International competition in vertically differentiated markets with innovation and imitation: Trade policy versus Free trade*

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Abstract

The important characteristic of international competition between firms from developed and less developed countries is vertical product differentiation, where firms' quality choices are strategic decisions. We consider a model with sequential quality choice and the possibility of imitation, and compare positive and normative aspects of this setup in free trade and under strategic trade policy. In particular, we identify conditions under which trade policy can initiate a *quality reversal* (a change in the quality ladders) and demonstrate that they are closely related to improvements in domestic welfare. Otherwise, commitment to free trade can be an optimal trade arrangement.

Keywords: vertical differentiation, free trade, strategic trade policy, quality reversal, leadership, imitation
JEL classification: D43, F12, F13, L13

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1 Introduction

Business these days is "...all about competition with everyone from everywhere for everything", as noted some time ago in a review "A bigger world" in *The Economist* (2008). One of the remarkable features of this global phenomenon is a growing number of companies from emerging markets taking part in this process. Moreover, emerging markets themselves are rapidly becoming ever more important scene of global competitive battles between the domestic companies and the firms from the developed world (The Economist 2008). A distinctive aspect of an emerging market is that a significant portion of consumers from this part of the world "...often demand products at far lower price and often in more basic form or smaller size than their developed countries counterparts." (The Economist 2008). Translating the above features into the jargon of industrial economics and international trade, there is vertical product differentiation on the demand side of the market while the supply side is characterized with intra-industry trade and imperfect competition between the firms from developed (DC) and firms from the emerging market or less developed countries (LDC). In fact, trade in vertically differentiated product seems to be prevailing pattern of trade between DC and LDC nowadays.[1] In particular, one would expect that typically DC firms produce product variety of high quality whereas the LDC firms produce variety of a lower quality.

Another important feature or stylized fact of such competition is that companies from the DC countries mostly act as market leaders when competing with their LDC counterparts even on the LDC market. The rationale for this is that the DC firms are (i) in general more technologically advanced than their LDC counterparts, and in particular; (ii) the firms that engage in international trade tend to be more efficient than the firms that operate only at home.[2] Thus, we can safely assume that DC firm assumes the role of technological leader on both counts. As we will see, this technological leadership transforms in general into the quality leadership so that the DC firm serves the upper tail of the market and it enables it to gain larger market share, charges higher price and earn larger profits than its LDC counterpart.

Last but not the least, it is well-known that the firms from the emerging markets rely on imitation when competing with the market leaders from the developed countries. In other words, there is plenty of evidence that imports in emerging markets countries from the developed world serves as a significant channel of technology diffusion via technological spillovers.[3] Moreover, the presence of technological spillovers could be traced

[1] In industries like automobiles, electronics, computer hardware and cosmetics, the products from Japan, the USA and Europe are associated with higher qualities than products from East Asia (Ghosh and Das 2001). See also Greenway, Hine, and Milner (1994), Clark and Stanley (1999), and Schott (2004) for empirical findings.

[2] See, for instance, Bernard and Jensen (1999) and Clerides, Lach, and Tybout (1998).

[3] See Acharya and Keller (2009) and Keller (2004, 2009) for an extensive review of this literature.

back to already long presence of multinational companies in the LDC markets not only through their export to LDC but also through FDI (outsourcing activities, import of inputs from DC, foreign acquisitions of firms from the LDC, etc). Thus, technological spillovers seems to be an outcome of a deliberate commitment to learning and matching international performance standards through ongoing interaction with foreigners (see Keller 2004). As Keller (2009) noted, technology transfer via the technological spillovers is likely to exceed the regular transfer via licensing (see also McNeil and Fraumeni 2005).[4]

It is important to stress that we consider technological spillovers to be exogenously determined as a byproduct of all these globalization processes. However, there exists by now already extensive literature that endogenizes imitation or technological spillovers by associating them with the Southern IPR regime.[5,6] Moreover, several authors related the presence of spillovers and imitation with the presence of FDI on the LDC markets.[7] With the exception of Morita and Nguyen (2011), all of the above articles do not analyze the vertically differentiated markets.

However despite the fact that the speed and power at which some of emerging market firms catch up, is very intense, as the above mentioned report by The Economist suggests, it is still an open question whether some current LDC firms could already be capable of becoming technological and market leaders generating goods that consumers perceive superior to the ones produced by their DC competitors (if both goods were offered at the same price).

On the other hand, there is a theoretical argument in the trade literature that within the considered setup of intra-industry trade and duopoly competition in vertically differentiated goods, trade policy leads to so called quality reversal (see Herguera, Kujal, and Petrakis 2002). That is, by means of trade policy (tariffs), the LDC firm opts for the higher while DC firm chooses lower quality in equilibrium.[8] Indeed, since the above competition that we focus on, takes place via international trade, it seems natural to explore the abilities of trade policy of the LDC to alter the free trade equilibrium. So no wonder that the recent trade literature has already started to explore the effects of trade policy in the above described markets as well as the possibilities of quality reversal (see the Section 1.1).

The aim of our paper is also to model the positive and normative aspects of the above described competition between the DC and LDC firms and revisit the issue of the

[4] See Keller (2004, 2009) for the detailed description of the channels of technology diffusion process.

[5] See for instance, Chin and Grossman (1990), Diwan and Rodrik (1991), Deardorff (1992), Helpman (1993), Žigić (1998, 2000), Lai and Qiu (2003), Kim and Lapan (2008), and Jinji (2011).

[6] In fact, there is a tight connection between technology spillovers and IPR protection. The degree of IPR protection greatly affects a country's level of spillovers in the sense that loose implementation of IPR protection policies enhance the intensity of spillovers (see Jinji 2011).

[7] See for instance, Glass and Saggi (1998, 1999, 2002), Naghavi (2007), and Morita and Nguyen (2011).

[8] In the industrial economics literature also known as leapfrogging. See also Brezis, Krugman, and Tsiddon (1993) for analysis of leapfrogging in economic growth context.

quality reversal. In particular, unlike the previous literature, we explicitly address the two described features of the competition between the DC and LDC firms in vertically differentiated products: (i) market leadership by the DC firm[9] and; (ii) R&D spillovers and imitation stemming from the leader to the follower. Moreover, unlike the rest of the relevant trade literature, we make an explicit comparison of the domestic welfare under free trade with the domestic welfare resulting from such a trade policy and discuss the policy implications of it.

We assume a rather simple trade policy that takes the form of an import tariff. Imposing import tariffs seems to be the most common and the most practical form of trade policies in LDCs.[10] The size of the tariff is chosen after both the leader's R&D investment decision (first stage) and the domestic firm's imitation decision (second stage), but precedes firms' pricing decisions (fourth stage). This seems to be a suitable timing assumption in this context due to the fact that the LDC governments may lack the commitment capability. Moreover, a trade policy is by its nature of second-best (or even third-best) character, and, consequently, it is plagued with the time consistency problem.[11] The above timing takes into account these phenomena, and the tariff that we calculate below is, in fact, a time consistent tariff.[12] Apparently, the action takes place in the domestic, LDC market and the strategic choice considered is the firms' selection of product qualities. The standard assumption in both horizontal and vertical differentiation setup is each firm makes a sunk cost investment (e.g., in R&D or technological improvements) in order to achieve a certain quality level. As Shaked and Sutton (1987, p. 136) suggest, 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." Finally, we assume that the marginal quality cost efficiencies differ among the firms.[13] Thus, the DC firm is assumed to have a higher R&D efficiency or better skilled workers reflecting their lower opportunity costs due to, say, a higher level of human capital. This consequently implies that lower investments are needed in order to achieve a certain quality level.

As for our findings, we identify conditions under which trade policy leads to quality reversal in equilibrium. Our results indicate that the optimal trade policy enhances the impact of imitation by the domestic follower and quality reversal becomes more likely

[9]The sequential choice of qualities has already been studied in the traditional industrial organization literature (Aoki and Prusa 1997; Lehmann-Grube 1997; Hoppe and Lehmann-Grube 2001). By addressing leadership, our paper also complements the emerging literature on market leaders (Etro 2004, 2006, 2007; Kováč, Vinogradov, and Žigić 2010).

[10]See also Zhou, Spencer, and Vertinsky (2002), Moraga-Gonzáles and Viaene (2005), and Kúnin and Žigić (2004).

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

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

[13]See also Zhou, Spencer, and Vertinsky (2002), Moraga-Gonzáles and Viaene (2005), and Kúnin and Žigić (2004).

when imitation is easier. More specifically, we show that quality reversal tends to occur only when the difference between the firms' technological levels (measured by marginal efficiencies of firms' investments in qualities) is "rather" small; this result, however, is amplified under the possibility of imitation and technological spillovers. In addition, when trade policy leads to quality reversal, and the degree of imitation is not large, it in general also improves the domestic country's domestic welfare *vis-à-vis* free trade. On the other hand, when trade policy does not induce quality reversal as an outcome, (and this is arguably empirically much more relevant case), then free trade yields generally a larger domestic welfare. This raises an interesting commitment issue and provides a new rationale for the domestic government to commit to free trade. Such a commitment can be achieved, for instance, by a bilateral trade agreement or participation in a trade union.

The remainder of the paper is organized as follows. After a brief literature review, in Section 2, we introduce the model and the underlying assumptions. In Sections 3 and 4, we solve for price competition equilibrium and the optimal tariff. In Section 5, we analyze firms' quality choices. In Section 6, we compare the free trade and the trade policy equilibria and address the welfare effects. Section 7 concludes and discusses our results. Appendix A contains the proofs of lemmas and propositions. A Supplementary Appendix is available on Eugen Kovac's homepage.[14]

1.1 Related literature

Early studies of strategic trade policy focused on markets with either perfectly substitutable or horizontally differentiated products (see Brander 1995 for a survey). In recent years the attention of trade economists has been shifted towards vertically differentiated markets. The idea of vertical differentiation capturing the difference between DCs and LDCs has already been well established in the international trade literature (see Flam and Helpman 1987 and Motta, Thisse, and Cabrales 1997). However, until recently it has not been used to analyze the effects of trade policies. One of the first theoretical studies analyzing strategic trade policies in the vertically differentiated markets 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.

[14]See `http://www.uni-bonn.de/~kovac/papers/it`.

Zhou et al. (2002) introduce endogenous choices of qualities. They capture the difference between the DC firm and the LDC firm by different costs of 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 et al. (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 firms' 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 the foreign firm produces a high quality variety of the good in free trade is not anymore an equilibrium once an 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.[15]

Moraga-Gonzáles and Viaene (2005) use a similar setup as Ghosh and 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). However, unlike the rest of the reviewed literature, they focus on the case of a 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 a LDC. In particular, their results indicate that quality reversals tend to be

[15]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 a more natural mode of competition in our setup, we do not consider a Cournot-type competition.

less likely than previously thought.

Finally, there are two recent related papers that study the leader-follower structure in quality choice in the North-South trade and also allow for technological spillovers or imitation and IPR violation. Both these papers appeared in the meantime, after the working paper version of this paper (Kováč and Žigić 2007) was available. In the first paper by Acharyya and García-Alonso (2009) the authors investigates rather specific issue of the IPR (patent rights) in the North-South context and within the pharmaceutical sector where the possibility of parallel imports (or patent exhaustions) exists. Unlike our paper, they do not use trade policy nor do allow for quality reversal possibility. The second paper by Morita and Nguyen (2011) is in its focus closer to our paper since the authors, much like we do, tackle the positive and normative aspects of imitation in the North-South setup where competing products are vertically differentiated. There are, however, also several distinctive features with our approach: first, the authors allow for both FDI and export as a mode of entry of DC firm into the Southern market whereby technological spillovers occur only if the DC firm enters via FDI. We, on the other hand, focus on the trade between the DC and LDC firms and allow for technological spillovers from import. As well known, the latter is rather well empirically documented (see Acharya and Keller 2009). Moreover, they consider technological spillovers to be the same thing as the strength of IPR and therefore they investigate the issue of the optimal IPR from the Southern point of view. We on the other hand treat spillovers as exogenous parameter. Second, as for the consumers' taste for quality, they assume that there are only two types of consumers while we allow for the continuum of consumers. Third, Morita and Nguyen (2011) implicitly assume that the LDC government can commit to its tariffs while we calculate time consistent tariffs that are arguably more realistic given that LDC governments often lack commitment power (see, for instance, Bhattacharjea 1995 or Karp and Perloff 1995). Finally, since absence of the government commitment may not always lead to socially more desirable policy outcome vis-a-vis free trade, we did an explicit comparison of trade policy outcome with the one of free trade.

2 Model

We start with a theoretical model of international trade in vertically differentiated products, where firms from an LDC and DC country compete in both qualities and prices in the LDC domestic market. We consider a single good 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: the *trade policy (TP) regime* represented by the import tariffs and the *free trade (FT) regime*. Actually, one can think about stage zero of the above game in which the LDC government decides which regime to choose. That is, whether to initiate a program of strategic trade policy or to commit itself to free trade.

As for the TP regime, there is usually a time lag between the announcement and the implementation of strategic trade policies (see for instance, Karp and Perloff 1995; Neary and O'Sullivan 1999; Grossman and Maggi 1998; Neary and Leahy 2000; and Ionaşcu and Žigić 2005). As a consequence, the government may be forced to select the concrete level of its policy instrument only *after* the strategic choice of domestic firms has taken place. Even without an explicit announcement of the policy, the inability of the government to commit to the level of the policy instrument prior to the strategic decision of the firms would result in the same game structure and timing. As Bhattacharjea (1995, p. 291) has noted in the context of an LDC "…it is historically appropriate to consider a scenario where the home market is initially monopolized by a foreign firm, and a domestic firm enters if it expects to cover its entry costs under the strategic tariff which would be rational for the government to impose after entry." Thus, our policy instrument is an *ex-post* tariff, where the tariffs are imposed after the firms' quality choices have been observed.[16]

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 tariffs). Such behavior may be induced by bilateral agreements or the country's membership in a trade organization (see also the welfare analysis in Section 6).

In order to solve the model for the time consistent tariff and optimal quality levels, 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 by an asymmetry in their cost structures and the 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. Under the free trade regime, the sequential structure gives Firm 1 the first-mover advantage,

[16]Alternative instruments to consider could be production subsidies, R&D subsidies, anti-dumping measures, or *ex-ante* tariffs (chosen before firms' qualities). We leave a detailed analysis of these instruments for future research.

when both firms have the same cost structure.[17] 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 the free trade regime equilibrium (i.e., $s_1 > s_2$) whereas it produces a lower quality in the strategic trade policy regime equilibrium (i.e., $s_2 > s_1$).[18]

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 a 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 the interval $[0, 1]$.[19,20]

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,

[17] Aoki and Prusa (1997) and Lehmann-Grube (1997) show this result in the framework equivalent to the free trade regime without imitation.

[18] 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 authors claim 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.

[19] Since the taste for quality is not a directly observable economic variable, a more realistic approach could be to characterize the consumers according to 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.

[20] More generally, one could consider the consumers uniformly distributed over $[0, \overline{\theta}]$, for example, in order to study the effect of changing the income level in the domestic country. Setting $\overline{\theta} = 1$ is without loss of generality and the model can easily be adjusted to incorporate the setting with an arbitrary $\overline{\theta}$ (see Remark 2). In addition, note that for any positive price, the consumer with $\theta = 0$ prefers not to buy the good. Hence, the market is *undercovered*. The assumption of a "narrow" market (with $[\underline{\theta}, \overline{\theta}]$ being support of θ and $\underline{\theta} > 0$) that is *covered* in equilibrium, however, significantly extends and complicates the analysis. Readers interested in the analysis of such markets are referred to Kúnin and Žigić (2004) for a treatment of the simultaneous quality choice model without imitation.

the firms' gross profits are

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

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. The gross profit (sometimes we will refer to it as just profit) does not take into account fixed costs. The fixed costs of R&D are sunk and hence do not influence firms' behavior in the last stage. The profit obtained from the gross profit after subtracting the fixed costs will be referred to as the *net profit*.

As mentioned above, in the free trade (FT) regime, the domestic (LDC) government takes no action, so the corresponding import tariff is 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 the consumer surplus (CS), income from tariffs net of subsidies T, and the domestic firm's net profit ($\Pi_2 - C_2$, where C_2 are its fixed costs):

$$DW = CS + T + \Pi_2 - C_2. \tag{2}$$

In stages 1 and 2, Firm 1 and Firm 2 choose their qualities in order to maximize their net profit. Firm 2's choice of quality in stage 2 is affected by technological spillovers that allow for imitation, which in turn lowers Firm 2's R&D costs of obtaining certain quality level.

The possibility of imitation has not been properly explored in the industrial organization literature, 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. In her approach, the leader chooses its quality (say s_1) by incurring a given, exogenously set level of fixed costs K, whereas the follower's fixed costs (of choosing quality s_2) are due to imitation only a fraction of it and have the form $K(s_1 - s_2)^2$. There are two important features of this cost structure which we consider not relevant in the international trade framework and in which our specification differs from Pepall (1997). First, the leader's fixed costs in her approach are constant and do not depend on the chosen quality s_1. Second, the follower's fixed costs are decreasing on interval $[0, s_1]$. As a consequence, the costs of achieving zero quality are paradoxically the largest (on that interval). As Pepall (1997, p. 267) suggests, K represents the costs incurred "to market a new product". In this sense the model may be appropriate to describe, for example, marketing ideas, where the follower's costs would be indeed close to zero when it copies, say, the same design. However, when quality is interpreted as reflecting the level of technology, we find Pepall's specification inappropriate. Even if the 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 an inferior copy of the invention. For example, it may be difficult to copy the recent technological inventions, but easy to copy older inventions of "lower quality" (e.g., slower microchips).

We assume that Firm 1 (leader) has quadratic cost function of the form

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

where $\gamma_1 > 0$ is a positive parameter that reflects, for example, 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 a certain quality level are lower. Under the above cost function, Firm 1's marginal costs (with respect to quality) 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 a lower degree of the country's economic development and the possibility of imitation (due to technological spillovers). In particular, we impose the following conditions:

(i) Without imitation, Firm 2's costs have the same form, with a lower efficiency of investments.

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

$$C_2(s_1, s_2) = \begin{cases} \tfrac{1}{2}\gamma_2(1-\mu)s_2^2, & \text{if } s_2 \le s_1, \\ \tfrac{1}{2}\gamma_2(1-\mu)s_1^2 + \tfrac{1}{2}\gamma_2(s_2^2 - s_1^2), & \text{if } s_2 > s_1 \end{cases} \tag{4}$$

with marginal costs equal to

$$\frac{\partial}{\partial s_2} C_2(s_1, s_2) = \begin{cases} \gamma_2(1-\mu)s_2, & \text{if } s_2 \le s_1, \\ \gamma_2 s_2, & \text{if } s_2 > s_1. \end{cases} \tag{5}$$

The parameter $\gamma_2 > 0$ represents Firm 2's efficiency of investments and $\gamma_2 \ge \gamma_1$ due to (i). The parameter $\mu \in [0, 1]$ represents the *degree of technological spillovers* or the *degree of imitation*. In what follows, we will use these two terms interchangeably. The value $1-\mu$ is the proportion mentioned in (ii). We also denote $\alpha = \gamma_1/\gamma_2$ the relative efficiency (or technological gap) of Firm 2 compared to Firm 1. By assumption $\alpha \in [0, 1]$.

Although imitation does not alter marginal costs when $s_2 > s_1$, note that it does affect the total costs in this case. An increase in the degree of imitation μ makes imitation easier as it leads to lower costs of generating higher quality for Firm 2. As we will show later none of the equilibrium values of qualities depends on μ when $s_2^* > s_1^*$ in equilibrium. In the extreme case $\mu = 0$, there is no imitation. On the other hand, the case $\mu = 1$ corresponds to full imitation, i.e., Firm 2 may replicate any quality $s_2 \leq s_1$ with no costs. The value $\alpha = 1$ (or $\gamma_2 = \gamma_1$) 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, i.e., Firm 2 is completely inefficient compared to Firm 1.

An notable feature of Firm 2's cost function is that, due to technological spillovers, it depends on Firm 1's quality (when $s_2 > s_1$). Namely, a decrease in Firm 1's quality induces a negative externality on Firm 2, as it raises its costs of developing a superior product. However, Firm 1 can drive Firm 2's cost only to the level induced by quality $s_1 = 0$. In this case Firm 2 does not benefit from imitation and its cost function is the same as when $\mu = 0$. It is also 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 $s_2 = s_1$. Note also that the conditions (i)–(iv) can be easily adjusted when the Firm 1's cost function has a different form.

3 Price competition in the last stage

Proceeding backwards, we start with the price competition in the last stage. In this respect, we 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:

$$D_1 = 1 - \theta_{12}, \quad D_2 = \theta_{12} - \theta_{20}, \qquad \text{where} \qquad \theta_{12} = \frac{p_1 - p_2}{s_1 - s_2}, \quad \theta_{20} = \frac{p_2}{s_2}$$

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 a maximization of firms' profits (1). It can be easily computed that the equilibrium prices are

$$p_1^* = \frac{2s_1(s_1 - s_2 + t)}{4s_1 - s_2}, \qquad p_2^* = \frac{s_2(s_1 - s_2 + t)}{4s_1 - s_2}. \tag{6}$$

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 the firms' equilibrium profits

$$\Pi_1^* = \frac{[2s_1(s_1 - s_2) - (2s_1 - s_2)t]^2}{(s_1 - s_2)(4s_1 - s_2)^2}, \qquad \Pi_2^* = \frac{s_1 s_2 (s_1 - s_2 + t)^2}{(s_1 - s_2)(4s_1 - s_2)^2}. \tag{7}$$

We denote $s = s_2/s_1$ the quality ratio that measures the toughness of competition. It is worthwhile to note that in this setup, tariff does not a have direct impact on relative prices, since $p_2/p_1 = s_2/(2s_1) = s/2$. Moreover, when $s \in (0, 1)$, an increase in s intensifies price competition leading to the Bertrand paradox in the limiting case when $s = 1$. Therefore, there is an important indirect effect of trade policy since, as we will see, the anticipation of tariffs does affect the equilibrium choice of qualities, s_1 and s_2, and hence quality ratio s.

In order for prices (6) 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 1). On the other hand, if the last condition holds with equality, Firm 1's gross profit is exactly zero resulting (in the 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. On the other hand, the domestic country may decide to subsidize imports because of the low quality of the domestic firm's good. When the subsidies are so high that the last inequality does not hold, the resulting market structure is foreign monopoly.

Remark 1. In the case of a 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 below) is $3s_M/8$, in the case of a domestic monopoly, and $(s_M - t)(s_M + 3t)/(8s_M)$ in the case of a 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 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 the 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 (7). This is in line with the basic idea of strategic tariffs: shifting the profits from the foreign firm to the domestic firm.

Similarly 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:

$$D_2 = 1 - \theta_{21}, \quad D_1 = \theta_{21} - \theta_{10}, \qquad \text{where} \qquad \theta_{21} = \frac{p_2 - p_1}{s_2 - s_1}, \quad \theta_{10} = \frac{p_1}{s_1}$$

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 a maximization of the profits (1), and it can be easily computed that:

$$p_2^* = \frac{s_2(2s_2 - 2s_1 + t)}{4s_2 - s_1}, \qquad p_1^* = \frac{2s_2t + s_1s_2 - s_1^2}{4s_2 - s_1}. \tag{8}$$

This yields 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 the firms' equilibrium profits

$$\Pi_2^* = \frac{s_2^2(2s_2 - 2s_1 + t)^2}{(s_2 - s_1)(4s_2 - s_1)^2}, \qquad \Pi_1^* = \frac{s_2[s_1(s_2 - s_1) - (2s_2 - s_1)t]^2}{s_1(s_2 - s_1)(4s_2 - s_1)^2}. \tag{9}$$

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

Again, with an 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 then be obtained from (6), (7) when $s_2 < s_1$, and from (8), (9) when $s_2 > s_1$, by setting $t = 0$. Firms' continuation profits (equilibrium profits from subsequent stages) are shown in Table 1 in Appendix B.

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 (in duopoly) can be rewritten as follows:

$$DW = \underbrace{\int_{\theta_{20}}^{\theta_{12}} (\theta s_2 - p_2)\,\mathrm{d}\theta + \int_{\theta_{12}}^{1} (\theta s_1 - p_1)\,\mathrm{d}\theta}_{CS} + \underbrace{t(1-\theta_{12})}_{T} + \underbrace{p_2(\theta_{12}-\theta_{20})}_{\Pi_2} - C_2 =$$

$$= s_2 \int_{\theta_{20}}^{\theta_{12}} \theta\,\mathrm{d}\theta + s_1 \int_{\theta_{12}}^{1} \theta\,\mathrm{d}\theta - \Pi_1 - C_2.$$

When choosing the tariff, the domestic government anticipates the price competition equilibrium in the last stage. Note, however, that Firm 2's fixed cost C_2 is sunk at this stage. Thus, it does not influence the domestic government's maximization problem, and it may be treated as a constant. In the equilibrium with prices given by (6), the domestic social welfare is

$$DW^* = \frac{s_1(s_1-s_2)(s_1+2s_2+2t) - (3s_1-2s_2)t^2}{2(4s_1-s_2)(s_1-s_2)} - C_2\,. \tag{10}$$

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 verified that under this tariff, duopoly is the equilibrium market structure (i.e., inequalities $0 \le \theta_{20}^* \le \theta_{12}^* \le 1$ hold). In addition, the comparison of the welfare for tariff t^* with welfare under other market structures (namely, domestic and foreign monopoly, as discussed in Remark 1) shows that duopoly is the equilibrium market structure, and tariff t^* is optimal.

Note that the optimal tariff is increasing in s_1 and decreasing in s_2.[21] Moreover,

[21]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

the optimal tariff is always positive. Thus, in the absence of a credible commitment mechanism, the domestic LDC country never prefers *ex-post* (after the qualities have been chosen) free trade over trade policy. Consequently, Firm 1's profit is lower and Firm 2's profit is higher than their respective profits in the free trade equilibrium, when $t = 0$ (according to the comparative statics results from the previous section).

If the LDC firm produces a higher quality, by the same procedure as in the previous case, we obtain $DW = s_1 \int_{\theta_{10}}^{\theta_{21}} \theta \, \mathrm{d}\theta + s_2 \int_{\theta_{21}}^{1} \theta \, \mathrm{d}\theta - \Pi_1 - C_2$, and in equilibrium

$$DW^* = \frac{s_2 s_1 (s_2 - s_1)(3s_2 + 2t) - (3s_2 - 2s_1)t^2}{2(4s_2 - s_1)(s_2 - s_1)} - C_2 \,. \tag{11}$$

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 verified that for such a tariff, duopoly is the equilibrium market structure (i.e., inequalities $0 \leq \theta_{10}^* \leq \theta_{21}^* \leq 1$ hold).[22] Again, a comparison of the welfare for tariff t^* with the welfare under other domestic and foreign monopoly shows that duopoly is the equilibrium market structure, and tariff t^* is optimal.

Likewise as in the previous case, the optimal tariff is positive and again without a possibility of credible commitment, the domestic country prefers *ex-post* trade policy over 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 the free trade equilibrium.

Table 1 summarizes the results and shows firms' continuation profits. Note that the profits are continuous (and equal to zero) when $s_1 = s_2$. In further analysis, we shall 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 shall use in most cases a general notation, without specifying the regime. Sometimes, when convenient, we add superscript FT for the free trade regime and superscript TP for the trade policy regime.

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 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

$\mathrm{d}t^* / \mathrm{d}s_2 = -s_1^2/(3s_1 - 2s_2)^2 < 0$.

[22] Note that $\theta_{10}^* \leq \theta_{21}^*$ holds, if and only if $t^* \leq s_1(s_2 - s_1)/(2s_2 - s_1)$, or equivalently $s_1 \leq s_2$.

form of the whole game with payoffs represented by continuation profits from Table 1. We will refer to this reduced game as the *quality choice game*.

Before we start with the formal analysis, for the ease of exposition, we shall introduce a new notation. In particular, we now use explicitly the variable $s = s_2/s_1$ (quality ratio) and we introduce a new variable

$$q = \gamma_2 s_1. \tag{12}$$

In addition let

$$\pi_i(s) = \Pi_i(1, s), \qquad c_1 = C_1(1)/\gamma_2 = \tfrac{1}{2}\alpha,$$
$$c_2(s) = C_2(1, s)/\gamma_2 = \begin{cases} \frac{1}{2}(1-\mu)s^2, & \text{if } s < 1, \\ \frac{1}{2}(1-\mu) + \frac{1}{2}(s^2 - 1) = \frac{1}{2}(s^2 - \mu), & \text{if } s > 1. \end{cases} \tag{13}$$

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, with interval $[0, \infty)$ as the set of available strategies for both firms. Moreover, since all continuation profits $\Pi_i(s_1, s_2)$ are homogeneous of degree 1 (see in Table 1), and all cost functions are homogeneous of degree 2 in (s_1, s_2), then

$$\Pi_i(s_1, s_2) = s_1 \Pi_i(1, s) = q\pi_i(s)/\gamma_2,$$
$$C_1(s_1) = \tfrac{1}{2}\alpha q^2/\gamma_2, \qquad C_2(s_1, s_2) = s_1^2 C_2(1, s) = q^2 c_2(s)/\gamma_2.$$

Thus, the new notation reduces the parameter space by one dimension. Instead of γ_1, γ_2, and μ, all strategic decisions (i.e., firms' equilibrium choices of q and s) will depend only on α and μ. Parameter γ_2 is just a multiplicative factor that can be omitted from future considerations. Equivalently, we may without loss of generality use the normalization $\gamma_2 = 1$.

Remark 2. As mentioned earlier (footnote 20), the model can be easily adjusted to consider consumers uniformly distributed on interval $[0, \overline{\theta}]$. Indeed, if we normalize the new variables π_1, π_2, and q by factor $1/\overline{\theta}$ (e.g., we define $q = \gamma_2 s_1/\overline{\theta}$), the results obtained in the following chapters do not change.

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 (revenue) and costs of achieving certain a quality, i.e., $\Pi_2(s_1, s_2) - C_2(s_1, s_2)$. Under the new notation, the follower's maximization problem is equivalent to:

$$\max_s \pi_2(s) - qc_2(s). \tag{14}$$

The exact expressions for $\pi_2(s)$ and $c_2(s)$ can be found in Table 1 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 intervals $[0, 1)$ and $(1, \infty)$. As shown in Lemma 2 (in Appendix A), Firm 2's profit $\pi_2(s) - qc_2(s)$ attains its maximum, which is always interior (i.e., $s \notin \{0, 1\}$). Thus, the optimal choice of s satisfies the first order condition

$$\pi_2'(s) = qc_2'(s). \tag{15}$$

The expressions for the first derivative of Firm 2's gross profit can be found in Table 1 and are illustrated in Figure 1 (both in Appendix B). Observe also that Firm 2's optimization problem (14), and hence its solution too, do not depend on α. Thus, all results presented in this section hold uniformly for all $\alpha \in (0, 1]$.

Let $s^1(q)$ be the solution of the first-order condition (15) on interval $(0, 1)$ and $s^2(q)$ the solution on interval $(1, \infty)$, if it exists.[23] Further denote $s^*(q)$ the maximizer of Firm 2's net profit (i.e., its best response). As shown in Lemma 3 (in Appendix A), solution $s^1(q)$ always exists and is unique, whereas solution $s^2(q)$ exists (in which case it is unique) if and only if $q < \bar{q}$, where $\bar{q}^{\mathrm{FT}} = \frac{4}{9}$ in FT regime and $\bar{q}^{\mathrm{TP}} = 1$ in TP regime. This in case $q \geq \bar{q}$, we obtain $s^*(q) = s^1(q)$. This means that if q is sufficiently high, Firm 2 chooses a lower quality. On the other hand, if $q < \bar{q}$, we have two candidates for Firm 2's optimal decision: $s^1(q)$ and $s^2(q)$. In order to find its best response, we need to compare its net profits from choosing qualities $s^1(q)$ and $s^2(q)$.

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

$$s^*(q) = \begin{cases} s^1(q) < 1, & \text{if } q > \hat{q}, \\ s^2(q) > 1, & \text{if } q < \hat{q}. \end{cases} \tag{16}$$

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 $(\hat{q}, \infty)$.*

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

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

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

[23] 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. In addition, for the purposes of comparative statics, we will use μ as subscript, e.g., we write $s^1_\mu(q)$.

See Appendix A for proofs and Figure 2 in Appendix B for illustration. According to Proposition 1, Firm 2 chooses a higher quality when q is below the threshold $\hat{q}$ and a lower quality when q is above the threshold. Note that the value of $\hat{q}$ depends only on the degree of imitation μ. However, the values of $\hat{q}$ in the FT regime and the TP regime may be different.[24]

Note that since $s^*(q)$ is decreasing in q, we have a situation of strategic substitutes. More precisely, 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., $s^*(q) > 1$). If, on the other hand, 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 a higher quality not profitable and will consequently choose a lower quality.

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

$$\pi_2'(s^1) = qc_2'(s^1),$$
$$\pi_2'(s^2) = qc_2'(s^2),$$
$$\pi_2(s^1) - qc_2(s^1) = \pi_2(s^2) - qc_2(s^2),$$

with unknowns q, s^1, s^2, where $s^1 < 1 < s^2$. The first two equations represent the first-order conditions for $s^1 < 1$ and $s^2 > 1$, respectively. Recall that the expressions for $\pi_2(s)$, and also $c_2(s)$, are different when $s < 1$ and when $s > 1$. The third equation represents the equality of net 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 propositions provide some comparative statics results with respect to the degree of imitation or technological spillovers μ (see Appendix A for their proofs).

Proposition 2. *For any fixed q such that $q \notin \{0, \hat{q}_\mu\}$, the follower's optimal net profit $\pi_2(s^*_\mu(q)) - qc_2(s^*_\mu(q))$ is increasing in the degree of imitation μ.*[25]

Proposition 3. *For any fixed q, the follower's best response $s^*_\mu(q)$ is non-decreasing in the degree of imitation μ. In particular:*

[24]Following Footnote 23 we will capture the dependence on μ using subscript μ (i.e., $\hat{q}_\mu$). In addition, we also denote $\hat{q}^{\mathrm{FT}}$ and $\hat{q}^{\mathrm{TP}}$ the values of $\hat{q}$ in the FT and the TP regimes, respectively.

[25]Recall that $c_2(s)$ depends on μ.

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

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

(iii) *The threshold* $\hat{q}_\mu$ *is increasing in* μ.

Proposition 2 suggests that imitation raises the follower's profit. Based on the *Envelope Theorem* argument, this effect is driven by the reduction of fixed costs due to imitation (see its proof). Proposition 3 suggests that imitation has also a positive effect on the follower's quality when it is lower than the leader's one. On the other hand, imitation has no effect on the follower's quality choice when it exceeds the leader's quality. This result follows from the fact that technological spillovers do not affect the follower's marginal costs when it chooses a higher quality. Finally, the last part shows that when μ increases, a larger q is necessary to make Firm 2 indifferent between choosing $s^1(q)$ and $s^2(q)$. The reason is that $s^1(q)$ increases in μ, and so a larger $\hat{q}$ is necessary to make Firm 2 indifferent between choosing a higher and a lower quality. The profile of $\hat{q}_\mu$ is depicted in Figure 3 in Appendix B (obtained numerically). The figure also shows that

$$\hat{q}^{\text{FT}}_\mu < \hat{q}^{\text{TP}}_\mu, \qquad \text{for all } \mu \in [0,1].$$

Quality reversal occurs when Firm 2 chooses a lower quality in the free trade regime (that is, $q > \hat{q}^{\text{FT}}_\mu$ holds), but by virtue of trade policy Firm 1's optimal choice is pushed to the "lower" quality levels (that is, $q < \hat{q}^{\text{TP}}_\mu$). Note, however, that q is Firm 1's strategic choice and its equilibrium value may be in general different in the FT and the TP regimes. The intuition behind quality reversal lies in the fact that the optimal tariff is increasing in Firm's 1 quality (see Footnote 21), and so anticipating this, the equilibrium strategy of the Firm 1 is to downgrade its quality. Thus, the optimal quality of Firm 1 in the trade policy regime may fall into the critical region of q, (that is, $q < \hat{q}^{\text{TP}}_\mu$) so that the optimal response for Firm 2 is to jump in the quality ladder. In the following section, we analyze Firm 1's choice of q in both regimes and identify the values of the 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 profit $\Pi_1(s_1, s_2) - C_1(s_1)$, subject to Firm 2's best response. This problem can be rewritten in an equivalent form:

$$\max_{q,s} \; q\pi_1(s) - \tfrac{1}{2}\alpha q^2 \tag{17}$$
$$\text{subject to} \quad s = s^*(q),$$

with $s^*(q)$ given by (16).[26] As Firm 2's best response has a jump in $q = \hat{q}_\mu$, Firm 1's net profit has a jump in this point as well. Furthermore, it is continuous on both intervals $[0, \hat{q}_\mu)$ and $(\hat{q}_\mu, \infty)$. The following lemma rules out some corner cases (see Appendix A for its proof).

Lemma 1. *For any $\alpha \in (0, 1]$ and $\mu \in [0, 1]$, Firm 1's profit $q\pi_1(s^*(q)) - \frac{1}{2}\alpha q^2$ attains its maximum. The optimal value of q^* satisfies either of the following conditions:*

(a) *$q^* \in (0, \hat{q}_\mu)$, leading to Firm 2's response $s^*(q^*) = s^2(q^*) > 1$;*

(b) *$q^* = \hat{q}_\mu$, with Firm 2 being indifferent between $s^1(q^*)$ and $s^2(q^*)$; or*

(c) *$q^* \in (\hat{q}_\mu, \infty)$, leading to Firm 2's response $s^*(q^*) = s^1(q^*) < 1$.*

In cases (a) and (c), the optimal value q^* satisfies the first-order conditions. Since it is not possible to find the follower's best response explicitly, we are also not able to find a closed form solution to the leader's problem. However, we may derive some comparative statics results, provided in the following proposition, and solve the problem numerically. We use the subscript μ to highlight the dependence of q^*_μ on μ. Note that then $s^*_\mu(q^*_\mu)$ is Firm 2's equilibrium choice of s and $q^*_\mu \pi_1(s^*_\mu(q^*_\mu)) - \frac{1}{2}\alpha(q^*_\mu)^2$ is the leader's equilibrium profit.

Proposition 4. *For any $\alpha \in (0, 1]$ and $\mu \in [0, 1]$, the following statements hold:*

(i) *If the leader chooses a higher quality in equilibrium (i.e., $q^*_\mu > \hat{q}_\mu$), then the leader's equilibrium profit is decreasing in the degree of imitation μ.*

(ii) *If the leader chooses a lower quality in equilibrium (i.e., $q^*_\mu < \hat{q}_\mu$), then both firms' equilibrium strategies q^*_μ and $s^*_\mu(q^*_\mu)$, and the leader's equilibrium profit do not depend on the degree of imitation μ.*

(iii) *If $q^*_\mu \notin \{0, \hat{q}_\mu\}$, then the leader's equilibrium profit is decreasing in the relative efficiency α.*

Corollary 2. *Consider a fixed $\alpha \in (0, 1]$. If $q^*_\mu < \hat{q}_\mu$ for some $\mu \in [0, 1)$, then $q^*_{\mu'} < \hat{q}_{\mu'}$ for all $\mu' \in [0, 1]$ such that $\mu' \geq \mu$.*

[26] 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.

The proof of Proposition 4 can be found in Appendix A. The first part of the proposition conforms to our intuition that imitation has a positive effect on the follower (see Proposition 2), but a negative effect on the leader, provided the follower prefers a lower quality. On the other hand, if the follower prefers a higher quality, then the equilibrium strategies (and also the leader's profit) do not depend on the degree of imitation. This, together with part (iii) of Proposition 3, directly implies the corollary. Note, however, that although the equilibrium strategies do not depend on μ, the follower's profit does; it is linear and increasing in μ (see Table 1). The last part of the proposition claims, consistently with intuition, that an increase in the gap between the developed foreign country and the less developed domestic country, benefits the foreign leader.

In order to find the equilibrium choices of qualities, we used numerical simulations.

The need for use numerical simulations arises from two reasons. First, due to the multi-period structure, subgame-perfect equilibrium involves a sequence of maximization problems that need to be solved and that, in turn, makes the problem rather complex. Second, due to the property of equilibrium with vertically differentiated products, the maximization problems of finding quality choices (and that is the last sequence to be solved) have as an outcome higher-order polynomials that preclude the analytical solutions of the first-order conditions

In order to find the equilibrium choices of qualities, we used numerical simulations.[27] The need to use numerical simulations, arises for two reasons. First, due to the multi-period structure, subgame-perfect equilibrium involves a sequence of maximization problems that need to be solved and that, in turn, makes the problem rather complex. Second, due to the structure of profits in equilibrium with vertically differentiated products (in the last stage), the maximization problems of finding quality choices (in earlier stages) involve higher-order polynomials that preclude the analytical solutions of first-order conditions. Our main findings from the simulations are summarized in two results below.[28] The first one presents the result for the free-trade regime.

Result 1. *For all $\alpha \in (0,1]$ and $\mu \in [0,1]$, Firm 1 chooses a higher quality in the free-trade regime equilibrium.*

Remark 3. Result 1 complements the results by Aoki and Prusa (1997) and Lehmann-Grube (1997). As we already mentioned, both papers analyze sequential choice of qualities with firms having identical cost structure (in a general form). They show that the leader

[27]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.

[28]As a byproduct of the simulations, we find that at the point of discontinuity $\hat{q}_\mu$, Firm 1's net profit jumps upwards. Hence, since in case (c) Firm 2 is indifferent between choosing qualities $s^1(q)$ and $s^2(q)$, only the situation when it chooses the former can occur in equilibrium (recall that we analyze pure strategy equilibria).

always chooses a higher quality. In our setting this corresponds to the case $\mu = 0$ and $\alpha = 1$. However, their methods of proofs rely on symmetry and independence of cost functions and cannot be modified to capture technological spillovers, where Firm 1's quality choice also directly affects Firm 2's costs.

Consider first the free trade regime in the benchmark case without imitation and when the firms are symmetric in terms of marginal investments efficiencies (i.e., $\alpha = 1$ and $\mu = 0$). In this case, we find that Firm 1, which 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 benefits Firm 1 even more, by providing it a cost advantage over Firm 2; see also Proposition 4, part (iii). More interestingly, allowing for imitation ($\mu > 0$) does not change the result qualitatively.

An increase in the intensity of imitation μ has a similar effect as an increase in α (i.e., a negative effect on Firm 1, but a positive effect on Firm 2) and that would in a setup without leadership result, after a certain threshold in relative efficiency is surpassed, in Firm 2 producing a 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.

Having established 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 a 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. The following result characterizes the set of parameters that lead to quality reversal.

Result 2. *For any $\mu \in [0, 1]$, there is a critical value $\hat{\alpha}_\mu \in (0, 1)$ such that quality reversal occurs if and only if $\alpha > \hat{\alpha}_\mu$. In addition, the critical value $\hat{\alpha}_\mu$ is decreasing in the degree of imitation μ.*

Figure 4 in Appendix B shows the values of $\hat{\alpha}_\mu$ and the region where quality reversal occurs.[30] As a striking result, we obtain that quality reversal occurs when the firms are symmetric in terms of investment efficiencies, irrespective of imitation. Namely, we find that quality reversal occurs for the benchmark case $\mu = 0$ 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, that are sunk in later stages. This allows other players who move

[29]Note that in such a 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 leadership in the standard *ex-ante* symmetric setup helps to establish the uniqueness of equilibrium.

[30]Based on a rough approximation of the critical value $\hat{\alpha}_\mu$ (using the same method as above; see Footnote 27), we used further numerical computations in order to evaluate it more precisely. In particular, for each value of μ from the grid (of size 100 on interval $[0, 1]$), we computed the value of α using the bisector method with absolute error less than 10^{-6}.

later, namely Firm 2 and the domestic government, to extract additional revenue. In particular, the domestic government may extract tariff revenues by imposing a high tariff (recall that the optimal tariff is increasing in s_1 when $s_1 > s_2$). This decreases the 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 (see Herguera et al. 2002 for a similar intuition). Consequently, quality reversal also occurs for all higher values of μ (Corollary 2).

On the other hand, lower values of α benefit 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, irrespective of the degree of imitation μ. In between, for any fixed μ, there is a critical value of α (denoted $\hat{\alpha}_\mu$) 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 Result 2), the critical value $\hat{\alpha}_\mu$ decreases when μ increases, reflecting the fact that quality reversal is more likely when imitation is easier (high values of μ). Intuitively it follows from the fact that both an increase in μ and an increase in α have similar effects — they benefit the domestic firm on the expense of the foreign firm.

Remark 4. Result 2 complements the results by Herguera et al. (2002, Proposition 1), who consider the firms to be symmetric and show that under the optimal trade policy the foreign firm always produces a low-quality good in equilibrium. In our setting this corresponds to the special (benchmark) case when $\alpha = 1$ and $\mu = 0$. However, our results and intuition suggest that when relaxing symmetry (by taking decreasing α), trade policy may not be sufficient to force the foreign firm to choose a lower quality.

6 Comparison of FT and TP equilibrium

In this section, we compare the domestic welfare in the free trade equilibrium with the welfare in the trade policy equilibrium. As it is not possible to characterize these equilibria explicitly, we obtain our results using numerical simulations. We first compare the firms' profits in both regimes and then look at the key determinants of the consumer surplus: average quality, total market size, and its redistribution caused by trade policy. The results are illustrated in Figures 5–8 and summarized in Table 2 in Appendix B.[31, 32]

[31] The simulations were performed in the same way as described in Footnote 27. Each figure shows the comparison for one particular variable — the shaded area corresponds to the values of parameters α and μ where its value in the FT equilibrium is *higher* than its value in the TP equilibrium. Table 2 contains the areas of these regions as shares of the whole region of parameters (α, μ), i.e., of the set $(0, 1] \times [0, 1]$. The areas are approximated by the number of grid points in the region.

[32] Table 2 contains the results of more comparisons than presented in this section and shown in Figures. The results of all comparisons can be found in the Supplementary Appendix available at `http://www.uni-bonn.de/~kovac/papers/it` (and from authors upon request).

Firms' profits. As expected, Firm 1's profit is harmed in the TP regime due to profit shifting. In particular, for all $\alpha \in (0,1]$ and $\mu \in [0,1]$, Firm 1 earns lower profit (both net and gross) in the TP equilibrium than in the FT equilibrium. On the other hand, this relationship is generally reversed for Firm 2. Its profit (both net and gross) in the FT equilibrium is almost always lower than the (corresponding) profit in the TP equilibrium.[33]

Market size and average quality. In a dominant part of the parameter space, the optimal trade policy reduces the market size (or aggregate demand).[34] The comparison of the market size provides first intuition on the effects on consumers. It, however, does not take into account the product qualities and, therefore, consumers' utilities. A complementary intuition can be provided by comparing the average quality weighted by the market shares. The simulations suggest that the optimal trade policy always reduces the average quality.

Welfare. The effect of trade policy on the consumer surplus may be decomposed into effects on market size (since only consumers who purchase some good obtain a positive utility) and the effect on quality (which determines each consumer's utility). Due to the reduction of the market size and average quality, we might expect that trade policy also tends to reduce the consumer surplus. The simulations indeed confirm this intuition. The optimal trade policy, therefore, benefits only the domestic firm but not the consumers. The change in the domestic welfare then depends on the balance of these two effects and, in addition, on the size of the tariff revenue (which is zero in the FT equilibrium and positive in the TP equilibrium). The simulations show that the optimal trade policy reduces the domestic welfare compared to the FT regime, when firms are asymmetric enough (α is small), but increases the domestic welfare when firms are close to being symmetric (α is close to 1) and technological spillovers are not strong (μ is not too large); see Figure 8.[35] In other words, the considered trade policy is socially beneficial only after the country has reached a certain relative threshold level of economic development (captured by α), and there is a certain level of intellectual property rights (IPR) protection. Figure 8 also

[33] In both cases, an exception is a small region with area approximately 1% of the whole feasible region of parameters, as shown in Figures 5 and 6.

[34] An exception is a small region where no quality reversal occurs (with area approximately 7%, as shown in Figure 7).

[35] Note that the boundary of the region where free trade yields a higher domestic welfare has a kink for $\mu \approx 0.84$ and $\alpha \approx 0.82$. When α increases, the boundary value of μ lies in the interval (0.84, 0.85); simulations with a finer grid indicate that it is in fact downward-sloping. The kink stems from intersection with the region of "corner solution" where it is optimal for Firm 1 to choose $q^* = \hat{q}_\mu$ (in the FT regime), making Firm 2 indifferent between a higher and a lower quality (see also Footnote 28). The simulations show that this occurs when both μ and α are sufficiently large. More details can be found in the Supplementary Appendix available at `http://www.uni-bonn.de/~kovac/papers/it` (and from the authors upon request).

indicates that there is a close relation between quality reversal and welfare improvements, as summarized in the following result.

Result 3. *Under the optimal trade policy quality reversal is a necessary, but not a sufficient condition for an improvement in domestic welfare (compared to free trade).*

The intuition that trade policy might be socially preferable for the domestic country to free trade when the domestic firm produces a higher quality seems apparent (since improvement in domestic gross profit is tremendous and there is a tariff gain in addition). However, the fact that free trade may yield a higher domestic welfare when μ is large enough even when trade policy leads to quality reversal (as indicated in Figure 8) is somewhat less obvious. To explain this, first recall that the consumer surplus is always higher in the FT regime than in the TP regime. Moreover, an increase in imitation in the FT regime makes price competition tougher (s increases) and the size of the market larger (the number of consumers served in equilibrium rises with μ), that in principle benefits domestic consumers.[36] At the same time, the size of the consumer surplus is obviously not affected by the change in the imitation parameter μ when there is trade induced quality reversal; see part (ii) of Proposition 4. Last but not the least, the sunk costs of imitation in the FT regime fall much faster with μ than in the TP regime with quality reversal, approaching zero for μ tending to 1. (Note that these costs are for any μ substantially lower in FT regime than in the TP regime since the domestic firm produces a lower quality in free trade.) This, in turn, rapidly decreases the difference in the corresponding net profits of the domestic firm in the FT and the TP regime, respectively. Thus, given the above effects, there is for any given value of α a critical value of μ beyond which the domestic welfare in the FT regime dominates its counterpart in the TP regime even in the case when trade policy leads to quality reversal.[37]

The policy implications of the above discussion indicate that the LDC government may wish to commit to free trade and strengthen its IPR rights in the cases where the gap in its relative economic development is substantial and where trade in vertically

[36] Note that FT dominates TP "excessively" for large values of parameters μ and α (right upper corner of Figure 8). In this region, there is a "corner solution," as described in Footnotes 28 and 35. Unlike in standard cases where optimal q comes from the "interior" set (i.e., when $q^*_\mu > \hat{q}_\mu$), Firm 1's optimal quality q^*_μ is now increasing in μ, as it is equal to $\hat{q}_\mu$, which we know to be increasing in μ (see Proposition 3 and Figure 3). That in turn, enables Firm 1 to be better off by choosing a higher quality. This phenomenon leads to even a stronger increase in the consumer surplus in μ compared to the values of μ that do not yield a "corner solution." It also explains the shape of that region (see also Supplementary Appendix).

[37] The phenomenon that strategic trade policy may yield a lower domestic welfare than free trade when the government cannot commit to *ex-ante* instruments has been observed in a rather different context of standard models with horizontal product differentiation or with homogenous goods where the action takes place in a third market (that is, the domestic welfare coincides with the domestic firm profit net of subsidies; see for instance, Karp and Perloff 1995; Neary and O'Sullivan 1999; Grossman and Maggi 1998; and Neary and Leahy 2000). The intuition for this result lies in manipulative strategic overinvestment by the domestic firm.

differentiated products prevails in its trade account. This commitment can be induced, for example, by joining a trade organization or signing a bilateral trade agreement.

7 Conclusion

The concept of imperfect competition with vertical product differentiation seems to capture an important aspect of the contemporary competition between the firms from developed countries (DC) and emerging markets countries (LDC). Contrary to the prediction of the classical international trade theory, it is often the case that firms from countries at rather different stages of development compete in the same oligopolistic market (Schott 2004; Hallak 2006). The products produced by firms from developed countries (DCs) are usually associated with a variety of higher quality than the ones produced by firms from less developed countries (LDCs). The important features of this competition are that (i) DC firms tend to act as market and quality leaders while the LDC firms act as followers that (ii) have a tendency to copy or imitate the products by firms from developed countries. Firms' choices of qualities are endogenous and may be influenced by some governmental policies. Thus, the attention of strategic trade policy literature has recently shifted towards international markets in vertically differentiated goods. It, however, has neglected the above two features of market leadership and imitation.

Our paper aims to fill this gap by introducing leadership and imitation into the vertical differentiation model of international trade at the 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! We first 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 the DC firm has no technological advantage and the degree of imitation is high. However, this result dramatically changes when we allow the LDC government to impose a tariff since such trade policy tends to have a positive impact on the follower's profits and enhances its incentives to produce a higher quality, leading to quality reversal. These incentives increase with the degree of imitation and with the decline in the 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, irrespective of the degree of imitation.

The importance of the quality reversal becomes evident after comparison of the domestic welfare in the LDC. It is indicative that gains in the domestic welfare due to trade policies are closely related to quality reversals. In other words, when the domestic government cannot induce quality reversal using the optimal trade policy (and this seems to be the most plausible outcome at the current technological gap between the DC and LDC), then it may prefer not to adopt the policy and engage in free trade. This may be achieved by a commitment to free trade. A bilateral trade agreement or a participation in a trade union can serve as mechanisms to achieve such a commitment. Therefore, our paper provides rationale for unilateral incentives to adopt free trade.

However, our analysis also points to the limitations of the trade policy for spurring economic development and the domestic welfare of an LDC. Namely, the technological gap has to be rather small and technological spillovers should not be "too large" for trade policy to be effective in promoting the domestic firm into the position of the technology and market leader and, consequently, increasing the domestic welfare. Arguably, for the vast majority of the LDCs, this is not the case. In this respect, there is a positive trend due to prevailing pressure for global IPR to be strengthened as the results of the Uruguay GATT round and subsequent resolutions of WTO. Thus, some more fundamental policies aimed at the increase of the LDC countries' human capital and technological competence have to be in place much before trade policy would be invoked for the purposes of enhancing domestic firms into the market and quality leaders.

A Appendix: Proofs

Derivation of Firm 2's cost function (4)*.* According to condition (i), without imitation, Firm 2's cost function has the form $\frac{1}{2}\gamma_2 s_2^2$, where γ_2 is a constant such that $\gamma_2 \geq \gamma_1$. 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 $\gamma_2(1-\mu)s_2$, where $\mu \in [0,1]$ is a constant (parameter) representing the degree of imitation. After integration, we obtain that Firm 2's cost function has the following form

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

where ξ_1 and ξ_2 are some constants. Since for $\mu = 0$ (no imitation), Firm 2's cost function needs to be equal to $\frac{1}{2}\gamma_2 s_2^2$, due to condition (i), then it is necessary that $\xi_1 = 0$. Moreover, due to condition (iv), the cost function is continuous when $s_2 = s_1$. Hence, $\frac{1}{2}\gamma_2(1-\mu)s_1^2 = \frac{1}{2}\gamma_2 s_1^2 + \xi_2$, which yields $\xi_2 = -\frac{1}{2}\gamma_2\mu s_1^2$. Summarizing, we obtain the expression given by (4). □

Lemma 2. *Firm 2's profit $\pi_2(s) - qc_2(s)$ attains its maximum. The optimal value of s lies either in interval $(0,1)$ or in interval $(1,\infty)$.*

Proof of Lemma 2. It is sufficient to show that Firm 2's net profit is bounded from above and its maximum is not attained for $s = 0$ and for $s = 1$. Note that the case $s = 1$ corresponds to minimal product differentiation, whereas the other two cases correspond to maximal product differentiation. If $s = 0$, Firm 2's net profit is zero, and for $s = 1$ 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).

To complete the proof we show that Firm 2's profit is positive when s is close to 0. It can directly verified that $\pi_2''(s) < 0$ for all $s > 0$. Alternatively, this can also be seen on Figure 1. 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. 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. □

Lemma 3. *For all $q \geq 0$, the following statements hold:*

(i) *There exists a unique solution of* (15) *on interval* $(0,1)$*.*

(ii) *There exists a solution of* (15) *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. This solution is then unique and does not depend on* μ*.*

Proof of Lemma 3. (i) 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 (15) on interval $(0, 1)$. Due to concavity, this solution is unique and represents the maximum of Firm 2's net profit on $(0, 1)$.

(ii) 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, is 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 1). Then (because of continuity), there always exists a solution of (15) on interval $(1, \infty)$. Due to concavity, this solution is unique and represents the maximum of Firm 2's net profit on $(1, \infty)$.

The proof for the TP regime is analogous. □

Lemma 4. *Functions $s^1(q)$ and $s^2(q)$ (when defined) have a continuous first derivative (are $\mathcal{C}^1$) and are decreasing in q.*

Proof of Lemma 4. Recall that $s^1(q)$ and $s^2(q)$ are (unique) solutions of (15) when $s < 1$ and $s > 1$, respectively. Since both π_2' and c_2' are $\mathcal{C}^1$, it follows from the *Implicit Function Theorem* also implies that the first derivative is continuous[38] and 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 $\mathrm{d}s^j(q)/\,\mathrm{d}q < 0$, which completes the proof. □

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 net 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 positive values when $q \to 0^+$ and negative values 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 $q < \hat{q}$ and $\Delta(q) < 0$ when $q > \hat{q}$.

Now it remains to show that $\Delta(q)$ is decreasing and attains positive values when $q \to 0^+$ and negative values 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 net 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 1).

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

Now consider $q \to 0^+$. In this case, we get $s^1(q) \to \frac{4}{7}$ in the FT regime and $s^1(q) \to \frac{2}{3}$ in the TP regime (see Table 1 and Figure 1). Consequently, $\pi_2(s^1(q)) - qc_2(s^1(q))$ is bounded when $q \to 0^+$. In addition, $s^2(q) \to \infty$. We show that then $\pi_2(s^2(q)) - qc_2(s^2(q)) \to \infty$. To see it, we use the first order condition (15), namely $qs^2(q) = \pi_2'(s^2(q))$, to obtain

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

When $q \to 0^+$, the last term μq converges to zero and the rest to infinity, since $\pi_2(s) - \frac{1}{2}s\pi_2'(s) \to \infty$ as $s \to \infty$.[39] Hence, $\Delta(q) \to \infty$ when $q \to 0^+$.

As the last step, we will show that $\Delta(q)$ is decreasing. Now recall that $s^1(q)$ and $s^2(q)$ represent local minima of Firm 2's net profit $\pi_2(s) - qc_2(s)$. Thus, it follows from the *Envelope Theorem* that

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

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

Proof of Proposition 2. The proposition follows from the *Envelope Theorem*. In particular, we obtain that the derivative of Firm 2's optimal profit with respect to μ is equal to $\frac{1}{2}q[s^1(q)]^2$ when $q > \hat{q}_\mu$, and to $\frac{1}{2}q$ when $q < \hat{q}_\mu$. Obviously, it is positive in both cases (when $q \neq 0$). □

Proof of Proposition 3. The claim that s^* is increasing in μ (for a fixed q) is simply a consequence of statements (i)–(iii). We will prove each of them separately.

(i) The proof that s^1_μ is increasing in μ is analogous to the proof that s^1_μ is decreasing in q, since s^1_μ depends only on the product $q \cdot (1-\mu)$; see the Proof of Lemma 4.

(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 3.

(iii) Let s^1_μ and s^2_μ denote the values of s^1 and s^2 that are chosen for $q = \hat{q}_\mu$. The values of s^1_μ, s^2_μ, and $\hat{q}_\mu$ are determined simultaneously by the system of three equations introduced before the proposition. According to the last equation

$$\pi_2(s^1_\mu) - \tfrac{1}{2}(1-\mu)\hat{q}_\mu(s^1_\mu)^2 = \pi_2(s^2_\mu) - \tfrac{1}{2}\hat{q}_\mu[(s^2_\mu)^2 - \mu].$$

[39] 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 $s \to \infty$.

Taking the derivative with respect to μ (and using the *Implicit Function Theorem*) we obtain

$$[\pi_2'(s^1_\mu) - (1-\mu)\hat{q}_\mu s^1_\mu]\frac{\mathrm{d}s^1_\mu}{\mathrm{d}\mu} + \tfrac{1}{2}\hat{q}_\mu (s^1_\mu)^2 - \tfrac{1}{2}(1-\mu)(s^1_\mu)^2\frac{\mathrm{d}\hat{q}_\mu}{\mathrm{d}\mu} =$$
$$= [\pi_2'(s^2_\mu) - \hat{q}_\mu s^2_\mu]\frac{\mathrm{d}s^2_\mu}{\mathrm{d}\mu} + \tfrac{1}{2}\hat{q}_\mu - \tfrac{1}{2}[(s^2_\mu)^2 - \mu]\frac{\mathrm{d}\hat{q}_\mu}{\mathrm{d}\mu}.$$

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

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

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

Proof of Lemma 1. It is sufficient to show that the leader's profit (i) diverges to $-\infty$, when $q \to \infty$; (ii) converges to 0, when $q \to 0^+$; and (iii) is increasing in q, when q is sufficiently small.

(i) If $q \to \infty$, then $q > \hat{q}_\mu$, $s^*(q) = s^1(q)$, and it follows from part (iv) of Corollary 1 that $s^*(q) \to 0^+$. In addition, $\pi_1(s)$ is bounded in some neighborhood of $s = 0$, as it converges to a finite limit when $s \to 0^+$ (see Table 1). Thus, $q\pi_1(s) - \frac{1}{2}\alpha q^2$ diverges to $-\infty$.

(ii) If $q \to 0^+$, then $q < \hat{q}_\mu$, $s^*(q) = s^2(q)$, and it follows from part (iv) of Corollary 1 that $s^*(q) \to \infty$. Again, $\pi_1(s)$ is bounded when s is sufficiently large, as it converges to a finite limit (which is $\frac{1}{16}$ in the FT regime and $\frac{1}{144}$ in the TP regime), when $s \to \infty$ (see Table 1). Hence, $q\pi_1(s) - \frac{1}{2}\alpha q^2$ converges to zero.

(iii) The derivative of Firm 1's continuation net profit with respect to q is

$$\pi_1(s^*(q)) + q\pi_1'(s^*(q))\frac{\mathrm{d}s^*(q)}{\mathrm{d}q} - \alpha q. \tag{18}$$

Now recall that for q sufficiently small ($q < \hat{q}_\mu$) we get $s^*(q) = s^2(q)$, which is continuously differentiable. Therefore, it is sufficient to show that the above derivative is positive when $q \to 0^+$. In that case $s^*(q) \to \infty$. We have already established in part (ii) that $\pi_1(s)$ converges to a positive limit when $s \to \infty$. Thus, the first term in (18) is positive when $q \to 0^+$. Obviously, the last term converges to zero in that case. We will show now that $A = \pi_1'(s^*(q))\frac{\mathrm{d}s^*(q)}{\mathrm{d}q}$ has a finite limit (when $q \to 0^+$), which implies that the second term (equal to qA) also converges to zero when $q \to 0^+$. For this recall that the first-order condition for Firm 2's profit maximization is $\pi_2'(s) = qs$. In addition, it follows from the proof of Lemma 4 that

$$\frac{\mathrm{d}s^*(q)}{\mathrm{d}q} = \frac{s}{\pi_2''(s) - q} = \frac{s^2}{s\pi_2''(s) - \pi_2'(s)}.$$

We may, therefore, rewrite A in terms of s and take the limit $s \to \infty$. We obtain $A = s^2\pi_1'(s)/[s\pi_2''(s) - \pi_2'(s)]$, which after computing the derivatives (from Table 1) implies that in the FT and the TP regime:

$$A^{\mathrm{FT}} = -\frac{(2s+1)(4s-1)}{4(16s^2 - 16s + 21)},$$
$$A^{\mathrm{TP}} = -\frac{(s-1)^2(2s-1)(3s-2)(4s-1)(7s+2)}{9(576s^6 - 2112s^5 + 3684s^4 - 3504s^3 + 1909s^2 - 568s + 72)}.$$

Thus, A^{FT} converges to $-\frac{1}{8}$ and A^{TP} converges to $-\frac{7}{216}$, when $s \to \infty$. This completes the proof. □

Proof of Proposition 4. (i) The *Envelope Theorem* implies that the (total) derivative of Firm 1's optimal profit is equal to

$$\frac{\partial}{\partial\mu}[q\pi_1(s_\mu^1(q)) - \tfrac{1}{2}\alpha q^2] = q\pi_1'(s_\mu^1(q))\frac{\partial s_\mu^1(q)}{\partial\mu},$$

evaluated at the optimal value of q. It follows from part (i) of Proposition 3 that $\partial s_\mu^1(q)/\partial\mu > 0$. In addition, it can be easily established that $\pi_1'(s) < 0$ when $s < 1$ (see the expressions in Table 1). This completes the proof.

(ii) The claim follows directly from two facts. First, Firm 1's (net) profit does not depend on μ directly. Second, according to part (ii) of Proposition 3, Firm 2's best response does not depend on μ, whenever it leads to a higher quality, i.e., when $s^*(q) > 1$.

(iii) The claim follows directly from the *Envelope Theorem* and from the fact that Firm 2's maximization problem (for a fixed q) and, hence, its best response function s^* do not depend on α. □

B Appendix: Figures and tables

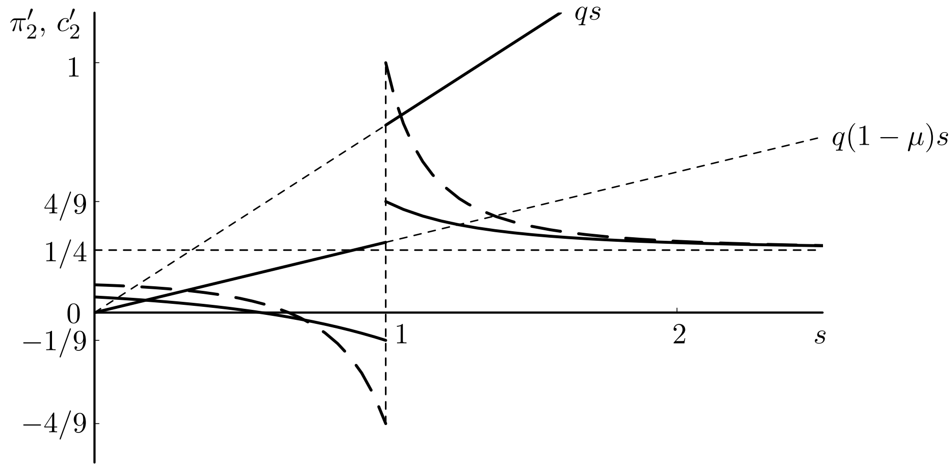

Figure 1: Derivative of Firm 2's profit $\pi_2'(s)$ (solid curves for the free trade regime and dashed curves under the optimal trade policy) and Firm 2's costs $c_2'(s)$; see Table 1 for particular expressions. The solution of the first-order condition (15) is given by the intersection of $\pi_2'(s)$ with the line $q(1-\mu)s$ when $s < 1$, and with the line qs when $s > 1$. Note that this solution depends on Firm 1's decision q only through the slope of this line.

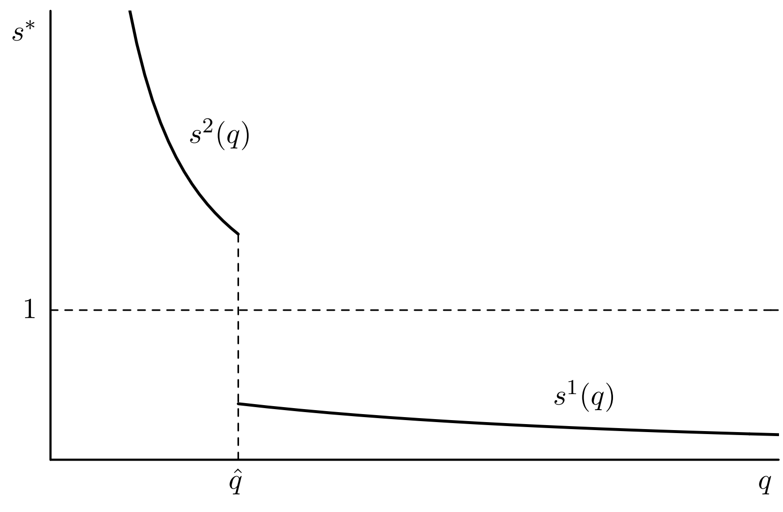

Figure 2: Firm 2's best response $s^*(q)$

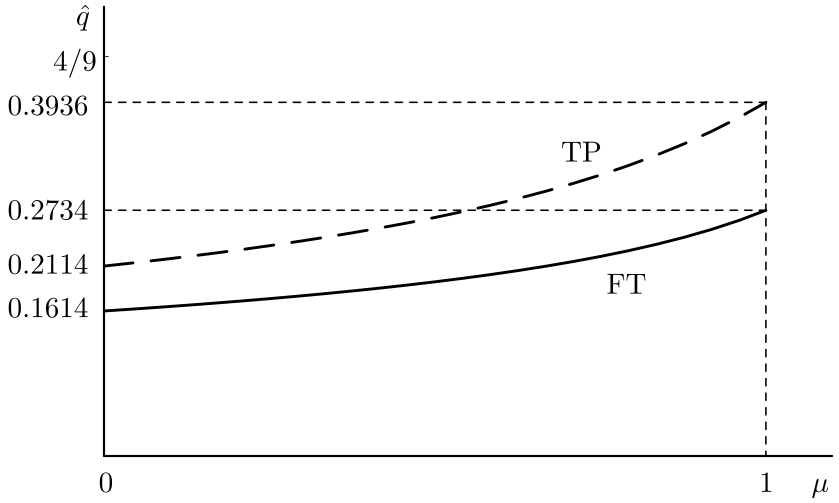

Figure 3: Profile of $\hat{q}$ in the free trade regime (solid line) and under optimal trade policy (dashed line); obtained numerically

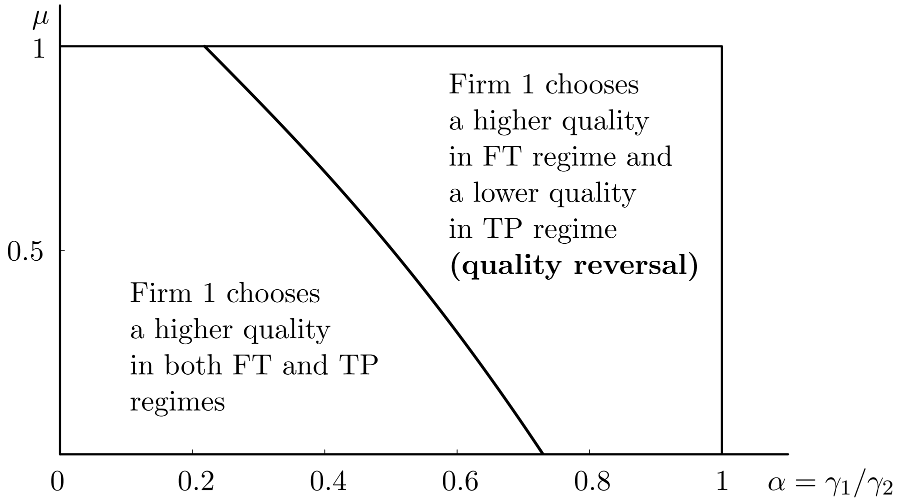

Figure 4: Region with quality reversal (numerical simulations)

Note: Each of the following figures shows the comparison of some variable in the FT equilibrium and in the TP equilibrium. The shaded area corresponds to the values of parameters α and μ where the equilibrium value of the variable in the FT equilibrium is *higher* than in the TP equilibrium.

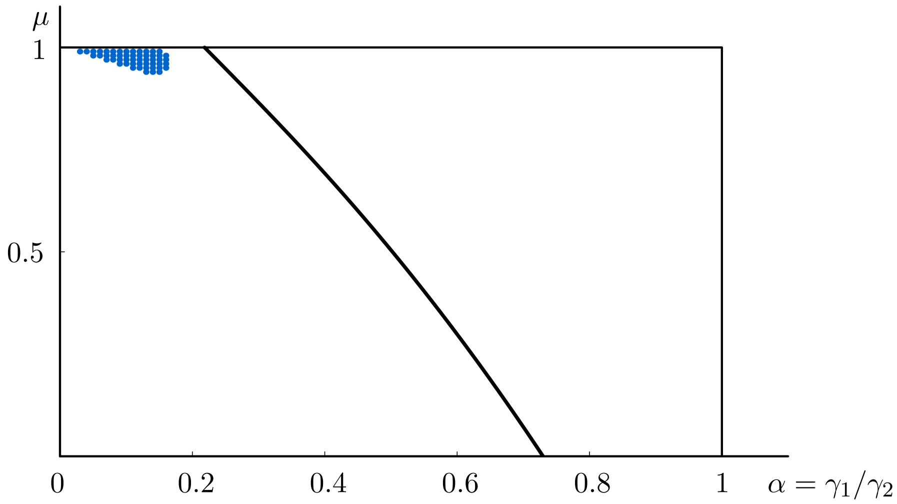

Figure 5: Comparison of Firm 2's net profit (num. simulations)

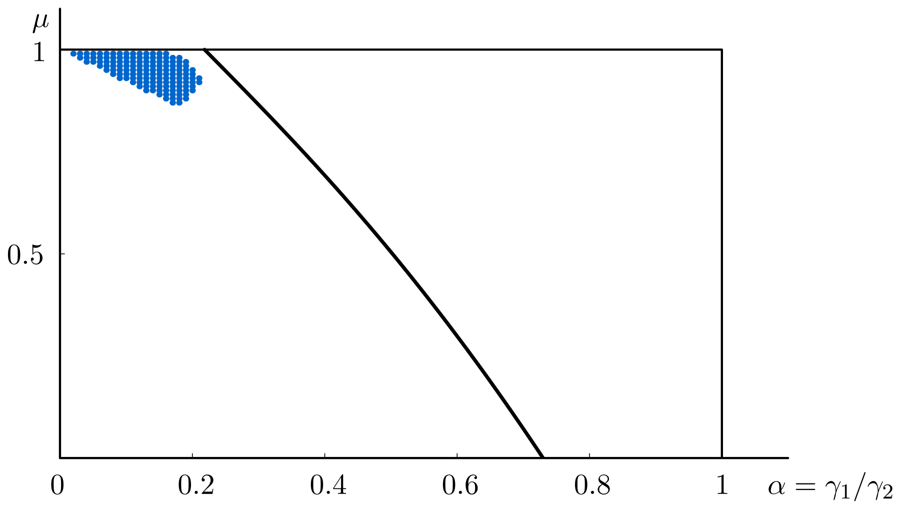

Figure 6: Comparison of Firm 2's gross profit (num. simulations)

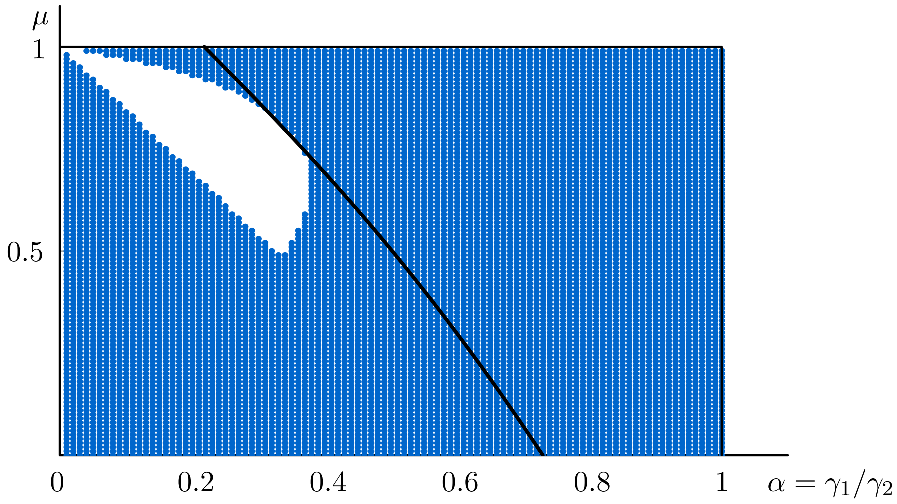

Figure 7: Comparison of the market size (num. simulations)

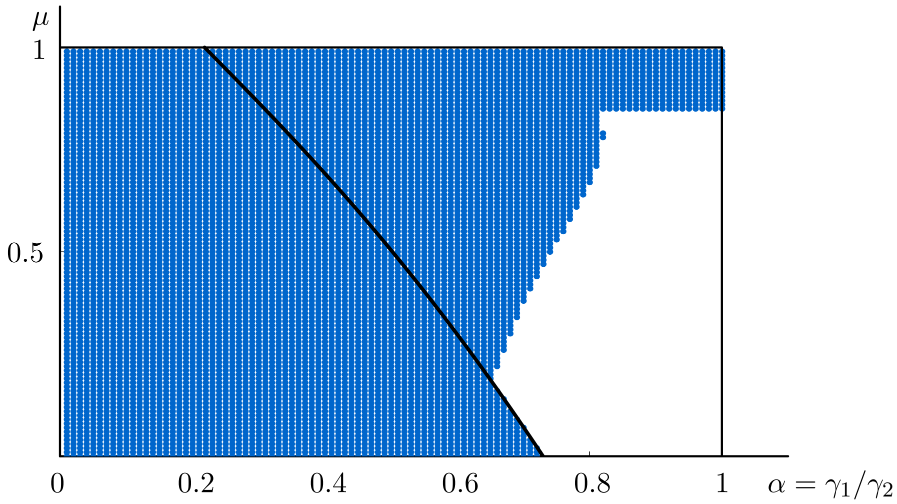

Figure 8: Comparison of the domestic welfare (num. simulations)

	Qualities ranking	Firm 1 FT regime	Firm 1 TP regime	Firm 2 FT regime	Firm 2 TP regime
$\Pi_i(s_1,s_2)$	$s_2<s_1$	$\frac{4s_1^2(s_1-s_2)}{(4s_1-s_2)^2}$	$\frac{s_1^2(s_1-s_2)(4s_1-3s_2)^2}{(3s_1-2s_2)^2(4s_1-s_2)^2}$	$\frac{s_1s_2(s_1-s_2)}{(4s_1-s_2)^2}$	$\frac{4s_1s_2(s_1-s_2)(2s_1-s_2)^2}{(3s_1-2s_2)^2(4s_1-s_2)^2}$
	$s_2>s_1$	$\frac{s_2s_1(s_2-s_1)}{(4s_2-s_1)^2}$	$\frac{s_2s_1(s_2-s_1)^3}{(3s_2-2s_1)^2(4s_2-s_1)^2}$	$\frac{4s_2^2(s_2-s_1)}{(4s_2-s_1)^2}$	$\frac{9s_2^2(s_2-s_1)(2s_2-s_1)^2}{(3s_2-2s_1)^2(4s_2-s_1)^2}$
$\pi_i(s)$	$s<1$	$\frac{4(1-s)}{(4-s)^2}$	$\frac{(1-s)(4-3s)^2}{(3-2s)^2(4-s)^2}$	$\frac{s(1-s)}{(4-s)^2}$	$\frac{4s(1-s)(2-s)^2}{(3-2s)^2(4-s)^2}$
	$s>1$	$\frac{s(s-1)}{(4s-1)^2}$	$\frac{s(s-1)^3}{(3s-2)^2(4s-1)^2}$	$\frac{4s^2(s-1)}{(4s-1)^2}$	$\frac{9s^2(s-1)(2s-1)^2}{(3s-2)^2(4s-1)^2}$
$\pi_i'(s)$	$s<1$	$-\frac{4(2+s)}{(4-s)^3}$	$-\frac{(4-3s)}{(4-s)^3(3-2s)^3}\times$ $\times(32-32s-3s^2+6s^3)$	$\frac{4-7s}{(4-s)^3}$	$\frac{4(2-3s)(2-s)}{(4-s)^3(3-2s)^3}\times$ $\times(12-13s+4s^2)$
	$s>1$	$-\frac{2s+1}{(4s-1)^3}$	$\frac{(s-1)(2s-1)(7s+2)}{(4s-1)^3(3s-2)^3}$	$\frac{4s(4s^2-3s+2)}{(4s-1)^3}$	$\frac{9s(2s-1)}{(4s-1)^3(3s-2)^3}\times$ $\times(24s^4-54s^3+51s^2-22s+4)$
	$s=0$	$-\frac{1}{8}$	$-\frac{2}{27}$	$\frac{1}{16}$	$\frac{1}{9}$
	$s\to 1^-$	$-\frac{4}{9}$	$-\frac{1}{9}$	$-\frac{1}{9}$	$-\frac{4}{9}$
	$s\to 1^+$	$\frac{1}{9}$	0	$\frac{4}{9}$	1
	$s\to\infty$	0	0	$\frac{1}{4}$	$\frac{1}{4}$

Table 1: Firms' continuation profits $\Pi(s_1,s_2)$, normalized continuation profits $\pi_i(s)$ and their derivatives $\pi_i'(s)$

Variable	Notation	Firm 1	Firm 2
net profit	$\Pi_i - C_i$	100%	< 1%
gross profit	Π_i	100%	1%
price	p_i	100%	6%
quality	s_i	100%	6%
hedonic price	p_i/s_i	21%	7%
quality ratio	$s = s_2/s_1$	0%	
quality gap*	s_i/s_j	49%	
market size*	$1 - \theta_{j0}$	93%	
average quality*	$(1 - \theta_{ij})s_i +$ $+(\theta_{ij} - \theta_{j0})s_j$	100%	
consumer surplus	CS	100%	
domestic welfare	DW	80%	
quality reversal		51%	

Table 2: Comparison of FT and TP equilibrium (numerical simulations)

*The formulas correspond to the case $s_i > s_j$.

Note: For each variable, the number represents the area of the range of parameters where its value in the FT equilibrium is higher than in the TP equilibrium (expressed as the share of the whole range of parameters); see Figures 5–8. Provided that the joint distribution of α and μ is roughly uniform, then it represents the probability that its value in the FT equilibrium is higher than in the TP equilibrium.

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