of them being domestic and the other foreign) to be symmetric in terms of both production technology and marginal efficiency in generating quality. They show that by virtue of ex-post tariffs the domestic firm always produces the high-quality good implying that the setup in which foreign firm produce a high quality variety of the good in free trade, is not anymore an equilibrium once optimal (ex-post) trade policy is applied. In addition, the authors show that the optimal ex-ante tariff is prohibitive resulting in a domestic monopoly whenever the domestic firm produces a lower quality.[2]

Moraga-Gonzáles and Viaene (2005) use a similar setup as Ghosh and

[2]The above results hold for Bertrand competition. Both Zhou et al. (2002) and Herguera et al. (2002) also analyze Cournot competition. Since the price competition seems to be more natural mode of competition in our setup, we do not consider a Cournot type competition.

Das (2001), but consider endogenous choices of qualities. They also introduce firms' asymmetry stemming from different costs in generating quality, in order to describe domestic markets in transition countries. Moraga-Gonzáles and Viaene (2005) provide a rationale for government to induce quality reversal and identify conditions under which it occurs. Kúnin and Žigić (2004) use similar assumptions concerning the difference of DC and LD firms in generating quality as in Zhou et al. (2002), and Moraga-Gonzáles and Viaene (2005), and a related domestic market ex-post tariff setup as in Herguera et al. (2002), but unlike the rest of reviewed literature, they focus on the case of so called *natural duopoly* (following the terminology by Shaked and Sutton 1983). In this case, the market is *covered* in equilibrium and cannot accommodate more than two firms. The authors find under which conditions the optimal trade policy leads to the quality reversal provided the domestic firm is from LDC. In particular, their results indicate that quality reversals tend to be less likely than previously thought.

Most of the literature (including the international trade literature) considers the firms' investment decision to take place simultaneously and allows the firms' efficiencies of investments to be ex-ante asymmetric in the sense that DC firms are assumed to have higher R&D efficiency or better skilled workers (reflecting, for example, better education). This consequently implies that lower investments are needed in order to achieve certain quality level. In this paper we revisit the traditional vertical differentiation model and make a further step by introducing leadership and imitation. In particular, the DC firm is assumed to be a leader in quality, i.e., it chooses its quality before the LDC firm. This allows us to analyze the effects of strategic trade policies on markets with leaders.[3] Besides leadership, we introduce the possibility of imitation by the LDC firm (follower). In practice, imitation is frequently used by firms from LDCs which try to "copy" the products from DCs, which obviously reduces the costs of innovation.

In order to study the impact of strategic trade policy on the vertically differentiated oligopolistic market with a leader and imitation, we adopt a four-stage game with price competition in the last stage, and a government setting trade policy in the preceding stage in the form of tariff.[4] In other words, we assume that the government's decision on the tariff policy follows both domestic firms' imitation stage (second stage) and a leader R&D investment stage (first stage), but precedes the pricing game (fourth stage). This seems a reasonable timing assumption in this context due to the fact

[3]In this sense our paper complements the emerging literature on market leaders; see Etro (2004, 2006a, 2006b), and Žigić, Vinogradov and Kováč (2006).

[4]Imposing import tariffs seems to be the most common and most practical form of trade policy in LDCs, see for instance, Bhattacharjea (1995) and Ionaşcu and Žigić (2005).

that, in general, the governments and firms are likely to differ in their ability to commit to future actions; see Neary and Leahy (2000). Moreover, trade policy is by its nature of second-best (or even third-best) character, and it is plagued with the time consistency problem.[5] The above timing takes into account these phenomena and the tariff that we calculate below is, in fact, a time consistent tariff.[6]

Apparently, the action takes place in the domestic market and the strategic choice considered is the firms' selection of product qualities. The standard assumption in both horizontal and vertical differentiation setup is that firms make sunk cost investment (e.g., in R&D or technological improvements) in order to achieve certain quality levels.[7] Finally, we assume that the marginal quality cost efficiencies differ among the firms; see also Zhou et al. (2002), Moraga-Gonzáles and Viaene (2005), and Kúnin and Žigić (2004).

As already stressed, we are particularly interested how the presence of leadership and imitation impacts on the phenomenon of quality reversals. We first identify conditions under which the optimal trade policy leads to a quality reversal (i.e., a change in the ranking of qualities). Our results indicate that the optimal trade policy gives incentive to the domestic follower to imitate and the larger is imitation, the more likely is quality reversal. More specifically, we show that quality reversal tends to occur when the difference between firms' technological levels (measured by marginal efficiencies of firms' investments) is small and this result is amplified under the possibility of imitation.

The reminder of the paper is organized as follows. In Section 2 we introduce the model and the underlying assumptions. In Sections 3 and 4 we solve for price competition equilibrium and optimal tariff. In Section 5 we analyze firms' quality choices. Section 6 concludes and discusses our results. Appendix A contains proofs of lemmas and propositions.

2 Model

We start with a theoretical model of international trade in vertically differentiated products, where firms from LDC and DC country compete in both qualities and prices, in the LDC domestic market. We consider a single good

[5]See, for instance, Staiger (1995) and survey of related literature of this issue there.

[6]More specifically, we calculate the subgame perfect tariff since subgame perfection implies time consistency but not necessarily, vice versa; see Fershtman (1989).

[7]Shaked and Sutton (1987) suggest that in the case of vertical product differentiation this assumption is "more likely to be valid in those industries in which the main burden of product improvement falls on fixed costs, rather than on variable costs."

produced by one foreign DC firm and one domestic LDC firm. The foreign firm (Firm 1) is assumed to be a leader in quality and the domestic firm (Firm 2) a follower. We describe the whole situation as a four-stage game:

1. Firm 1 (the leader) decides whether to be active in the market and chooses its quality (by incurring sunk costs).
2. Firm 2 (the follower) decides whether to be active in the market and chooses its quality (by incurring sunk costs).
3. Domestic government decides on its trade policy.
4. Firms 1 and 2 compete in prices.

We consider two regimes: *trade policy (TP) regime* and *free trade (FT) regime*. In the trade policy regime, the domestic government chooses its trade policy by setting import tariffs.[8] The above timing corresponds to so-called *ex-post tariffs*, where the tariffs are imposed after the firms' quality choices have been observed.[9] On the other hand, in the free trade regime, the domestic government does not behave strategically and takes no action in the third stage (corresponding to zero tariff). Such behavior may be induced by bilateral agreements or country's membership in a trade organization. In order to solve the model we look for the subgame perfect equilibrium in pure strategies and apply the standard backwards induction concept.

We capture the difference between DC and LDC firms is by asymmetry in their cost structures and sequential nature of their quality choices and investments. The costs incurred to achieve a certain quality level may be interpreted as R&D costs or investments into technology, which are sunk in later stages. As will be shown later, under free trade regime, the sequential structure gives Firm 1 the first-mover advantage, when both firms have the same cost structure. Moreover, the LDC firm may have cost disadvantages meaning that its opportunity cost to achieve a certain quality level may be higher than for the DC firm. The reason for postulating the differences in the quality cost efficiency stems from different abilities of the firms from the LDC (compared with DC) to elevate the quality levels of its products. Denote s_1 the quality of Firm 1's product and s_2 the quality of Firm 2's product. We say, that *quality reversal* occurs when the leader produces a higher quality in

[8] We restrict the analysis of available policy instruments to import tariffs. Other instruments could be, for example, production subsidies (for the domestic firm), investment subsidies, or anti-dumping.

[9] One might also consider *ex-ante tariffs* which are chosen in the first stage, before the firms' qualities. However, these may not be time-consistent and require commitment of the policy maker.

the free-trade regime equilibrium (i.e., $s_1 > s_2$) whereas it produces a lower quality in the strategic trade regime equilibrium (i.e., $s_2 > s_1$).[10]

2.1 Assumptions of the model

We use the classical model of vertical differentiation, with each consumer being characterized by a parameter θ and having the following utility function:

$$U_\theta = \begin{cases} \theta s - p, & \text{if he buys good with quality } s \text{ for price } p, \\ 0, & \text{if he does not buy.} \end{cases}$$

The parameter θ can be interpreted as consumer's appreciation of quality or taste for quality, meaning that the consumer is willing to pay θ for an increase in quality by one unit. We assume that θ is uniformly distributed over interval $[0, 1]$. This yields in equilibrium an undercovered market, with not all consumers being served. Our model can be potentially extended in the spirit of Kúnin and Žigić (2004) by considering narrower markets, i.e., with consumers uniformly distributed on some interval $[\underline{\theta}, \overline{\theta}]$.

Remark 1. Since the taste for quality is not directly observable economic variable, a more realistic approach could be to characterize the consumers according their income, as in Shaked and Sutton (1982). However, Tirole (1992, pp. 96–97) shows that these two approaches are equivalent, where $1/\theta$ can be interpreted as marginal rate of substitution between quality and income. For consumers with a higher income is the marginal rate lower, i.e., θ is higher.

Based on the qualities (denoted s_1 and s_2) and prices (denoted p_1 and p_2) offered by Firms 1 and 2, the consumers choose between buying the product from Firm 1 or from Firm 2, or not buying at all. This choice then determines firms' demands D_1 and D_2. We assume that the production is costless, but R&D yielding a particular product quality may involve certain fixed costs (incurred in stages 1 and 2 and sunk later). Therefore, the firms' gross[11] profits are

$$\Pi_1 = (p_1 - t)D_1, \qquad \Pi_2 = p_2 D_2, \tag{1}$$

[10] Our definition of quality reversal resembles Herguera et al. (2002) and Kúnin and Žigić (2004). On the other hand, Moraga-Gonzáles and Viaene (2005) use a slightly different definition. They obtain multiple equilibria and select one of them using risk-dominance criterion. The author say that quality reversal occurs, when the domestic (less efficient) firm becomes the high-quality producer in the unique (risk-dominant) equilibrium of the export game.

[11] In this section, by profit we mean always the gross profit which does not include fixed costs. The fixed costs of R&D are sunk and hence do not influence firms' behavior in the last stage.

where t is the tariff imposed on the foreign firm's imports. The value of t is chosen by the domestic government in stage 3.

As mentioned above, in the free trade (FT) regime, the domestic (LDC) government takes no action, so corresponding import tariffs equal to zero. On the other hand, under the trade policy (TP) regime, the domestic government decides on its trade policy by setting the optimal level of the import tariff in order to maximize the *domestic welfare*. The domestic welfare (DW) is defined as the sum of consumer surplus (CS), domestic firm's profit (Π_2) and income from tariffs net of subsidies T.[12] Formally,

$$DW = \Pi_2 + T + CS. \tag{2}$$

In stages 1 and 2, Firm 1 and Firm 2 choose their qualities in order to maximize their net profit. The net profit is defined as the difference of the gross profit and firm's fixed costs necessary to develop certain quality. By introducing the possibility of imitation, we affect Firm 2's choice of quality in stage 2, by allowing it to obtain certain quality levels with lower costs (i.e., without incurring the full costs of R&D).

The possibility of imitation has not been properly explored in the industrial organization, within the vertical differentiation model. As an exception Pepall (1997) considers a model with two firms: one being a leader in quality, the other a follower. Imitation is captured by altering follower's fixed costs. The leader chooses its quality (say s_1) by incurring sunk costs K, whereas the follower's costs (of choosing quality s_2) are $K(s_1 - s_2)^2$. There are two important features of this cost structure which we consider not relevant in international trade and in which our specification differs from Pepall (1997). First, the leader's costs are fixed and do not depend in quality s_1. Second, the follower's costs are decreasing on interval $[0, s_1]$. As a consequence, the costs of achieving zero quality are positive and depend on s_1. As Pepall (1997) suggests, K represent the costs incurred "to market a new product" In this sense the model is appropriate to describe, for example, marketing ideas, where the follower's costs would be indeed zero when it copies the same idea. However, when quality is interpreted as level of technology, we find Pepall's specification not appropriate. Even if fixed costs are interpreted as costs of R&D in order to achieve some invention, high costs may be necessary in order to copy the same invention, but lower costs to make a inferior

[12]Similarly as for profits, by domestic welfare we mean the gross domestic surplus which does not include fixed costs. The fixed costs of R&D are sunk in the third stage and hence do not influence firms' and domestic government's behavior in the fourth and third stage. Firm's profit obtained from gross profit after subtracting the fixed costs will be referred to as *net profit*.

copy of the invention.[13]

We assume that Firm 1 (leader) has the following cost function:

$$C_1(s_1) = \tfrac{1}{2}\gamma_1 s_1^2, \tag{3}$$

where $\gamma_1 > 0$ is a positive parameter and corresponds, for example, to the efficiency of investments (like investments in R&D). A lower value of γ_1 means that investments are more efficient, in the sense that the costs of achieving certain quality level are lower. Under the above cost function, Firm 1's marginal costs are $C_1'(s_1) = \gamma_1 s_1$.

On the other hand, Firm 2's cost function is more complex, since it should reflect both lower degree of development and possibility of imitation. In particular, we impose the following conditions:

(i) Without imitation, Firm 2's costs are proportional to leader's costs by a factor larger than 1. This reflects a lower technological level or a lower R&D efficiency of the LDC firm.

(ii) Due to imitation, Firm 2's marginal costs decrease proportionally when it produces a lower quality good.

(iii) Imitation does not alter Firm 2's marginal costs when it produces a higher quality good (i.e., costs of quality improvement by an additional unit are unchanged).

(iv) Firm 2's cost function is continuous.

Under these conditions, there exists parameters γ_2 and μ satisfying inequalities

$$0 < \gamma_1 \leq \gamma_2, \qquad 0 \leq \mu \leq 1, \tag{4}$$

such that Firm 2's cost function can be written as (see Appendix A for details)

$$C_2(s_1, s_2) = \begin{cases} \tfrac{1}{2}\gamma_2 \mu s_2^2, & \text{if } s_2 \leq s_1, \\ \tfrac{1}{2}\gamma_2 [s_2^2 - (1-\mu)s_1^2], & \text{if } s_2 > s_1. \end{cases} \tag{5}$$

Firm 2's marginal costs then are

$$\frac{\partial}{\partial s_2} C_2(s_1, s_2) = \begin{cases} \gamma_2 \mu s_2, & \text{if } s_2 \leq s_1, \\ \gamma_2 s_2, & \text{if } s_2 > s_1. \end{cases} \tag{6}$$

[13] It may be difficult to copy the recent technological inventions, but easy to copy older inventions of "lower quality" (e.g., slower microchips).

The parameter γ_2 similarly corresponds to Firm 2's investment efficiency and the parameter μ represents to imitation. The inequality $\gamma_1 \leq \gamma_2$ reflects the fact that without imitation LDC firm needs to incur higher (or equal) costs than DC firm in order to achieve certain same quality level. The inequality $\mu \leq 1$ means that imitation decreases costs. In particular, when $\mu = 1$, then there is no imitation. If, in addition, $\gamma_2 = \gamma_1$, then Firm 2's cost function is the same as the Firm 1's one. On the other hand, if $\mu = 0$, corresponds to full imitation, i.e., Firm 2 may replicate any quality $s_2 \leq s_1$ with no costs. In general, the lower the value of μ, the more easier is imitation. Therefore, $1 - \mu$ can be interpreted as a *degree of imitation*: value 0 corresponds to no imitation, value 1 to full imitation. It is worthwhile to note that although Firm 2's cost function is continuous, its marginal costs are not. In particular, $C_2(s_1, s_2)$ has a kink when $s_2 = s_1$.

3 Equilibrium of price competition in the last stage

Proceeding backwards, we start with the price competition in the last stage. In this respect we need to analyze two cases, depending on the ranking of qualities. First we analyze the case where Firm 2 (the domestic LDC firm) produces a lower quality, i.e., $s_1 > s_2$. When Firms 1 and 2 offer their products for prices p_1 and p_2, they face the following demands:

$$D_1 = 1 - \theta_{12}, \qquad D_2 = \theta_{12} - \theta_{20},$$

where

$$\theta_{12} = \frac{p_1 - p_2}{s_1 - s_2}, \qquad \text{and} \qquad \theta_{20} = \frac{p_2}{s_2}$$

denote the consumer who is indifferent between buying the good from Firms 1 and 2, and the consumer who is indifferent between buying the good from Firm 2 and not buying at all, respectively.

The equilibrium in the last stage is given by maximization of firms' profits (1). It can be easily computed that:

$$p_1^* = \frac{2s_1(s_1 - s_2 + t)}{4s_1 - s_2}, \qquad p_2^* = \frac{s_2(s_1 - s_2 + t)}{4s_1 - s_2}. \tag{7}$$

This yields the indifferent consumers

$$\theta_{12}^* = \frac{(2s_1 - s_2)(s_1 - s_2 + t)}{(s_1 - s_2)(4s_1 - s_2)}, \qquad \theta_{20}^* = \frac{s_1 - s_2 + t}{4s_1 - s_2}.$$

and firms' equilibrium profits

$$\Pi_1^* = \frac{[2s_1(s_1 - s_2) - (2s_1 - s_2)t]^2}{(s_1 - s_2)(4s_1 - s_2)^2}, \qquad \Pi_2^* = \frac{s_1 s_2 (s_1 - s_2 + t)^2}{(s_1 - s_2)(4s_1 - s_2)^2}. \tag{8}$$

It is worthwhile to note that in this setup, tariff does not have direct impact on relative prices, since $p_2/p_1 = s_2/(2s_1) = s/2$, where $s = s_2/s_1 < 1$ and s can be interpreted as measure of quality gap; see also Moraga-Gonzáles and Viaene (2005). However, there is an important indirect effect of trade policy since, as we will see, the anticipations of tariffs do affect the equilibrium choice of qualities, s_1 and s_2, and hence quality gap s. Note that s determines the degree of product differentiation and toughness of price competition, in turn. When $s < 1$, then any increase in s intensifies price competition leading to the Bertrand paradox in the limiting case when $s = 1$.

In order for prices (7) to form an equilibrium, it is necessary that the inequalities $0 \leq \theta_{20}^* \leq \theta_{12}^* \leq 1$ hold. The inequality $\theta_{12}^* \leq 1$ holds, if and only if $t \leq 2s_1(s_1 - s_2)/(2s_1 - s_2)$, implying that the optimal tariff has to be lower than s_1. If the last condition does not hold, the tariff is so high that the Firm 1's market share cannot be positive. In this case, Firm 2 is the only one in the market and the only viable market structure is *domestic monopoly* (see Remark 2). On the other hand, if the last condition holds with equality Firm 1's profit is exactly zero resulting (in absence of fixed costs) in the market structure called *constrained domestic monopoly.* That is, Firm 1 is indifferent between being active and not active in the market, but its presence still influences Firm 2's decision. The inequalities $0 \leq \theta_{20}^*$ and $\theta_{20}^* \leq \theta_{12}^*$ are equivalent and hold, if and only if $t \geq -(s_1 - s_2)$. This is obviously satisfied when the tariff is non-negative.[14]

Remark 2. In case of monopoly, the monopolist firm with quality s_M maximizes its profit $\Pi_M = p_M(1 - p_M/s_M)$, yielding the optimal price $p_M^* = s_M/2$ and profit $\Pi_M^* = s_M/4$. The domestic welfare (see later) is $3s_M/8$, in case of domestic monopoly, and $(s_M - t)(s_M + 3t)/(8s_M)$ in case of foreign monopoly when tariff t is imposed.

The explicit solution of the price competition equilibrium also offers interesting insights about comparative statics with respect to the import tariff t. One can easily see that both firms' equilibrium prices are increasing in t. Intuitively, Firm 1's price is higher, since it compensates for losses caused by a higher tariff. Due to strategic complementarity, Firm 2 is also willing to raise its price, leading to equilibrium with higher prices. On the other

[14] On the other hand, the domestic country may decide to subsidize imports because of low quality of the domestic firm's good. In this case, the only viable market structure is foreign monopoly.

hand, note that Firm 1's price net of tariff, that is $p_1 - t$, is decreasing in t, which reflects the standard impact of tariffs to improve terms of trade of the domestic country. Due to higher prices, the measure of consumers served in equilibrium (that is, the size of the market, which is $1 - \theta_{20}$) is decreasing in t. Despite this, the domestic firm (Firm 2) faces an increase in its demand (equal to $\theta_{12} - \theta_{20}$), provided the tariff leads to duopoly (i.e., it satisfies the above conditions).

The straightforward consequences of this is that Firm 1's profit is decreasing in t, whereas Firm 2's profit is increasing in t; see also the expressions for equilibrium profits (8). This is consistent with the basic idea of import tariffs: protection domestic firms again foreign ones.

Analogically we may proceed in the case where Firm 2 produces a higher quality, i.e., $s_2 > s_1$. In this case the firms' demands are:

$$D_2 = 1 - \theta_{21}, \qquad D_1 = \theta_{21} - \theta_{10},$$

where

$$\theta_{21} = \frac{p_2 - p_1}{s_2 - s_1}, \qquad \text{and} \qquad \theta_{10} = \frac{p_1}{s_1}$$

denote the consumer who is indifferent between buying the good from Firms 2 and 1, and the consumer who is indifferent between buying the good from Firm 1 and not buying at all, respectively. The equilibrium in the last stage is given by maximization of the profits (1) and it can be easily computed that:

$$p_2^* = \frac{s_2(2s_2 - 2s_1 + t)}{4s_2 - s_1}, \qquad p_1^* = \frac{2s_2t + s_1s_2 - s_1^2}{4s_2 - s_1}, \tag{9}$$

yielding the indifferent consumers

$$\theta_{21}^* = \frac{(s_2 - s_1)(2s_2 - s_1) - s_2t}{(s_2 - s_1)(4s_2 - s_1)}, \qquad \theta_{10}^* = \frac{s_1(s_2 - s_1) + 2s_2t}{s_1(4s_2 - s_1)},$$

and firms' equilibrium profits

$$\Pi_2^* = \frac{s_2^2(2s_2 - 2s_1 + t)^2}{(s_2 - s_1)(4s_2 - s_1)^2}, \qquad \Pi_1^* = \frac{s_2[s_1(s_2 - s_1) - (2s_2 - s_1)t]^2}{s_1(s_2 - s_1)(4s_2 - s_1)^2}. \tag{10}$$

Much like before, in order for the above to be an equilibrium, it is necessary that the inequalities $0 \leq \theta_{10}^* \leq \theta_{21}^* \leq 1$ hold. We will not elaborate in these conditions further, since it does not provide any additional insights. However, later we check that they are satisfied by the optimal tariff.

Again, with explicit solution of the price competition equilibrium, we are able to derive insights about comparative statics with respect to the import tariff t. One can easily observe that the effect of tariff on equilibrium prices, firms' demands, and firms' profits is the same as in the previous case. In particular, we point out that Firm 1's profit is decreasing in t, whereas Firm 2's profit is increasing in t.

4 Tariff choice

In the free trade (FT) regime, the domestic government takes no action in the third stage, which may be represented by tariff $t = 0$. The corresponding price competition equilibrium can be then obtained from (7), (8) when $s_2 < s_1$ and from (9), (10) when $s_2 > s_1$, by setting $t = 0$. Firms' continuation profits (equilibrium profits from subsequent stages) are shown in Tables 1 and 2 in Appendix B (first column).

On the other hand, under the trade policy (TP) regime, the domestic government decides on its trade policy by maximizing the domestic welfare given by (2). If the LDC firm (Firm 2) produces a lower quality, then the domestic welfare can be rewritten as follows:

$$DW = \underbrace{p_2(\theta_{12} - \theta_{20})}_{\Pi_2} + \underbrace{t(1 - \theta_{12})}_{T} + \underbrace{\int_{\theta_{20}}^{\theta_{12}} (\theta s_2 - p_2)\,\mathrm{d}\theta + \int_{\theta_{12}}^{1} (\theta s_1 - p_1)\,\mathrm{d}\theta}_{CS} =$$

$$= s_2 \int_{\theta_{20}}^{\theta_{12}} \theta\,\mathrm{d}\theta + s_1 \int_{\theta_{12}}^{1} \theta\,\mathrm{d}\theta - \Pi_1.$$

When choosing the tariff, the domestic government anticipates the price competition equilibrium in the last stage. In the equilibrium with prices given by (7), the equilibrium domestic welfare is

$$DW^* = \frac{s_1(s_1 - s_2)(s_1 + 2s_2 + 2t) - (3s_1 - 2s_2)t^2}{2(4s_1 - s_2)(s_1 - s_2)}. \qquad (11)$$

Obviously, the domestic welfare is concave in tariffs and attains its maximum for

$$t^* = \frac{s_1(s_1 - s_2)}{3s_1 - 2s_2},$$

which consequently represents the tariff chosen by the domestic country in the subgame perfect equilibrium. It can be easily shown that under this tariff, duopoly is the equilibrium market structure (i.e., inequalities $0 \leq \theta_{20}^* \leq \theta_{12}^* \leq 1$ hold). Note that the optimal tariff is increasing in s_1 and decreasing in s_2.[15] Moreover, the optimal tariff is always positive which means that

[15] This may be obtained by taking derivatives $\mathrm{d}t^*/\mathrm{d}s_1 = [2(s_1-s_2)^2+s_1^2]/(3s_1-2s_2)^2 > 0$, and $\mathrm{d}t^*/\mathrm{d}s_2 = -s_1^2/(3s_1 - 2s_2)^2 < 0$.

domestic LDC country never prefers free trade. Consequently Firm 1's profit is lower and Firm 2's profit is higher than their respective profits in free trade equilibrium, when $t = 0$ (according to the comparative statics results from the previous section). The price competition equilibrium resulting from this tariff can be then obtained from (7) and (8); see Tables 1 and 2 (second column).

If the LDC firm produces a higher quality, analogically as in the previous case, we obtain

$$DW = s_1 \int_{\theta_{10}}^{\theta_{21}} \theta \,\mathrm{d}\theta + s_2 \int_{\theta_{21}}^{1} \theta \,\mathrm{d}\theta - \Pi_1,$$

and in equilibrium

$$DW^* = \frac{s_2 s_1 (s_2 - s_1)(3s_2 + 2t) - (3s_2 - 2s_1)t^2}{2(4s_2 - s_1)(s_2 - s_1)}. \tag{12}$$

Again, the domestic welfare is concave in tariffs and attains its maximum for

$$t^* = \frac{s_1(s_2 - s_1)}{3s_2 - 2s_1}.$$

It can be easily shown that for such tariff, duopoly is the equilibrium market structure (i.e., inequalities $0 \leq \theta_{10}^* \leq \theta_{21}^* \leq 1$ hold).[16] Likewise in the previous case the optimal tariff is positive and hence the domestic country never prefers free trade. Moreover, by the same argument sa above, Firm 1's profit is lower and Firm 2's profit is higher than their respective profits in free trade equilibrium.

Tables 1 and 2 in Appendix B summarize the results and show firms' continuation profits. Note that the profits are continuous when $s_1 = s_2$. Moreover, they are equal to zero when $s_1 = s_2$, since the goods are homogeneous. In further analysis we will use only those continuation profits and hence we omit the stars denoting equilibrium. Moreover, since most of the results hold generally for both regimes, we will use in most cases a general notation, without specifying the regime.[17]

5 Quality choices

In the previous sections we have found the equilibrium of the price competition in the last stage and corresponding optimal tariffs chosen by the

[16] Note that $\theta_{21}^* \leq 1$ holds if and only if $s_1(s_2 - s_1)/(3s_2 - 2s_1) \geq 2s_1(s_1 - s_2)/(2s_1 - s_2)$, which is equivalent to $s_1 \geq s_2$.

[17] However, sometimes, when convenient, we add superscript FT for the free trade regime and superscript TP for the trade policy regime.

domestic country in the third stage. In this section, we analyze the choice of qualities in the first and second stage. Having established the equilibrium in later stages, it is sufficient to analyze a reduced form of the whole game with payoffs represented by continuation profits from Tables 1 and 2 in Appendix B.

Before we start with the formal analysis, for the ease of exposition, we will introduce a new notation. In particular, we now use explicitly variable s (quality gap) and we introduce a new variable q, which are defined as

$$s = \frac{s_2}{s_1}, \qquad q = \gamma_2 s_1. \tag{13}$$

In addition, we denote

$$\alpha = \gamma_1/\gamma_2, \qquad c_2(s) = C_2(1,s)/\gamma_2, \qquad \pi_i(s) = \Pi_i(1,s), \quad i = 1,2. \tag{14}$$

The new parameter α represents the technological advantage of Firm 1 compared to Firm 2.[18] According to the above assumptions, we have $0 < \alpha \leq 1$. The value $\alpha = 1$ implies that (without imitation) the firms are symmetric as to the cost structure. On the other hand, values of α close to zero mean that Firm 1's production is almost costless compared to Firm 2.

Since all profits in Tables 1 and 2 in Appendix B are homogeneous of degree 1 in (s_1, s_2), then

$$\Pi_i(s_1,s_2) = s_1\Pi_i(1, s_1/s_2) = s_1\pi_i(s_1/s_2) = q\pi_i(s)/\gamma_2.$$

Therefore, the new notation corresponds to a normalization $s_1 = 1$. Moreover, both firms' costs are homogeneous of degree 2 in (s_1, s_2), therefore, we may similarly write

$$\begin{aligned} C_1(s_1) &= \tfrac{1}{2}\gamma_1 s_1^2 = \tfrac{1}{2}\alpha q^2/\gamma_2, \\ C_2(s_1,s_2) &= s_1^2 C_2(1, s_2/s_1) = s_1^2\gamma_2 c_2(s_1/s_2) = q^2 c_2(s)/\gamma_2. \end{aligned}$$

Due to the sequential structure of decisions and the fact that q does not depend on s_2, we may consider q as Firm 1's decision variable and s as Firm 2's decision variable. As we will see later, the introduction of q and α reduces the parameter space by one dimension. Instead of (γ_1, γ_2), all strategic decisions (i.e., firms' equilibrium choices of q and s) will depend only on α (and μ).

[18] Its inverse, $1/\alpha$, then represents the factor from condition (i).

5.1 Follower's maximization problem

In the second stage, the follower (Firm 2) maximizes its net profit anticipating the price competition equilibrium and domestic government's tariff choice. The net profit is the difference between firm's gross profit and costs of achieving certain quality, i.e., $\Pi_2(s_1, s_2) - C_2(s_1, s_2)$. With the new notation, we may write the follower's maximization problem as

$$\max_s \pi_2(s) - qc_2(s). \tag{15}$$

The exact expressions for $\pi_2(s)$ and $c_2(s)$ can be found in Table 4 in Appendix B. Note that both $\pi_2(s)$ and $c_2(s)$ are continuous, but have a kink in $s = 1$. Moreover, both have a continuous second derivative (are $\mathcal{C}^2$) on both intervals $[0, 1]$ and $[1, \infty)$. Therefore, Firm 2's net profit function can, in principle, attain maximum in any of the following cases:

(a) $s = 0$;

(b) $s \in (0, 1)$ satisfying the first order conditions;

(c) $s = 1$;

(d) $s \in (1, \infty)$ satisfying the first order conditions;

(e) there is no maximum (net profit is not bounded from above).

Note that cases (a) and (e) corresponds to maximal product differentiation, and case (c) corresponds to minimal product differentiation. In case (a) Firm 2's net profit is zero, whereas in case (c) it is negative (gross profit is zero, but costs are positive). Moreover, it can be also easily established that $\pi_2(s) - qc_2(s) \to -\infty$ (for any $q > 0$) as $s \to \infty$ (since the costs are of "higher order" than profits). Therefore, we may exclude cases (c) and (e) as candidates for maximum. The first order conditions for interior solution (cases (b) and (d)) can be written as

$$\pi_2'(s) = qc_2'(s). \tag{16}$$

The expressions for the first derivative of Firm 2's gross profit can be found in Table 5 and are illustrated in Figure 1 in Appendix B. The solid line represents the derivative in the FT regime, the dashed line in the TP regime (see Table 6 in Appendix B for particular values). The figure shows that in both regimes, the derivative is decreasing on interval $[0, 1]$ and on interval $[1, \infty)$, with a jump upwards at $s = 1$. Hence Firm 2's gross profit is concave on these intervals, in both regimes. This can be obtained also by verifying that $\pi_2''(s) < 0$ for all $s > 0$.

Moreover, observe that $c_2'(0) = 0$, which implies $\pi_2'(0) - qc_2'(0) = \pi_2'(0) > 0$. Therefore, Firm 2's net profit is increasing and hence positive when s is close to zero. Thus, we may also exclude case (a). Now we know that Firm 2's net profit attains its maximum either in case (b) or (d), i.e., the first order condition (16) is satisfied. Its solution is then given by the intersection of $\pi_2'(s)$ with the line $q\mu s$ when $s < 1$, and with the line qs when $s > 1$ (see Figure 2 in Appendix B for illustration). Note that this solution depends on Firm 1's decision q only through the slope of this line. The following lemmas provide some basic results (see Appendix A for their proofs).

Lemma 1. *For all $q \geq 0$, there exists a unique solution of* (16) *on interval* $(0, 1)$.

Lemma 2. *There exists a solution of* (16) *on interval* $(1, \infty)$*, if and only if $q < \bar{q}$, where $\bar{q} = \frac{4}{9}$ in the free trade regime, and $\bar{q} = 1$ in the trade policy regime.*[19] *This solution is then unique and does not depend on μ.*

Let $s^1(q)$ be the solution of the first order condition (16) on interval $(0, 1)$ and $s^2(q)$ the solution on interval $(1, \infty)$, if it exists.[20] Furthermore, denote $s^*(q)$ the maximizer of Firm 2's profits (i.e., its best response). The above analysis and Lemmas 1 and 2 show that $s^*(q) = s^1(q)$ for $q \geq \bar{q}$, with $\bar{q}$ defined accordingly to the regime. Let us now concentrate on the case, when $q < \bar{q}$. In order to find Firm 2's best response, we need to compare its net profits from qualities $s^1(q)$ and $s^2(q)$.

Lemma 3. *Functions $s^1(q)$ and $s^2(q)$ (when defined) have a continuous first derivative (are $\mathcal{C}^1$) and are decreasing in q.*

Proposition 1. *For any $\mu \in [0, 1]$ there exists $\hat{q} \in (0, \bar{q})$ such that:*

$$s^*(q) = \begin{cases} s^1(q) < 1, & \text{if } q > \hat{q}, \\ s^2(q) > 1, & \text{if } q < \hat{q}. \end{cases} \tag{17}$$

Corollary 1. *For any $\mu \in [0, 1]$, Firm 2's best response $s^*(q)$ has the following properties:*

(i) *$s^*(q)$ is continuously differentiable and decreasing on $[0, \hat{q})$ and on $(\hat{q}, \infty)$.*

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[19] Sometimes, when convenient, we add a superscript determining the regime, i.e., $\bar{q}^{FT} = \frac{4}{9}$ and $\bar{q}^{TP} = 1$.

[20] With superscripts 1 and 2 we distinguish between the solutions from interval $(0, 1)$ where Firm 1 produces a higher quality, and from interval $(1, \infty)$ where Firm 2 produces a higher quality.

(ii) *$s^*(q) > 1$ on $[0, \hat{q})$ and $s^*(q) < 1$ on $(\hat{q}, \infty)$.*

(iii) *$s^*(q)$ has a jump downwards in $q = \hat{q}$.*

(iv) *$s^*(q) \to \infty$ when $q \to 0^+$, and $s^*(q) \to 0$ when $q \to \infty$.*

See Appendix A for proofs. Note that the value of $\hat{q}$ depends only on the imitation parameter μ; sometimes we will capture this dependence using notation $\hat{q}(\mu)$. However, the values of $\hat{q}$ in the FT regime and the TP regime may be different.[21]

Proposition 1 shows that if Firm 1 chooses its quality s_1 sufficiently low (i.e., $q = \gamma_2 s_1$ is sufficiently low), then Firm 2 chooses a higher quality $s_2 > s_1$ (i.e., $s^*(q) > 1$). On the other hand, if Firm 1 chooses its quality s_1 sufficiently high (i.e., q is high), then Firm 2 chooses a lower quality $s_2 < s_1$ (i.e., $s^*(q) < 1$). Intuitively, by choosing a low quality, Firm 1 leaves enough space for Firm 2, which consequently finds it profitable to choose a higher quality. Conversely, when Firm 1 chooses a high quality, Firm 2 will find higher quality not profitable and will consequently choose a lower quality.

The particular value of $\hat{q}$ can be found by solving the following system of three equations

$$\begin{aligned} \pi_2'(s^1) &= qc_2'(s^1), \\ \pi_2'(s^2) &= qc_2'(s^2), \\ \pi_2(s^1) - qc_2(s^1) &= \pi_2(s^2) - qc_2(s^2), \end{aligned}$$

with unknowns q, s^1, s^2, where $s^1 < 1 < s^2$. The first two equations represent the first order condition for $s^1 < 1$ and $s^2 > 1$, respectively. Recall that the expressions for $\pi_2(s)$ and $c_2(s)$ are different when $s < 1$ and when $s > 1$. The third equation represents the equality of profits, i.e., Firm 2 is indifferent between choosing a higher quality s^2 and a lower quality s^1 than Firm 1.

It is not possible to solve the above system explicitly in terms of μ. However, we may still derive certain properties of the solution and for any $\mu \in [0, 1]$ we may solve the system numerically. The following proposition provides some comparative statics results (see Appendix A for its proof).

Proposition 2. *For any fixed q, Firm 2's best response $s^*(q)$ is non-increasing in μ. In particular:*

(i) *For any fixed q, s^1 is decreasing in μ.*

(ii) *For any fixed q, s^2 does not depend on μ.*

[21] Again, let us denote $\hat{q}^{FT}$ the value of $\hat{q}$ in the FT regime and $\hat{q}^{TP}$ the value of $\hat{q}$ in the TP regime.

(iii) *Function $\hat{q}(\mu)$ is decreasing in μ.*

The above proposition indicates that although $s^2(q)$ does not depend on μ, Firm 2's best response $s^*(q)$ depends on μ through the value of $\hat{q}$ as well as through $s^1(q)$. Moreover, it indicates that (abstracting from Firm 1's strategic choice of q) Firm 2 is more likely to choose a higher quality than Firm 1 when μ is low. Intuitively, a lower value of μ makes imitation easier, by decreasing follower's costs of achieving certain quality level. Therefore, Firm 2 is expected to choose a higher quality. The particular profile of $\hat{q}(\mu)$ is depicted on Figure 4 in Appendix B (obtained numerically). The figure also shows that

$$\hat{q}^{FT}(\mu) < \hat{q}^{TP}(\mu)$$

for all $\mu \in [0, 1]$.

Quality reversal occurs when Firm 2 chooses a lower quality in free trade regime (that is, $q > \hat{q}^{FT}$ holds), but by virtue of trade policy optimal Firm 1's optimal choice is pushed to the "lower" quality levels (that is, $q < \hat{q}^{TP}$).[22] The intuition lies in the fact that the optimal tariff is increasing in Firm's 1 quality (see Footnote 15) and so anticipating this, the equilibrium strategy of the Firm 1 is to downgrade its quality. Thus optimal quality of Firm 1 in the trade policy regime may fall into the critical region of q, (that is, $q < \hat{q}^{TP}$) so that optimal response for Firm 2 is to jump in quality ladder. In the following section we analyze Firm 1's choice of q in both regimes and identify the values of parameters where quality reversal occurs.

5.2 Leader's maximization problem

In this section we analyze the leader's quality choice in the first stage. Anticipating the follower's best response and equilibrium in further stages, the leader (Firm 1) maximizes its net following profit $\Pi_1(s_1, s_2) - C_1(s_1)$, subject to Firm 2's best response. Using the notation introduced in (13)–(14), Firm 1's maximization problem can be written as

$$\max_{q,s} \; q\pi_1(s) - \tfrac{1}{2}\alpha q^2 \qquad (18)$$
$$\text{subject to} \quad s = s^*(q),$$

where $s^*(q)$ is given by (17).[23] Obviously, Firm 1's decision depends only on parameters μ and α. Therefore, for all pairs (γ_1, γ_2) with the same ratio, we

[22] Note, however, that q is Firm 1's strategic choice and its equilibrium value may be in general different in FT and TP regimes.

[23] Recall that the parameter $\alpha \in (0, 1]$ represents the cost advantage of the leader. Provided there is no imitation, then $\alpha = 1$ means that both firms are on the same technological level.

also obtain the same equilibrium.

Figure 5 in Appendix B shows an example of Firm 1's (indirect) net profit, when anticipating Firm 2's best response. The net profit has one point of discontinuity, namely $\hat{q}$ (recall that Firm 2's best response has a jump in $q = \hat{q}$) and is continuous on both intervals $[0, \hat{q})$ and $(\hat{q}, \infty)$. Firm 1's optimal choice q satisfies, therefore, one of the following:

(a) $q = 0$, leading to an infinite value of s (since $s^*(q) \to \infty$ as $q \to 0$);

(b) $q \in (0, \hat{q})$ satisfying the first order conditions and leading to Firm 2's response $s^*(q) = s^2(q) > 1$;

(c) $q = \hat{q}$, with Firm 2 being indifferent between $s^1(q)$ and $s^2(q)$;

(d) $q \in (\hat{q}, \infty)$ satisfying the first order conditions and leading to Firm 2's response $s^*(q) = s^1(q) < 1$;

(e) there is no maximum because the net profit is unbounded.

First observe that Firm 1's net profit converges to zero when $q \to 0$.[24] On the other hand, Firm 1's net profit becomes negative when $q \to \infty$.[25] Therefore, we can rule out case (e). Since it is not possible to find follower's best response explicitly, we used numerical simulations in order to find certain properties Firm 1's equilibrium strategy.[26] In particular, we find that Firm 1 can always attain a positive profit by choosing some $q \in (0, \hat{q})$, which also rules out case (a).

Moreover, the simulations show that in the point of discontinuity $\hat{q}$, Firm 1's profit jumps upwards. In general, however, each of cases (b), (c), and (d) can describe Firm 1's optimal choice. It is important to note that in case (c), Firm 2 is indifferent between choosing qualities $s^1(q)$ and $s^2(q)$. Since Firm 1's profit has a jump upwards, only the situation when Firm 2 chooses $s^1(q)$ can occur in equilibrium (recall that we analyze pure strategy equilibria).

In order to find the equilibrium choices of qualities we again used numerical simulations.[27] Our main findings are summarized in the following propositions.

[24]In this case $s = s^*(q) \to \infty$ and $\pi_1(s)$ is bounded, as it converges to a finite limit (see Table 3 in Appendix B). Hence, $q\pi_1(s) - \frac{1}{2}\alpha q^2$ converges to zero.

[25]When $q \to \infty$, then $s = s^*(q) \to 0$, and consequently, $\pi_1(s)$ is bounded (see Table 3 in Appendix B). Thus, $q\pi_1(s) - \frac{1}{2}\alpha q^2$ converges to $-\infty$.

[26]Simulations were performed using the *Mathematica 5.0* software. We used a grid of 100×100 in the (α, μ)-space. For each point (α, μ) from the grid, we verified whether the property holds or not. The program code can be obtained from authors upon request.

[27]The simulations were performed in the same way as described above (Footnote 26).

Proposition 3. *Firm 1 always (irrespectively on parameters μ and α) chooses a higher quality in the free trade regime equilibrium.*

Proposition 4. *For each value of μ (imitation parameter), there is a critical value $\hat{\alpha} \in (0, 1)$ such that quality reversal occurs if and only if $\alpha > \hat{\alpha}$. In addition, the critical value $\hat{\alpha}$ is increasing in μ.*

Figure 6 in Appendix B shows the values of $\hat{\alpha}$ and illustrates the results on quality reversal.[28] Consider first the free trade, and the benchmark case without imitation and when the firms are symmetric in terms of marginal investments efficiencies (i.e., $\alpha = 1$ and $\mu = 1$). In this case we find that Firm 1, that has a first-mover advantage, produces a higher quality in equilibrium. Clearly, this result is reinforced when α decreases, since a lower value of α favors Firm 1 even more, by providing it a cost advantage over Firm 2. More interestingly, allowing for imitation ($\mu < 1$) does not change anything. An increase in the intensity of imitation (a decrease in μ) is in spirit similar to a decrease in α, and that would in a setup without leadership result, after certain threshold in relative efficiency is surpassed, in Firm 2 producing variety of a higher quality.[29] However, the very existence of the leader reverts this, showing the value of first-mover advantage in this setup.

Establishing that Firm 2 always chooses a lower quality in the free trade equilibrium, consider now the trade policy equilibrium. As we already indicated, the trade policy in this setup has potentially conspicuous effect that may deprive Firm 1 of its leadership position and lead to quality reversal. In order to identify the conditions under which quality reversal occurs, it is sufficient to find out when Firm 2 chooses a higher quality in equilibrium. Our most striking result is that quality reversal occurs when the firms are symmetric in terms of investment efficiencies, irrespectively on imitation. In particular, we find that quality reversal occurs for the benchmark case $\mu = 1$ and $\alpha = 1$. The intuition behind these results stems from the sequencing of moves. If Firm 1 chooses a high quality, it incurs significant costs, which are sunk in later stages. This allows other players who move later, namely Firm 2 and domestic government, to extract additional revenue. In particular, the domestic government may extract tariffs revenues by imposing a high

[28] Based on the rough approximation of the critical value $\hat{\alpha}$ (using the same method as above; see Footnote 26), we used further numerical computations in order to evaluate it more precisely. In particular, for each value of μ from the grid (of 100 on interval $[0, 1]$), we computed the value of α using the bisector method with absolute error less than 10^{-6}.

[29] Note that in a such setup but in the absence of leadership there are two equilibria since each firm can *a priori* choose either of the quality. Thus, the introduction of the leadership in the standard ex-ante symmetric setup helps to establish the uniqueness of equilibrium.

tariff (recall that the optimal tariff is increasing in s_1 when $s_1 > s_2$). This decreases leader's net profits and may eliminate its first-mover advantage. The leader may, therefore, rather decide to choose a low quality, allowing for quality reversal.[30] Consequently, quality reversal also occurs for all lower values of μ, which only favor Firm 2. On the other hand, lower values of α favor Firm 1. In the extreme case where α is close to zero (Firm 1's production is almost costless compared to Firm 2's production), we find that Firm 2 always chooses a lower quality, irrespectively on the imitation parameter μ. In between, for any fixed μ, there is a critical value of α (denoted $\hat{\alpha}$) such that quality reversal occurs if and only if α exceeds this critical value, i.e., the firms are close enough to be symmetric. In addition (see Proposition 4) the critical value $\hat{\alpha}$ increases when μ increases, reflecting the fact that quality reversal is more likely when imitation is easier (low values of μ).

6 Conclusion

The attention of strategic trade policy literature has recently shifted towards international markets in vertically differentiated goods since this framework is particularly suitable for describing international trade between countries on different stages of development. Thus the firms from developed countries are usually associated with product variety of higher qualities and represent the innovative firms with significant investments into R&D. On the other hand, firms from less developed countries are associated with lower qualities and less innovative activity. They rather have a tendency to copy or imitate the products by firms from developed countries. Despite the importance of firm's position as either leader (innovator) or imitator (follower) in general and for the international trade in particular, current trade literature did not explicitly treat this aspect. Our paper aims to fill this gap by introducing leadership and imitation into the vertical differentiation model of international trade at LDC market. In this setup we analyze a time consistent strategic trade policy that appears in a simple and the most common form of import tariff. This is particularly important since the striking effect of trade policy (or, more precisely, its anticipation) in this setup, is that it can lead to quality reversal. In other words, it is possible that under certain conditions the market follower becomes leader in quality! Thus, no wonder that our main focus is to study the conditions that lead to policy induced quality reversal. We fist show that under free trade, the leader (foreign firm from the DC) always produces a high quality variety. This holds even in the extreme case when DC firm has no technological advantage and the degree of imitation is high. However, this

[30]Similar intuition is provided by Herguera et al. (2002).

dramatically changes when we allow for LDC government to impose a tariff since such trade policy tends to have a positive impact on follower's profits and enhance its incentives to produce a higher quality, leading to quality reversal. These incentives increase with the degree of imitation or with the decline in leader's technological advantage. In particular, we show that policy induced quality reversal occurs even when the firms are symmetric in terms of R&D investment efficiencies, irrespectively on the degree of imitation.

Our analysis also sheds some light on so called East Asian "economic miracles" since it seems consistent with empirical observations of successful trade and other policies which promoted technological and economic growth. For instance, policy induced quality reversals might also have contributed to Japan's economics success after World War II. Japan started as a less developed country with its firms mostly imitating western products. For example, Japanese photographic industry started its rapid growth in 1950s with companies like "Nikon and Canon turning out copies and derivatives of German photographic instruments of the time such as the Leica and Contax rangefinder and lenses."[31] After imposing trade policies in order to restrict imports and promote exports, and encouraging imitation (or reverse engineering; see Rodrik 2001), many of Japan industries (including photographic industry) have evolved to world's technological and quality leaders. Thus, one of the straightforward extensions of our model is to allow LDC government to endogenously choose the degree of imitation μ (or a degree of intellectually property rights (IPR) protection), in addition to tariff. This would enable us to study the interaction of tariffs and IPR protection.[32] It seems that in our setup the LDC government would prefer to stretch the degree of imitation or the IPR violation at the maximal acceptable level in order to promote technological and quality upgrading of its industries, and that may more than offset a possible adverse effect on consumer surplus and tariff revenue.

[31] Source: `en.wikipedia.org/wiki/Pentax`.

[32] See, for instance, Naghavi (2002) or Žigić (2000) for such an analysis in the non-vertically differentiated market.

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A Appendix: Proofs

Derivation of Firm 2's cost function. According to condition (i), without imitation, Firm 2's cost function can be written as $\frac{1}{2}\gamma_2 s_2^2$, where γ_2 is a constant such that $\gamma_2 > \gamma_1$. This yields marginal costs $\gamma_2 s_2$. According to (iii), these are also Firm 2's marginal costs when $s_2 > s_1$. On the other hand, when $s_2 \leq s_1$, the marginal costs can be, due to (ii), written as $\gamma_2 \mu s_2$, where $\mu \in [0, 1]$ is a constant (parameter) representing imitation (the value $\mu = 1$ corresponds to no imitation). After integration, we obtain that Firm 2's cost function has the following form

$$C_2(s_1, s_2) = \begin{cases} \frac{1}{2}\gamma_2 \mu s_2^2 + \xi_1, & \text{if } s_2 \leq s_1, \\ \frac{1}{2}\gamma_2 s_2^2 + \xi_2, & \text{if } s_2 > s_1, \end{cases}$$

where ξ_1 and ξ_2 are some constants. Since for $\mu = 1$ (no imitation), Firm 2's cost function needs to be equal to $\frac{1}{2}\gamma_2 s_2^2$ (due to condition (i)), it is necessary that $\xi_1 = 0$. Moreover, due to condition (iv), the cost function is continuous when $s_2 = s_1$. Hence, $\frac{1}{2}\gamma_2 \mu s_1^2 = \frac{1}{2}\gamma_2 s_1^2 + \xi_2$, which yields $\xi_2 = -\frac{1}{2}\gamma_2(1 - \mu)s_1^2$. Summarizing, we obtain the expression given by (5). □

Proof of Lemma 1. Since $\pi_2'(0) - qc_2'(0) > 0 > \pi_2'(1) - qc_2'(1)$ for any $q \geq 0$, then (because of continuity) there always exists a solution of (16) on interval $(0, 1)$. Due to concavity, this solution is unique and represents the maximum of Firm 2's profit on $(0, 1)$. □

Proof of Lemma 2. If $q \geq \frac{4}{9}$, then $\pi_2'(s) < qc_2'(s)$ for all $s > 1$ in the FT regime, since the line $qc_2'(s)$ lies above the graph of $\pi_2'(s)$. In this case $\pi_2(s) - qc_2(s)$ is decreasing, and hence, negative on $[1, \infty)$. On the other hand, if $q < \frac{4}{9}$, then $\pi_2'(1) - qc_2'(1) > 0$. Moreover, $\pi_2'(s) - qc_2'(s) \to -\infty$ as $s \to \infty$ (see Table 5 in Appendix B). Then (because of continuity), there always exists a solution of (16) on interval $(1, \infty)$. Due to concavity, this solution is unique and represents the maximum of Firm 2's profit on $(1, \infty)$.

The proof for the TP regime is analogous. □

Proof of Lemma 3. Recall that $s^1(q)$ and $s^2(q)$ are (unique) solutions of (16) when $s < 1$ and $s > 1$, respectively. The continuity of the first derivative follows from the implicit function theorem,[33] since both π_2' and c_2' are $\mathcal{C}^1$.

The implicit function theorem also implies that

$$[\pi_2''(s^j(q)) - qc_2''(s^j(q))] \frac{\mathrm{d}s^j(q)}{\mathrm{d}q} = c_2'(s^j(q)),$$

for $j = 1, 2$. Since $c_2' > 0$, $c_2'' > 0$, and $\pi_2'' < 0$, we obtain that $\mathrm{d}s^j(q)/\,\mathrm{d}q < 0$, which completes the proof. □

[33] Note that $\frac{\mathrm{d}}{\mathrm{d}s}[\pi_2'(s) - qc_2'(s)] \neq 0$, since $c_2'' > 0$ and $\pi_2'' < 0$.

Proof of Proposition 1. Let us denote

$$\Delta(q) = [\pi_2(s^2(q)) - qc_2(s^2(q))] - [\pi_2(s^1(q)) - qc_2(s^1(q))],$$

which represents the difference between Firm 2's maximal profits when it chooses $s < 1$ and when it chooses $s > 1$. Therefore, $s^*(q) = s^1(q)$ if $\Delta(q) < 0$ and $s^*(q) = s^2(q)$ if $\Delta(q) > 0$. We will show that $\Delta(q)$ is decreasing and attains a positive value when $q \to 0^+$ and a negative value when $q \to \bar{q}^-$. Since $\Delta(q)$ is continuous, this would mean that there exists $\hat{q} \in (0, \bar{q})$ such that $\Delta(\hat{q}) = 0$. Clearly, the value of $\hat{q}$ depends only on the parameter μ (and not on γ_1 and γ_2). Due to monotonicity, $\Delta(q) > 0$ when $q < \bar{q}$ and $\Delta(q) < 0$ when $q > \bar{q}$.

Now it remains to show that $\Delta(q)$ is decreasing and attains a positive value when $q \to 0^+$ and a negative value when $q \to \bar{q}^-$. First consider $q \to \bar{q}^-$. In this case, $s^2(q) \to 1$ and consequently $\pi_2(s^2(q)) - qc_2(s^2(q)) < 0$. Since the net profit for $s^1(q)$ is always positive (as optimal profit when $s < 1$), then $\Delta(q) < 0$ when q is close to $\bar{q}$. Note also that $s^1(q) \to 0$ when $q \to \infty$ (see Figure 2 in Appendix B).

Now consider $q \to 0^+$. In this case, we get $s^1(q) \to \frac{1}{16}$ in the FT regime and $s^1(q) \to \frac{1}{9}$ in the TP regime. Consequently, $\pi_2(s^1(q)) - qc_2(s^1(q))$ is bounded when $q \to 0$. Besides that $s^2(q) \to \infty$ (see Table 5 and Figure 2 in Appendix B) and $\pi_2(s^2(q)) - qc_2(s^2(q)) \to \infty$. This can be obtained from the following computation:

$$\begin{aligned} \pi_2(s^2(q)) - qc_2(s^2(q)) &= \pi_2(s^2(q)) - \tfrac{1}{2}[s^2(q)]^2 q + (1-\mu)q = \\ &= \pi_2(s^2(q)) - \tfrac{1}{2}s^2(q)\pi_2'(s^2(q)) + (1-\mu)q, \end{aligned}$$

where we used (16): $qs^2(q) = \pi_2'(s^2(q))$. When $q \to 0$, the last term $(1-\mu)q$ converges to zero and the rest to infinity, since $\pi_2(s) - \frac{1}{2}s\pi_2'(s) \to \infty$ as $s \to \infty$.[34] Hence we obtain $\Delta(q) \to \infty$ when $q \to 0$.

As the last step, it remains to show that $\Delta(q)$ is decreasing. For this consider

$$\begin{aligned} \frac{\mathrm{d}\Delta(q)}{\mathrm{d}q} = &\ [\pi_2'(s^2(q)) - qc_2'(s^2(q))]\frac{\mathrm{d}s^2(q)}{\mathrm{d}q} - [\pi_2'(s^1(q)) - qc_2'(s^1(q))]\frac{\mathrm{d}s^1(q)}{\mathrm{d}q} - \\ &- c_2(s^2(q)) + c_2(s^1(q)). \end{aligned}$$

The definition of s^1 and s^2 implies that the first and second term are equal to zero. Therefore,

$$\frac{\mathrm{d}\Delta(q)}{\mathrm{d}q} = -c_2(s^2(q)) + c_2(s^1(q)) < 0,$$

since $c_2(q)$ is increasing and by definition $s^1(q) < 1 < s^2(q)$. □

Proof of Proposition 2. The claim that s^* is decreasing in μ (for a fixed q) is simply a consequence of statements (i)–(iii). We will prove each of them separately.

[34]It can be easily established that $\pi_2(s) - \frac{1}{2}s\pi_2(s)$ is equal to $2s^3(4s-7)/(4s-1)^3$ in the FT regime and to $9s^3(2s-3)(2s-1)(12s^2-13s+4)/[2(4s-1)^3(3s-2)^3]$ in the TP regime. Both these expressions diverge to infinity when $s \to \infty$.

(i) The proof that s^1 is decreasing in μ is analogous to the proof that s^1 is decreasing in q, since s^1 depends only on the product $q \cdot \mu$ (see the Proof of Lemma 3).

(ii) In order to establish that this solution does not depend on μ, it is sufficient to recognize that the derivatives of Firm 2's gross profits and costs also do not depend on the parameter μ (see the Proof of Lemma 2).

(iii) The equality of net profits for s^1 and s^2 can be rewritten as

$$\pi_2(s^1) - \frac{1}{2}q\mu \cdot (s^1)^2 = \pi_2(s^2) - \frac{1}{2}q[(s^2)^2 - (1-\mu)]$$

Taking the derivative with respect to μ (and using the implicit function theorem) we obtain

$$[\pi_2'(s^1) - qs^1]\frac{\mathrm{d}s^1}{\mathrm{d}\mu} - \frac{1}{2}q \cdot (s^1)^2 - \frac{1}{2}\mu \cdot (s^1)^2 \frac{\mathrm{d}q}{\mathrm{d}\mu} =$$
$$= [\pi_2'(s^2) - qs^2]\frac{\mathrm{d}s^2}{\mathrm{d}\mu} - \frac{1}{2}q - \frac{1}{2}[(s^2)^2 - (1-\mu)]\frac{\mathrm{d}q}{\mathrm{d}\mu}.$$

According to the first order conditions, the first term on the left-hand side and the first term on the right-hand side are equal to zero. Therefore,

$$[(s^2)^2 - (1-\mu) - \mu(s^1)^2]\frac{\mathrm{d}q}{\mathrm{d}\mu} = q[(s^1)^2 - 1],$$

which means that $\mathrm{d}q/\mathrm{d}\mu < 0$, since $(s^2)^2 - (1-\mu) - \mu(s^1)^2 = 2[c_2(s^2) - c_2(s^1)] > 0$ (as c_2 is increasing) and $s^1 < 1$.

□

B Appendix: Figures and tables

Qualities ranking	Free trade (FT)	Optimal trade policy (TP)
$s_1 > s_2$	$\frac{4s_1^2(s_1-s_2)}{(4s_1-s_2)^2}$	$\frac{s_1^2(s_1-s_2)(4s_1-3s_2)^2}{(3s_1-2s_2)^2(4s_1-s_2)^2}$
$s_1 < s_2$	$\frac{s_2 s_1(s_2-s_1)}{(4s_2-s_1)^2}$	$\frac{s_2 s_1(s_2-s_1)^3}{(3s_2-2s_1)^2(4s_2-s_1)^2}$

Table 1: Continuation profit $\Pi_1(s_1, s_2)$ of Firm 1 (leader)

Qualities ranking	Free trade (FT)	Optimal trade policy (TP)
$s_1 > s_2$	$\frac{s_1 s_2(s_1-s_2)}{(4s_1-s_2)^2}$	$\frac{4s_1 s_2(s_1-s_2)(2s_1-s_2)^2}{(3s_1-2s_2)^2(4s_1-s_2)^2}$
$s_1 < s_2$	$\frac{4s_2^2(s_2-s_1)}{(4s_2-s_1)^2}$	$\frac{9s_2^2(s_2-s_1)(2s_2-s_1)^2}{(3s_2-2s_1)^2(4s_2-s_1)^2}$

Table 2: Continuation profit $\Pi_2(s_1, s_2)$ of Firm 2 (follower)

	Free trade (FT)	Optimal trade policy (TP)
$s < 1$	$\frac{4(1-s)}{(4-s)^2}$	$\frac{(1-s)(4-3s)^2}{(3-2s)^2(4-s)^2}$
$s > 1$	$\frac{s(s-1)}{(4s-1)^2}$	$\frac{s(s-1)^3}{(3s-2)^2(4s-1)^2}$

Table 3: $\pi_1(s)$ after substitution

	Free trade (FT)	Optimal trade policy (TP)	Costs
$s < 1$	$\frac{s(1-s)}{(4-s)^2}$	$\frac{4s(1-s)(2-s)^2}{(3-2s)^2(4-s)^2}$	$\frac{1}{2}\mu s^2$
$s > 1$	$\frac{4s^2(s-1)}{(4s-1)^2}$	$\frac{9s^2(s-1)(2s-1)^2}{(3s-2)^2(4s-1)^2}$	$\frac{1}{2}[s^2-(1-\mu)]$

Table 4: Continuation profit $\pi_2(s)$ and costs $c_2(s)$ of Firm 2 after substitution

	Free trade (FT)	Optimal trade policy (TP)
$s < 1$	$\frac{4-7s}{(4-s)^3}$	$\frac{4(2-3s)(2-s)(12-13s+4s^2)}{(4-s)^3(3-2s)^3}$
$s > 1$	$\frac{4s(2-3s+4s^2)}{(4s-1)^3}$	$\frac{9s(2s-1)(4-22s+51s^2-54s^3+24s^4)}{(4s-1)^3(3s-2)^3}$

Table 5: Derivatives of Firm 2's profits $\pi_2'(s)$

	Free trade (FT)	Optimal trade policy (TP)
$s = 0$	$\frac{1}{16}$	$\frac{1}{9}$
$s \to 1^-$	$-\frac{1}{9}$	$-\frac{4}{9}$
$s \to 1^+$	$\frac{4}{9}$	1
$s \to \infty$	$\frac{1}{4}$	$\frac{1}{4}$

Table 6: Some values of derivatives of Firm 2's profits $\pi_2'(s)$

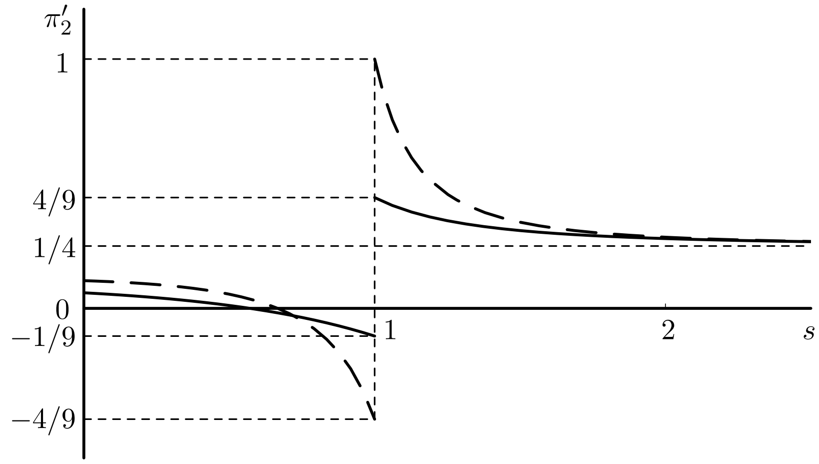

Figure 1: Derivative of Firm 2's profit $\pi_2'(s)$ in free trade regime (solid lines) and under optimal trade policy (dashed lines)

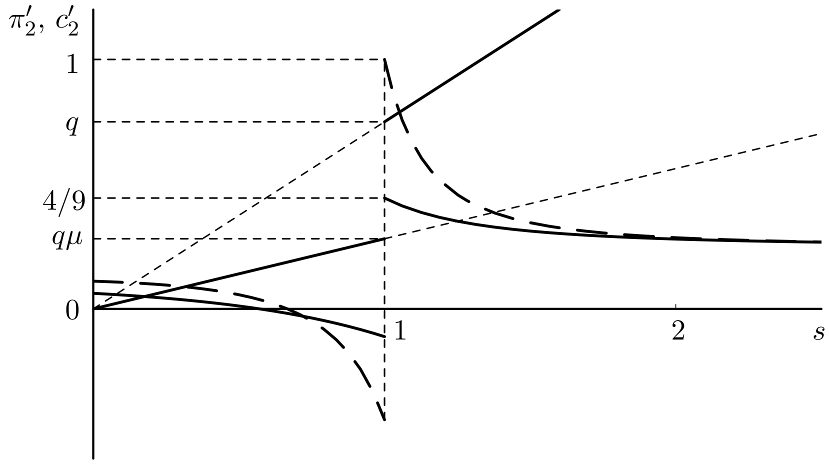

Figure 2: Derivatives of Firm 2's profit $\pi_2'(s)$ and costs $c_2'(s)$

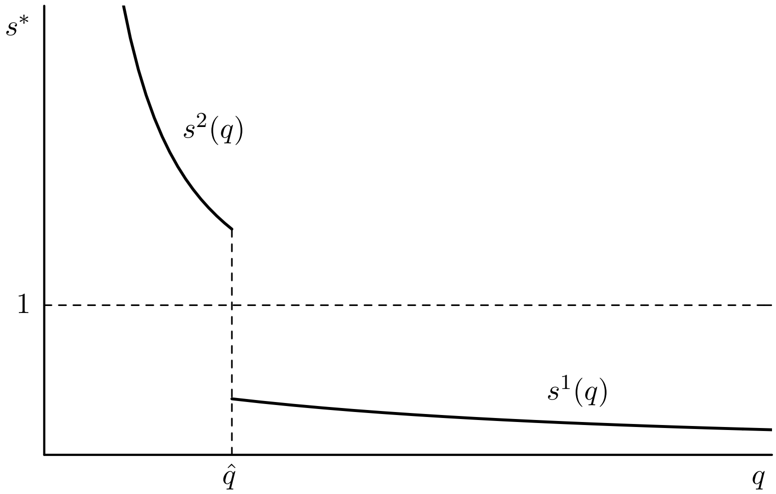

Figure 3: Firm 2's best response $s^*(q)$

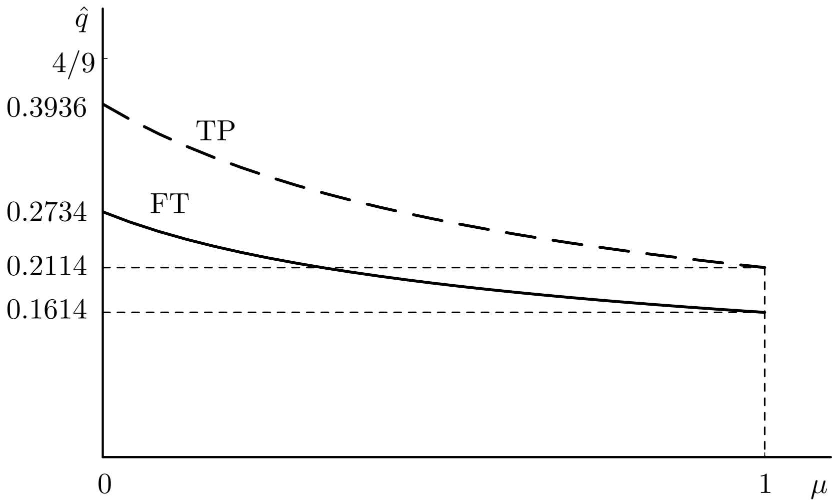

Figure 4: Profile of $\hat{q}$ in free trade regime (solid line) and under optimal trade policy (dashed line); obtained numerically

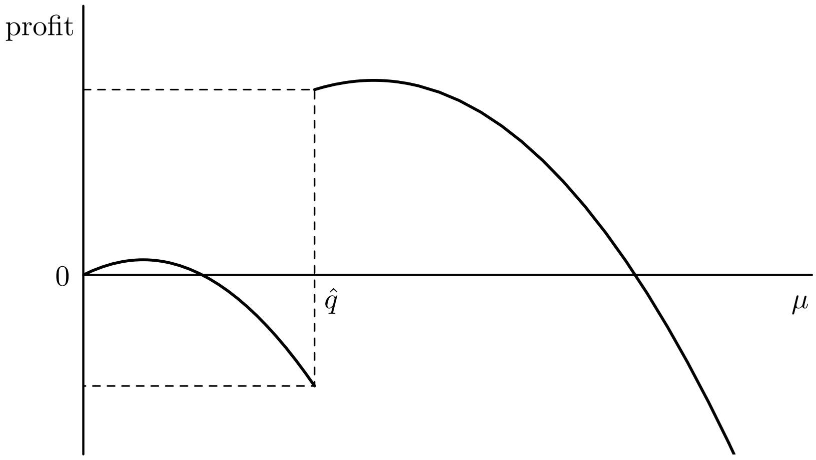

Figure 5: Leader's net (indirect) profit $q\pi_1(s^*(q)) - \frac{1}{2}\alpha q^2$ (numerical example: FT regime, $\alpha = \frac{7}{8}$, $\mu = \frac{3}{4}$)

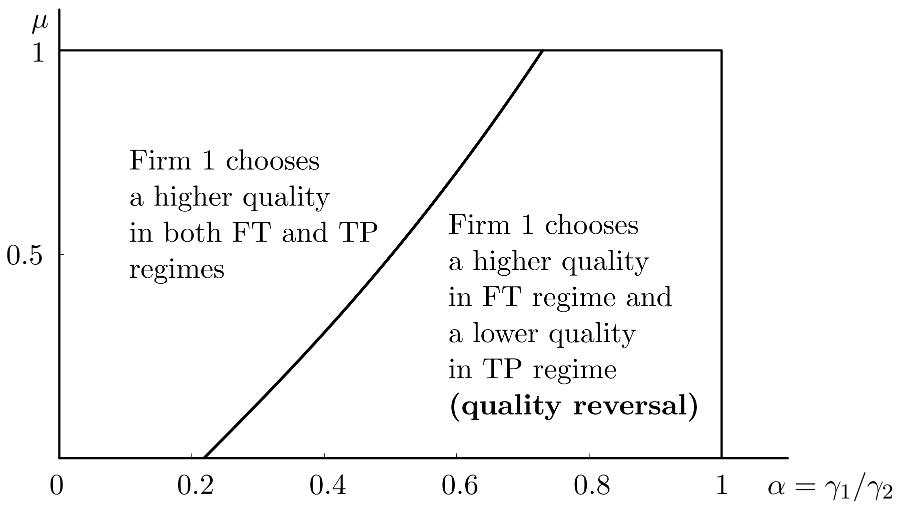

Figure 6: Region with quality reversal (numerical simulations)