Theory of Strategic Trade Policy in North–South Trade:

Optimal Northern and Southern Tariffs in an Inherently Asymmetric Environment

KREŠIMIR ŽIGIĆ

CERGE-EI

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Krešimir Žigić*
CERGE–EI,Prague
CEPR, London

Charles University in Prague
Center for Economic Research and Graduate Education

Economics Institute
Academy of Sciences of the Czech Republic

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To Branka, Vladimir, and Sandra

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Chapter I

INTRODUCTION

The appearance of the theory of strategic trade policy posted a challenge to the prevailing concept of free trade and put forward a possible new paradigm in international trade. The key claim of the theory is that a significant share of international trade takes place in an imperfectly competitive environment and so strategic interaction among participating firms becomes relevant. Consequently, the proper description of this strategic interaction requires oligopoly theory as an underlying concept. Morever, the government is viewed as an important actor in this context that possesses the ability to alter the above strategic interactions in favour of the domestic firm, and possibly in favour of domestic consumers and the domestic treasury. In other words, it is socially beneficial for a government to intervene by tariff, subsidy, quotas, etc. in order to secure higher domestic social welfare (through improving domestic terms of trade, profits shifting to domestic firm, increased tariff revenue, increased consumer surplus, etc.).

On the other hand, the design of optimal strategic trade policy depends critically on details concerning market structure and market conduct that impose a demanding information requirement on policy makers. The most striking example of this is Eaton and Grossman (1986), who showed that, depending on the type of market competition, levying both a tax and a subsidy can be an optimal trade policy if domestic and foreign firms compete in a third market. Moreover, there are the well–known political economy concerns about the use of strategic trade like political pressure, lobbying, or rent seeking.[1] In other words, the issue of the sensitivity and robustness of strategic trade policy seems to be critical for the successful implementation of the

[1] However, it is important to note that the lack of key information and rent-seeking "…would speak against all forms of government intervention, inasmuch as policy makers rarely have all the information they need to implement the policies prescribed by economic theory" (Grossman and Maggi, 1998) and inasmuch as they are exposed to interest group pressure.

policy.

The main issues of this monography are an inquiry into strategic trade policy in the "North–South" *intra-industry trade* context and an analysis of some of the above mentioned sensitivity and robustness questions from both a Northern and Southern perspective. The context of North–South trade implies that international trade takes place among *ex ante* asymmetric actors. This asymmetry can, (among other things) arise from a) the presence of unilateral R&D spillovers from the Northern to the Southern firm, b) the difference in unit costs of production or c) different sunk (fixed) quality costs among the firms.

Given the above asymmetries, we explore some properties of optimal strategic trade policy as well as its sensitivity and its social welfare implications with respect to different modes of competition, possible information asymmetry and variations in ability of government to pre-commit to its policy choice.

In chapter II we assume that the asymmetry takes the form of unilateral R&D spillovers and these spillovers stem from Southern intellectual property rights (IPR) violation. More specifically, we consider a duopoly game where Northern (or domestic) and Southern (or foreign) firms compete in quantities on an imperfectly competitive domestic market and there are R&D spillovers from the domestic to the foreign firm. In this set up, we examine the interaction between the Northern strategic trade policy (in the form of tariff) and the Southern government's incentives to set the level of IPR protection and the corresponding social welfare implications. In addition we examine the issue of the optimal IPR protection from the global welfare point of view.

We show that optimal Northern tariffs have some additional roles besides their traditional role as a device to shift foreign profit to the domestic treasury and to domestic profit. Tariffs also act as an instrument that may reduce IPR violations and, therefore, drive the domestic firm to invest in socially beneficial R&D that in turn leads to better exploitation of scale economies. In this setup, optimal tariffs are higher than in the standard duopoly model without R&D investment and IPR violations.

The Southern government sets the IPR policy strategically by anticipating the Northern firm's R&D decision and Northern government decision on tariffs. The Southern government would prefer to set a maximal slack in IPR protection, but it cannot do this (unless the R&D efficiency is "very low") since such an IPR violation triggers a prohibitive tariff. Since the appropriation of R&D output by the South is a form of informal technology transfer, it is not *a priori* clear that the world planner should discourage it.

The world planner would have to weigh carefully the benefits of innovation diffusion and the costs of diminished incentives and decreased R&D investment in the North. Such considerations will urge a zero or low tariff if R&D efficiency is low, but will require a prohibitive tariff if R&D efficiency is high.

A few testable predictions also arise from the above analysis: first, given that the Southern government sets the IPR for all industries under the same conditions, we should observe higher tariff levels on products for which the production process (or the product) is subject to higher spillovers. Second, the Northern innovating firm (firms where scale economies are important) faced with spillovers but without tariff support (or any other effective IPR protection) will operate at a lower scale in comparison to Northern firms where there is effective IPR protection.

In chapter III we relax the standard assumption that the government can commit to its policy instrument prior to the strategic action of domestic firm based on the reason that governments and firms are likely to differ in their ability to commit to future action. Thus, the government may lack credibility with the firms whose behaviour it tries to influence or there may be a time lag between the announcement and the implementation of strategic trade policies. As a consequence, the government may be forced to select its policy only *after* the strategic choice of domestic firms has taken place. This gives a strategic motive to the domestic firm to influence (or manipulate) the government's policy response. In these circumstances, it has been claimed, implementing a strategic trade policy can cause inefficiencies and consequently can lead to lower social welfare compared to the corresponding social welfare under free trade.

Given these observations, the logical research question would be to test the robustness of the conclusions reached in chapter II by allowing the domestic government to react only after the strategic choice of the domestic firm has taken place (the strategic variable in our set up is investment in R&D). Thus, we analyse the effect of different degrees of government commitment on social welfare applying the same set up as in chapter II. More specifically, we distinguish between "committed" and "non-committed" policy regimes where a "committed" government selects the policy instrument before the strategic choice of the domestic firm occurs (as in chapter II) while its "non-committed" counterpart sets the policy instrument only after the strategic variable of the domestic firm is already in place. Another departure from chapter II is that we also analyse the robustness of industrial policy in the form of R&D subsidies in the above context.

Concerning government policy, we make a distinction between the "first–best" and the "second–best" policy. The first–best policy, in principle, includes more than one policy instrument in order to induce a socially desirable level of strategic choice variables. The strategic choice variable in our set up is unit cost reduction and consequently, investment in R&D. In many circumstances, however, the government may be constrained to a smaller number of policy instruments than the number of targets. In such a constrained policy environment government can only implement a second–best policy. Indeed, there may be only one instrument at the government's disposal. Since in our context the domestic firm has two choice variables—the level of R&D investment and the quantities to be produced—the second–best policy implies either an R&D subsidy or an import tariff (but not both of them).

As for the second–best policy when import tariffs are the only instrument, we show that (contrary to the results prevailing in the literature) when R&D spillovers prevail, social welfare in the non-committed regime is higher than social welfare in the committed regime and, consequently, higher than the corresponding welfare under a free trade regime. This result can be attributed to the fact that the optimal tariff in the non-committed regime is lower than the optimal tariff in the committed regime creating a smaller distortional effect on consumer surplus and tariff revenue.

With regard to the optimal R&D subsidy we demonstrate that it is always positive in both the first–best and second–best policy setup, irrespective of the level of spillovers. The reason for this is the socially inefficient level of private R&D due to the appropriability problem that subsidy primarily aims to correct and due to the scale economies that larger R&D investment brings about. The role of the optimal subsidy in the first–best setup is somewhat modified due to R&D spillovers since, besides its primary role in correcting for socially insufficient R&D, the first–best subsidy also affects the optimal tariff and thus, at least indirectly, has a profit shifting role.

In chapter IV we change sides and analyse Southern tariffs. This means that now the Southern country and the Southern firm become the "domestic" ones. The Southern firm invests in technological upgrading since it lags behind the Northern firm that has mature technology and so this investment is of an imitative nature rather than a true investment in technological improvement. In a sense, we relax the assumptions made in the chapters II and III that imitations or spillovers are costless. In this setup we analyse different domestic policy options that occur due to reasons like the mode of the oligopoly conduct, the (in)ability of the domestic (Southern) government to commit to its policy and information asymmetry. We initially start with a perfect, symmetric information setup and explore the role of oligopoly conduct and the ability of the Southern government to commit to the level of its policy instrument. We consider three policy options: government commitment regime, government non–commitment regime, and free trade. We find that regardless of the market conduct and the ability of the domestic government to commit in advance to the level of its policy, the optimal tariff protection improves not only domestic social welfare but also the effort to imitate of the domestic firm. However, free trade, as a policy option *per se,* has its virtues since the information requirement for its implementation is virtually zero. Thus we introduce policy criteria beyond generated social welfare (including information requirement, time consistency, and the threat of agency and manipulative behavior) in order to evaluate the policy options under consideration. We show that the most robust policy choice is the government "non–commitment" regime where there is a low information requirement, the optimal tariff is time consistent and there is no fear of manipulation by the domestic firm. In addition, we show that the social welfare loss *vis-à-vis* the government commitment regime is negligible.

We somewhat unconventionally assume that information asymmetry stems from the government's uncertainty about the market conduct. We introduce two kinds of information asymmetry and briefly explore how the most desirable policy under perfect information — i.e. a non–commitment regime — fares in the presence of such government's uncertainty. Asymmetric information setup in general worsens the social welfare compared to the analogous symmetric information but is on the other hand less information intensive. We nevertheless identify situations when the expected social welfare can be increased compared to the full information counterpart.

In the last chapter, we invoke the concept of the *vertical product differentiation*. The analysis of the strategic interactions in the chapters II to IV is based on the assumption of either homogenous goods (as in chapters II and III) or the assumption of horizontal product differentiation (as in chapter IV). However, recent empirical trade literature has managed to distinguish between intra–industry trade based on horizontal product differentiation and intra–industry trade based on vertical product differentiation, pointing out different factors that determine these trade flows. In general vertical intra–industry trade represents a significantly larger share in the total intra–industry trade (Greenaway et al., 1994 and 1995). Schott (2004), on the other hand, has demonstrated, that vertical intra–industry trade is also consistent with the Heckscher-Ohlin type of specialization, but only within products (varieties) where the producers from a capital and skill-intensive country use their advantage to produce vertically superior varieties, that is, varieties that are relatively more capital or skill-intensive and of higher quality.

Vertical intra–industry trade is an important pattern in trade between North and South (Clark and Stanley, 1999). In other words, this trade is characterised by the differences in qualities of products that they offered in the same market.[2] Thus, in the last chapter, we put forward a simple duopoly model with vertical product differentiation where the competition takes place in the Southern market (as in chapter IV, the Southern government and its firm are considered "domestic"). The strategic choice considered is the firms' selection of product qualities, and duopoly as a market structure emerges endogenously from the nature of the competition and the size of the market. The number of firms is not arbitrarily set at two but is the outcome of the given size of the market (determined in turn by the distribution of the consumers' taste for quality) and the nature of the competition that enables only two firms to survive in equilibrium. This kind of duopoly is called a "natural duopoly" and is an appropriate setup if, roughly speaking, the taste for quality is predominant in the market in the sense that even the consumer with the lowest valuation for quality prefers to buy a quality good than to buy nothing. Once again, the trade policy in question is an import tariff and finally, the government sets the tariff only after the firms' quality choice has taken place. In other words, we concentrate

[2] The same phenomenon holds (or at least used to hold) for transition countries as well. For instance, Landesmann and Burgstaller (1997) observe quality differences between Western and Eastern European intra- industry trade. Even more striking, Aturupane et al. (1999) find that vertically differentiated intra-industry trade accounts for 80 to 90 percent of the total intra-industry trade between the EU and advanced Central European transition economies.

on the "non–commitment" regime.

We also assume that the quality cost efficiencies differ at margin among the firms. The reason for postulating the differences in the quality cost efficiency is motivated by the different abilities of the firms from the South to elevate the quality level of their products. The generation of high quality commodities is tightly connected with R&D investment, learning by doing and the level of human capital and therefore it seems natural that at the margin an increase in quality would require more effort and higher costs by the firm in the less developed country.

The conspicuous effect of strategic trade policy in this setup is that it may affect the market structure as well as induce a firm's leap–frogging from the low to high quality production and vice versa. We demonstrate that optimal tariffs have a somewhat limited ability to induce this "quality reversal". The lag in quality cost efficiency of the firm in Southern country *vis-à-vis* the firm coming from the North should be relatively small (less than double) for a quality reversal to be the best response for the initially low quality, domestic firm.

Chapter II

The Interaction between Northern Strategic Trade Policy and Southern Intellectual Property Rights Protection

1. INTRODUCTION

The theory of strategic trade policy that came into existence in 80's represented a challenge to the prevailing concept of free trade and suggested a possible new paradigm in international trade. One of its main messages was that it is, in general, socially beneficial for a government to intervene by tariff, subsidy, quotas, etc. in order to secure higher profits for its domestic firms. Despite its theoretical attractiveness and tempting conclusion, "strategic trade policy" arguments have not convinced the majority of trade economists that the profession's traditional support for free trade should be abandoned. To a large extent, this reaction reflected the *a priori* bias of trade economists against trade activism, rather than being the implication of rigorous analysis (see, for instance, Baghwati, 1989, Grossman and Maggi,1998, Krugman, 1987). Their intuition may have been right in general, since some results, based on "calibration" models, indicate that indeed the gains are at best modest when strategic trade policies are applied as profit shifting or facilitating devices (see Venables, 1994). However, in the particular case where free trade leads to the unilateral violations of intellectual property rights (IPR), losses may be large due to the well known appropriability problem.[1] Moreover, lack of appropriability may result in lower output that does not fully utilize scale economies (see Krugman, 1984, for a discussion of scale economies in the international trade context).

[1]See Levine et al. (1987) for a comprehensive empirical analysis of the causes, forms and aspects of attenuated appropriability due to inability to capture the induced benefits of innovating activity and intellectual property. Vishwasrao (1993) for example, refers to USITC documents (1988) reporting the aggregate losses for US firms amounting to 23.8 billion dollars due to inadequate IPR protection.

The Uruguay round of the GATT negotiations and several recent cases where trade sanctions have been imposed suggest that the issue of (trade–related) IPR violation and its prevention is especially critical in North–South trade. For instance, the European Community suspended Generalized System of Preferences benefits for Korean products in 1987 as a response to Korean violations of IPR. A year later the United States imposed a 100 percent (punitive) tariff against some Brazilian goods (see Braga, 1990). In 1995, the U.S. threatened China with a similar 100 percent (punitive) tariff on exports to the U.S. in response to IPR violations.

From the academic point of view, the importance of IPR protection in the North–South relationship has already made its way into economic encyclopaedias.[2] The theoretical literature in this area focuses mainly on the social welfare consequences of different levels of IPR protection, including, for example, conditions under which the South benefits in welfare terms from protecting IPR, the welfare consequences for the North if the South fails to protect IPR, optimal IPR protection from a world welfare point of view, and the level of conflict between North and South (Chin and Grossman, 1991, Diwan and Rodrik, 1991, Deardorff, 1992, Helpman, Vishwasrao 1994, Žigić, 1996a and 1998a). The empirical literature, on the other hand, has concentrated mostly on measurable considerations such as the impact of IPR protection on the type, structure and volume of Northern foreign direct investment in the South (Mansfield, 1994, Ferrantino, 1993), the role of IPR protection as a part of the international policy mix (Ferrantino, 1993), and the impact of IPR protection on economic growth (Gould and Gruben, 1996).

This chapter aims to show that the distinctive function of strategic trade policy in the specific case when IPR violation prevails is not a profit shifting role but rather being a supplement to IPR policy that may help in overcoming appropriability problems. More

[2] The third volume of *The Handbook of International Economics* contains, in the chapter "Technology and Trade," a separate section entitled "Intellectual Property Rights and North–South Trade. See E. Helpman, G. Grossman: "Technology and Trade," *The Handbook of International Economics*, Vol. 3, North–Holland, 1995.

specifically, we combine the strategic trade approach with the issue of IPR protection in order to explore the role of tariffs as instruments influencing IPR protection, innovative activity and trade patterns. In other words, by demonstrating that tariffs can promote innovation and attenuate or eliminate the illegal appropriation of R&D output, this chapter provides an alternative rationale for the policy recommendations put forward in the strategic trade literature.

IPR violations are assumed to be closely related to "R&D spillovers," defined as the leakage of important pieces of technical information which can be used by the recipient at zero or small marginal costs. The channels through which spillovers take place have been well documented (see, for instance, Levin, et al., 1987, Mansfield et al., 1981, Mansfield 1985, Damien and Neven, 1996). This information may come from common suppliers of inputs and customers, reverse engineering, hiring of employees from innovating firms, informal communications networks among engineers and scientists, industrial espionage and technological sourcing, publications and technical meetings, patent disclosure, conversations with the employees of innovating firms, etc. As Mansfield (1985) pointed out, this intelligence–gathering process varies considerably from industry to industry. Bayoumi, et al. (1996) stress the importance of international trade as a major transmission mechanism by means of which spillovers take place. They refer to "mutual interdependence across countries" manifested in the usage of common intermediate goods, consumer and capital goods, technology transfer and learning as a source of important technical information.

R&D spillovers in general (and in the context of international trade in particular) have two components or, in other words, are subject to two restrictions: technological and IPR restrictions. Thus, even when it is rather easy to gain relevant information about new products and processes (that is, when technological restriction is "not binding"), there is the question of whether these pieces of information could be legally exploited by recipients. This is where the issue of IPR comes into play. Namely, the government has the discretion to determine how easy it will be "to invent around a patent", just what the scope of a patent will be, how easy it will be to copy trademarks, whether the country complies with the Berne and Paris conventions, or not, etc.

The interaction of tariffs and IPR protection in the North–South trade relationship is modelled by relying on the concept of strategic interaction. The market of interest is the Northern market since the real world examples of trade sanctions such as those presented above indicate the existence of products which the South exports to the Northern market where violations of IPR by the South have taken place[3]. Moreover, numerous U.S. firms have cited huge losses in sales incurred in their domestic (that is, the U.S.) market due to the inadequate foreign protection of intellectual property.[4] The "Northern" market is assumed to be important for the Southern exporter either because it is big, or because the North has enough power to seriously constrain or even prevent the Southern firm selling the goods in question on the world market (or some "third market")[5] . Finally, we assume that the IPR in the Northern market is strict so that other domestic firms are not allowed to imitate the innovating firm which is therefore fully protected by its patent.

We consider a sequential (four–stage) game. In the first stage, the Southern government selects a level of IPR protection taking into account the impact on the subsequent choice of tariff (and the choice of all other strategic variables). In the second stage the Northern government selects the tariff, taking into account the ensuing R&D investment choice by its firm and subsequent competition in quantities. In the third stage, the Northern firm chooses its R&D

[3]Another North–South issue relevant to IPR emerges when Northern firms (usually multinational corporations) are, or consider becoming, located in the South (see, for instance, Mansfield, 1985,1994, Ferrantino, 1993, and Vishwasrao, 1994).

[4] See the International Trade Commission (1988) survey devoted to IPR protection where 64 U.S. corporations reported losses in sales totalling $ 1.80 billion in the domestic market due to foreign IPR violations.

[5] The example of this is the recent China – US case when the US threatened China with the sanctions due to the IPR infringement on CDs. The US had the power to effectively prevent China redirecting sales of the CD's to, for instance, the European Union or Latin America.

investment taking into account the spillovers and following competition in quantities. Finally, in the fourth stage, the firms select quantities, and consequently, profits and welfare are realised.

Analytically, the model is related to the "R&D with spillovers" types of models.[6] The underlying idea is that the "spillovers parameter," β, measures the strength of IPR protection. Thus, we assume that by setting a loose IPR regime the Southern government stimulates imitation and thus enhances spillovers and vice versa. Looser IPR would imply higher spillovers so that the intensity of spillovers is then interpreted as reflecting the strength of IPR protection. An alternative interpretation not exploited here is that the technological restrictions are always non–binding so that relevant information can be obtained relatively easily but the available information can be used legally by the Southern firm only up to the level of the strength of IPR protection.

The new insights the analysis provides can be summarized as follows:

a) The impact of tariffs on the innovative activity of the Northern firm hinges crucially on the prevailing market form. If, for instance, duopoly is the outcome of the game, then the tariff serves as a technological policy instrument to restore the incentive for investing in socially desirable research and development (R&D).

b) Depending on the prevailing market structure, tariffs reduce or completely eliminate illegally appropriated research output and thus thwart IPR violations by the South.

c) Despite the fact that the level of IPR protection is assumed to be under the full control of the Southern government, duopoly is a viable market form only if the efficiency of innovative activity is sufficiently "small." That is, beyond a given innovative efficiency threshold a welfare maximizing Northern government will prefer to impose a prohibitive tariff that forces the Southern firm to leave the market regardless of the level of IPR protection.

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[6]For the examples of "R&D with spillovers" models, see, for example, Spence, 1986, Katz, 1986, D'Aspremont–Jacquemin, 1988, Kamien et al.,1992, Suzumura, 1992, De Bondt et al., 1992.

d) Due to its impact on innovative activity, a positive tariff may be optimal even from the world welfare point of view.

A few testable predictions also arise from the model: first, given that the Southern government sets the IPR for all industries under the same conditions, we should observe higher tariff levels on products for which the production process (or the product) is subject to higher spillovers. Second, the innovating firm (firm where scale economies are important) faced with spillovers but without tariff (or any other effective IPR) protection will operate at a lower scale in comparison to firms where there is effective IPR protection.

The remainder of the chapter proceeds as follows. Section 2 states and discusses the assumptions of the game between the Northern and the Southern firms, develops the core duopoly model, and discusses the role of tariffs in it. Section 3 is devoted to the solution of the third and fourth stages of the game and to comparative statics concerning the impact of tariffs on the relevant economic variables in both the duopoly and constrained monopoly outcomes. This analysis is a prerequisite for the subsequent analysis of optimal tariffs and the optimal IPR protection level examined in Section 4 and Section 5 respectively. Section 6 is devoted to world welfare considerations while Section 7 contains concluding remarks.

2. THE MODEL

2.1. Assumptions

Two firms, each from one of the two types of "countries"— North and South—engage in international trade. A more concrete definition of "North," can be found in the cluster analysis of countries' international IPRs and other international policies performed by Ferrantino (1993). He came up with several stylized facts, the first one being that "...the intranational economic polices of developed countries are markedly different than those of developing countries. " An examination of his Table 1 shows that this is valid for IPR policy in particular. On the other hand, the "South" as a group of countries with rather weak IPR protection can be, for instance, represented by the "Asian New Industrial Countries," which have a rather low value describing the degree of IPR protection (see Table 1 in Ferrantino 1993). As Helpman (1993) pointed out, most technological imitation takes place in newly industrialized countries, while the majority of less developed countries engage in this activity only marginally. Thus, the former group is relevant in the model developed in this chapter and is referred to as the "South."

As was already indicated, the market of interest is the Northern market. By assumption, the Northern firm produces only for the domestic market while the Southern firm exports all of its production to the Northern country. Alternatively, and more generally, one could introduce the "segmented market" hypothesis in which the Southern firm produces for both markets but it perceives the two markets to be different (e.g. the Southern firm considers the Northern market to be different from its domestic market and, consequently, its optimization problem for the Southern market is independent of its optimization decision for the Northern market). In other words, arbitrage is not important (because it may be too costly) and it is not allowed for in the analysis (see, for instance, Brander and Spencer, 1982, 1983, and 1984 Brander and. Krugman 1983). In addition, we assume that the export to the Northern market is essential for the Southern firm.[7] This assumption is needed to prevent the uninteresting and trivial outcome in which IPR violation is complete and the Southern firm produces only for its domestic market or for some "third markets".

We further assume that initially both the Northern and the Southern firms have access to an "old" technology to produce a demanded good. However, the Northern firm is the only one assumed to conduct R&D. Again, this assumption is taken almost for granted in the related literature. The assumption is, however, not so restrictive if we recall that the world patent

[7] The reason for this may be a too small Southern market or balance of payment considerations. Furthermore, the Northern market may be the only relevant market for the good under consideration, or its presence on the Northern market may enhance spillovers, etc.

statistics show that developing countries hold only one per cent of existing patents (see Braga,1990 and Appendix 3 concerning the R&D expenditures statistics of the "North" and "South").

The Southern firm does not perform R&D but benefits through lax IPR protection reflected in costless spillovers from the R&D activity of the Northern firm. The focus is on what is known as "process innovations."[8] An "R&D production function" captures the effects of R&D on unit costs. The function displays "diminishing returns," that is, every additional dollar invested in decreasing unit costs results in less and less of a reduction in unit costs.[9]

Much like in Žigić (1998b), the core model in this chapter is a model of duopolistic competition between the Northern (or "domestic") and the Southern (or "foreign") firm.

The domestic firm has unit costs of production $C = \alpha - f(x)$ where x stands for the R&D expenditures and f(x) can be viewed as an "R&D production function" with classical properties, $f(x) \le \alpha$, $f(0) = 0$, $f'(x) > 0$ for $x > 0$ and $f''(x) < 0$. Parameter α can be thought of as pre–innovative unit costs describing the old technology initially accessible to both the Northern and the Southern firms.

The foreign firm benefits through spillovers from the R&D activity carried out by the domestic firm. If it exports its products, the foreign firm also pays a specific tariff *t* per unit of production. Its unit (pre–tariff) cost function is $c = \alpha - \beta f(x)$ and β denotes the level of spillovers (or, equivalently, level of the strength of IPR protection). The value of β can take values from zero to one.

The inverse demand function of the domestic market (assumed to be linear with units chosen such that the slope of the inverse demand function is equal to one) is $P = A - Q$ where

[8]As Spence(1986) shows, the difference between the concept of process innovation *vis–à–vis* product innovation is semantic rather than fundamental.

[9] This specification reflects empirical observations and was listed, for instance, as a "stylized fact" in Dasgupta (1986), p. 523.

$Q = q_s+q_n$ and $A > \alpha$. Parameter *A* captures the size of the market, whereas q_s and q_n denote the choice variables, that is, the corresponding quantities, of the domestic and the foreign firms.

Social welfare (W) is defined as the sum of consumer surplus (S) and the firm's profit (Π) and the revenue from tariffs (R). In the case of a linear demand, consumer surplus is defined as $S_n = (1/2)(q_s+q_n)^2$.

2.2. The Role of Tariff

The optimal policy mix when foreign and domestic firms compete on the home market is well known tariff–cum–subsidy scheme where a tariff is imposed on imports while domestic output is subsidized. The "division of labor" between these two instruments is such that the subsidy is aimed at eliminating the domestic oligopoly distortion[10] whereas the tariff is used to transfer some foreign income to the domestic treasury (see for instance, Dixit, 1988, Cheng, 1988, Levy and Nolan 1992). However, as noted by Dixit (1988), subsidies are likely to be an infeasible instrument. Moreover, Bhattacharjea (1995) demonstrated that implementing a subsidy might be troublesome for numerous reasons arising from the high information content required to implement the optimal subsidy to the distorting effects of taxes necessary to finance the subsidy. Similar considerations are valid for the subsidizing R&D investment. Thus, following these authors, we also confine our analysis to tariffs as only feasible instruments[11].

Tariffs change the nature of the "game" among foreign and domestic firms by altering the strategic interactions among them. What is crucial to this result is that the government has the credibility to commit to its policy choice (e.g. tariff) before the firms make their choices.

Another important feature of a tariff is that it is a device by means of which the

[10] Oligopoly distortion comes from the fact that the equilibrium price exceeds marginal costs. The optimal subsidy eliminates completely this distortion. See Neary (1994) and Leahy and Neary (1997) for the thorough analysis of the optimal subsidy in the oligopoly with spillovers setup and Hinloopen (1997) for the discussion of the R&D subsidy.

[11] Subsidy as an instrument might be used when domestic firm compete on the "third market" since tariff is not available in this case. As an implication of this argument, it might be reasonable to expect that the Southern government supports its firm by an export subsidy. However, allowing for this export subsidy will change the analysis in no qualitative way. The only consequence will be the higher optimal tariff since tariff will act then as a "countervailing duty" (see Dixit 1994).

government can influence the market structure. Confining our analysis, for instance, to the simplest case of two firms, there are three possible market patterns which could arise in equilibrium as a consequence of the erected tariff: duopoly, constrained monopoly, and unconstrained monopoly. Thus, duopoly will be the viable market form unless the tariff reaches a certain critical value (labelled "t_p") at and beyond which the constrained monopoly arises. The optimal strategy for the domestic firm is to commit to the level of R&D for which the rival firm's optimal production (as well as profit) is zero. By increasing the tariff beyond t_p, the difference in the marginal costs becomes so large that at (and beyond) the value of the tariff (denoted by t_m), the domestic firm gains an unconstrained monopoly position.[12]

3. THE GAME—THE LAST TWO STAGES

3.1. The Case of Duopoly

Duopoly is assumed to be a viable market form before the tariff is set. We now start to solve the game backwards. In the last (fourth) stage, the firms choose the equilibrium quantities. The domestic firm maximizes

$$\underset{q_n}{Max}[\Pi_n] = (A - Q)q_n - Cq_n - x \tag{1.a}$$

given q_s .

The first–order condition for a maximum is $\partial\Pi_n/\partial q_n = 0$ and yields $A - 2q_n - q_s - C = 0$.

The optimization problem for the foreign firm yields[13]:

[12] We assume away the possibility of negative tariff (subsidizing imports) since it is most likely infeasible.

[13] We neglect the profit which the Southern firm earns on its home market if we adopt segmented market hypotheses since it is irrelevant to the maximization problem under considerations.

$$\underset{q_s}{Max}[\Pi_s] = (A - Q)q_s - cq_s - tq_s \tag{1.b}$$

given q_n and t. The first–order condition is: $A - 2q_s - q_n - c - t = 0$. Solving the reaction functions yields the Cournot outputs as a function of R&D investment and tariff:

$$q_n(x(t),t) \;=\; \frac{(A + c[x(t)] - 2C[x(t)] + t)}{3} \tag{2.a}$$

$$q_s(x(t),t) \;=\; \frac{(A - 2c[x(t)] + C[x(t)] - 2t)}{3}. \tag{2.b}$$

Substituting (2.a) and (2.b) into (1.a) yields the domestic firm profit function expressed in terms of R&D investment and tariff:

$$\Pi_n(x(t),t) \;=\; \frac{(A + c[x(t)] - 2C[x(t)] + t)^2}{9} \; - x(t). \tag{3}$$

In the third stage of the game, the domestic firm selects x in order to maximize its profit. Note that the set of R&D actions is given by X where $x \in X = [0, x^{\otimes}]$ and $x^{\otimes}$ is the solution of the equation $\alpha - f(x) = 0$.[14] Substituting expressions for C and c into (3) and maximizing with respect to R&D investment gives the first order condition and (implicitly) x^*_c :

$$\frac{2(2 - \beta)(A - \alpha + t + (2 - \beta)f(x_c^*))f'(x_c^*)}{9} \;=\; 1. \tag{4}$$

The second–order condition requires :

[14] We assume that α is big enough that the optimal R&D is always in the interior of the set X.

$$\frac{2(2-\beta)[(2-\beta)f'(x_c^*)^2+(A-\alpha+t+(2-\beta)f(x_c^*))f''(x_c^*)]}{9} < 0. \qquad (5)$$

3.2. The Impact of Tariffs on R&D, Profit and Consumer Surplus in Duopoly

We first start with the R&D expenditures.

LEMMA 1. *An increase in tariff increases the R&D expenditures if duopoly is the equilibrium market form in the post–tariff situation*.

PROOF. Differentiating (4) with respect to t gives

$$\frac{dx_c^*}{dt} = \frac{f'(x_c^*)}{-[(2-\beta)f'(x_c^*)^2+(A-\alpha+t+(2-\beta)f(x_c^*))f''(x_c^*)]} > 0. \qquad (6)$$

Function f'(x*) is positive by definition for x > 0 while the denominator of (6) is also positive, as can be seen from comparing it with the second order condition (5).

The intuition for this result lies in a specific "feedback" mechanism: an increase in the tariff increases the unit costs of the competitor and leads to a higher output of the domestic firm in the new equilibrium. The higher the output, the more it pays to reduce unit costs and, therefore, the higher R&D investments will be. Higher R&D investments enhance the firm's cost advantage that results in higher equilibrium output and so on.

Since an increase in tariff has a positive both direct and indirect (via increased R&D expenditures) impact on the output of the Northern firm, the corollary of Lemma 1 is that tariff in duopoly may help to better exploit the scale economies of the firm[15]. Thus, the testable prediction that arises at this point is that, ceteris paribus, the firms faced by IPR violation but protected by tariff operate at higher scale than the firms of comparable sizes where there is IPR violation but no tariff protection.

[15] It can be shown that average costs of the Northern firm are monotonically declining as tariff increase from zero on.

LEMMA 2. *An increase in the tariff brings about higher profit if duopoly is the equilibrium market form in a post–tariff situation.*

PROOF. First note that $d\Pi^*(x^*_c,t)/dt = \partial\Pi^*(x^*_c,t)/\partial x \, dx^*_c/dt + \partial\Pi^*(t)/\partial t = \partial\Pi^*(t)/\partial t$ since the first part is zero according to the first order condition. Finally

$$\frac{d\Pi^*(t)}{dt} = \frac{\partial\Pi^*(t)}{\partial t} = \frac{2[A-\alpha+t+(2-\beta)f(x_c^*)]}{9} > 0 \qquad for\ t \in [0,t_p] \tag{7}$$

holds.

LEMMA 3. *The impact of a tariff on consumer surplus is ambiguous a priori.*

PROOF. $dS^*(x^*_c,t)/dt = \partial S^*(x^*_c,t)/\partial x \, dx^*_c/dt + \partial S^*(x^*_c,t)/\partial t$ *where*

$\partial S^*(x^*_c,t)/\partial x \, dx^*_c/dt > 0$ *and* $\partial S^*(x^*_c,t)/\partial t < 0$.

To see this, note that

$$S^*(x_c^*,t) = 1/2(q_s^*+q_n^*)^2 = \frac{[2(A-\alpha)-t+(1+\beta)f(x_c^*)]^2}{18}. \tag{8}$$

The sign of $\partial S^*(t)/\partial t$ is then

$$\frac{\partial S^*(t)}{\partial t} = \frac{2(\alpha-A)+t-(1+\beta)f(x_c^*)}{9} < 0 \quad for\ t \in [0,t_p] \qquad \wedge$$

$$\frac{\partial S^*(x_c^*,t)}{\partial x} = \frac{(1+\beta)[2(A-\alpha)-t+(1+\beta)f(x_c^*)]f'(x_c^*)}{9} > 0 \Rightarrow \frac{\partial S^*(x_c^*,t)}{\partial x}\frac{dx_c^*}{dt} > 0$$

for $t\in[0,t_p]$.

As is well known, the direct effect of a tariff on consumer surplus is always negative, since price is higher in the new equilibrium. The indirect effect of the tariff on consumer surplus is, however, always positive in duopoly, since increases in the tariff stimulate investment in R&D (see Lemma 1), which, in turn, increases output and consumer surplus. Thus, the sign of $dS^*(x^*_c,t)/dt$ is *a priori* ambiguous.

3.3. The Constrained Monopoly and Strategic Predation

Strategic predation (or limit pricing) behaviour is the optimal strategy for the domestic firm in the situation in which, for a given t, predatory profit is equal to or bigger than the profit in duopoly. Equivalently, this strategy becomes optimal if the imposed tariff reaches or exceeds a certain critical level (t_p). The timing of the game remains the same as before. We refer here only to the last two stages: in the second to last stage the domestic firm commits to an R&D level which forces the foreign firm to choose zero output in the last stage of the game. In the last stage, two firms are supposed to compete in quantities, but the best that the foreign rival can do under the given circumstances is to produce zero quantity and thus exit the market. The domestic firm, which remains in the market, then chooses the monopoly output. However, this output (and correspondingly, this price) is generally different than the output which would result were the domestic firm to select the unconstrained monopoly R&D expenditures[16].

The corresponding predatory level of R&D (labelled x^*_p) is implicitly obtained by substituting the expressions for C and c into (2b) and equating this expression to zero:

$$\frac{A+\alpha-2t-f(x_p^*)-2(\alpha-\beta f(x_p^*))}{3} = 0, \tag{9}$$

where t is now from the interval $t\in[t_p, t_m]$. Equating (2b) to zero when $x = x^*_c$ and solving for tariff yields "t_p":

[16]For an excellent and comprehensive review of the entry deterrence and predation, see Martin (1993).

$$t_p = \frac{A - \alpha - (1-2\beta)f(x_c^*)}{2}. \quad (10)$$

Tariff t_p just suffices to eliminate the competitor from the market and we refer to it as a "predatory tariff"[17].

Differentiation of (9) with respect to t provides us with two important additional lemmas:

LEMMA 4. *An increase in tariff decreases R&D expenditures if spillovers are small (β < 1/2) provided that strategic predation is the optimal strategy for given t.*

PROOF.

$$\frac{dx_p^*}{dt} = \frac{-2}{(1-2\beta)f'(x_p^*)} < 0 \quad if \quad \beta < 1/2.$$

The question is, however, what caused such a reverse reaction of the domestic firm here in comparison with its behaviour in the duopoly case. (Recall that in duopoly the optimal R&D increases as a response to an increase in the tariff.)

The answer is not difficult once we understand the logic of "predatory" behaviour. When the domestic firm preys, and there are small spillovers, it spends more resources on innovative activity than it would if it followed myopic (unconstrained monopoly) profit maximization (see Appendix 1 for formal proof). In other words, the firm commits to higher R&D to induce the exit (or prevent the entry) of the rival. An increase in tariff has the same effect. In fact, the government, by increasing the tariff (assumed to be initially in the predation interval $t \in [t_p, t_m]$), preys somewhat for its firm, and it pays for the firm to decrease its R&D expenditure towards the (monopoly) profit maximizing level of R&D investment after the tariff has been increased.

[17] Note that $t_m = [A - \alpha - (1 - 2\beta) f(x^*_m)]/2$ where x^*_m stands for the R&D investment which an unconstrained monopoly would select. Further, note that $t_m \geq t_p$ (see Appendix 2).

These considerations, however, bear an important policy implication: a tariff set too high will decrease R&D spending, decrease output and, as a result, may have a counterproductive implication for social welfare. This particular situation is consistent with the stylized fact reported in Braga and Willmore (1991), where technological innovativeness is negatively related with the degree of trade protection. Here this is the case when $\beta < 1/2$ and when high trade protection expressed in tariff $t \in [t_p, t_m]$ induces domestic firm to undertake the strategic predation strategy.

The policy conclusions are exactly reversed in the situation characterized by high spillovers ($\beta > ½$).

LEMMA 5. *An increase in tariff increases R&D expenditures if spillovers are large ($\beta > 1/2$) and predation is an optimal strategy for given t.*

PROOF. Analogous to Lemma 2.

Note that here, the actual level of R&D is lower than the corresponding monopoly R&D (see Appendix 1) due to the high disincentives caused by spillovers. An increase in tariff lessens potential competition from the foreign firm and reduces disincentives to invest in R&D. Thus, the optimal response of the profit–seeking firm is to increase the R&D level and move towards the monopoly (or myopic) profit maximizing point. The policy concern now is not to put the tariff too low.

Furthermore, observe that, at the level of spillovers of one–half ($\beta = 1/2$), the optimal level of R&D coincides with the "decision theoretical" solution (see Appendix 1). That is, the selected level of R&D to induce the exit of the foreign firm is the same as if the domestic firm were an unconstrained monopoly, ($t_p = t_m$ at $\beta = 1/2$).

What remains to be discussed is the impact of the tariff on predatory profit and consumer surplus which arises in these circumstances. The domestic firm selects predatory R&D investment, $x^*_p(t)$, in such a way as to exclude the foreign firm. Given x^*_p and t, the last stage payoff is given by

$$Max[\Pi^p] = (A - q_p)q_p - Cq_p - x_p^* \ . \qquad (11)$$

The first–order condition for a maximum yields

$$\frac{d\Pi^p}{dq_p} = 0 \Rightarrow A - 2q_p - C(x_p^*(t)) = 0 \Rightarrow q = \frac{A - C(x_p^*(t))}{2} \ . \qquad (12)$$

Substituting (12) into (11), gives the predatory profit function $\Pi^p(x^*_p)$ as a function of predatory R&D expenditures and tariff:

$$\Pi^p(x_p^*) = \frac{[A - \alpha + f(x_p^*(t))]^2}{4} - x_p^*(t). \qquad (13)$$

LEMMA 6. *An increase in tariff induces higher profit if constrained monopoly is the equilibrium market form in a post–tariff situation*.

PROOF. Differentiating (13) with respect to t reveals only the existence of the indirect effect, $\partial\Pi^p/\partial x \; dx^*_p/dt$ since the tariff now influences profit only via its impact on R&D expenditures. Note that $\partial\Pi^p/\partial x < 0$ if $\beta < 1/2$ due to overinvestment in R&D implying $x^*_p > x^*_m$. If, however, $\beta > 1/2$, then $\partial\Pi^p/\partial x > 0$ since large spillovers produces large disincentive to invest in R&D and, as a consequence $x^*_p < x^*_m$ holds (see Appendix 1). Combining these results with the Lemmas 4 and 5 yields unambiguously $d\Pi^p/dt = \partial\Pi^p/\partial x \; dx_p/dt > 0$.

Thus, a tariff, irrespective of the level of spillovers, improves the profit of the domestic firm, since it dampens the strength of the potential competition from the foreign firm and brings the domestic firm closer to the unconstrained monopoly position.

As far as consumer surplus in the "predation region" is concerned, here also only an indirect effect of tariff exists and its sign is entirely determined by the level of spillovers .

LEMMA 7. *An increase in tariff generates an increase in consumer surplus if spillovers are large ($\beta > 1/2$) whereas the opposite holds for small spillovers ($\beta < 1/2$).*

PROOF. Note that now consumer surplus, $S^{*p} = (A - \alpha + f(x_p^*))^2 / 8$ whereas its derivative is

$$\frac{dS^{*p}}{dt} = \frac{\partial S^{*p}}{\partial x}\frac{dx_p^*}{dt} = \frac{(A-\alpha+f(x_p^*))f'(x_p^*)}{4}\frac{dx_p^*}{dt}.$$

Since $\partial S^p/\partial x > 0$ always and $dx^*_p/dt > 0$ for $\beta > 1/2$, this implies that $dS^{*p}/dt > 0$ for $\beta > 1/2$. Thus, $dS^p/dt = \partial S^p/\partial x \; dx_p/dt > 0$ if $ß > 1/2$. By the same token, note that $dS^{*p}/dt < 0$ for $\beta < 1/2$.

An increase in R&D expenditures has always a beneficial effect on consumer surplus. When coupled with large spillovers the overall effect of tariff is unambiguously positive since an increase in tariffs boosts R&D expenditures. When spillovers are small, however, the optimal reply to an increase in tariffs requires cutting R&D expenditures, thus lowering the consumer surplus.

3. 4. Impact of Tariff on the Appropriated Research Output by the South

The total research output appropriated by the South through IPR violations is defined as $F[x_c^*(t),t] \equiv \beta \; f(x_c^*) \, q_s^* =$

$$F[x_c^*(t),t] \equiv \frac{\beta f(x_c^*)(A-\alpha-2t-(1-2\beta)f(x_c^*))}{3}$$

whereas the impact of tariff's change is given as $dF(t)/dt = \partial F(t)/\partial x \; dx_c^*/dt + \partial F(t)/\partial t =$

$$\frac{dF(t)}{dt} = \frac{-2\beta f(x_c^*)}{3} + \frac{\beta(A-\alpha-2t-2(1-2\beta)f(x_c^*))f'(x_c^*))}{3}\frac{dx_c^*}{dt}. \qquad (14)$$

To illustrate intuition that dF(t)/dt < 0, we use here a specific R&D production function $f(x^*) = (g\, x^*)^{1/2}$ evaluated at the optimal R&D investment, x*, (see expression (19) for the value of x*). Substituting $(g\, x^*)^{1/2}$ and its derivative for $f(x_c^*)$ and $f'(x_c^*)$ in (14) respectively, and evaluating the expression at zero tariff[18], we obtain

$$\frac{dF(0)}{dt} = \frac{(A-\alpha)(-2+\beta)\beta g(3-2\beta g+\beta g)}{(9-(2-\beta)^2 g)^2}.$$

Taking into account the values of g and β consistent with duopoly (see subsection 4.2 and Fig 1), Sign[dF/dt(t)] = Sign[-2+β] = -1. Thus, an increase in tariffs reduces illegally appropriated research output and thwarts IPR violations. As we will see later, such an increase in tariffs can be caused by an increase in IPR violation. Obviously, if tariffs are at or above t_p value, then F(t) = 0 and the IPR violation is completely eliminated.

4. THE SECOND STAGE—THE OPTIMAL TARIFF IN DUOPOLY

4.1. The welfare improving R&D expenditures and tariff

Before we move to the determination of the optimal tariff, it is important to note that the role of the tariff in duopoly is not only to be a strategic tool to capture the foreign firm's producer surplus, but also to help increase R&D expenditures towards the socially optimal level[19] (see Lemma 1).

LEMMA 8. *An increase in the R&D expenditures enhances the social welfare*.

PROOF. We define social welfare as $W^*[x_c^*(t),t] = \Pi^*(x_c^*) + S^*(x_c^*) + R^*(x_c^*)$ where $R^*(x^*) = t\, q^*_s$ is revenue from tariffs. First, note that $d\Pi^*(x_c^*)/dx = 0$ by the first order condition of

[18] Note from (14) that dF/dt monotonically declines in t, thus dF/dt(0) < 0 is sufficient condition for dF/dt(t) <0.

[19] Note that tariff has this role also when the Northern firm is constrained monopoly (strategic predation) and spillovers are large(see Lemma 5).

profit maximizing. This requires that the joint impact of R&D on consumer surplus and tariff revenue at point x_c* has to be positive, that is, $dS^*(x_c^*)/dx + dR^*(x_c^*)/dx > 0$ to have $dW^*(x_c^*)/dx > 0$. It is, however, straightforward to see that the impact of R&D investment on consumer surplus in duopoly is always positive (not only in point x_c*), that is, differentiating S(x) with respect to x gives always $dS(x)/dx > 0$. The tariff revenue as a function of x is, after appropriate substitution given by (15)

$$R(x) = \frac{t\,(A+\alpha-2t-f(x)-2(\alpha-\beta f(x)))}{3} \tag{15}$$

and $dR(x)/dx = -[(1 - 2\beta)\, t\, f'(x)]/3$. Interestingly enough, $dR(x)/dx > 0$ for $\beta > 1/2$ but $dR(x)/dx < 0$ for $\beta < 1/2$. Thus, the only thing we have to prove is that "net sum" is positive when spillovers are small (that is, $dS(x)/dx + dR(x)/dx > 0$ for $\beta < 1/2$). The "net sum" is given by

$$\frac{dR(x)}{dx} + \frac{dS(x)}{dx} = \frac{5\beta t-4t+(1+\beta)[2(A-\alpha)+(1+\beta)f(x)]f'(x)}{9}. \tag{16}$$

Since (16) is monotonically decreasing in t, we substitute the highest permissible value of tariff, t_p ,to get,

$$\frac{[3\beta(A-\alpha)+(2-3\beta+4\beta^2)f(x)]f'(x)}{6} > 0$$

for all $\beta < 1/2$ (and, therefore, for all $\beta \in [0,1]$).

4.2. The optimal tariff

So far, tariffs have been considered as though they were arbitrarily set. However, a benevolent domestic government should desire to set tariffs at the optimal welfare maximizing level. Determining the optimal tariff requires selection of the optimal (welfare maximizing) market structure. Remember that we assumed duopoly to be a viable market form in the pre–tariff situation. Thus, the government has three options: a) to maintain duopoly by charging a "low" tariff, b) to constrain its firm through potential competition from abroad by imposing a tariff which forces the foreign firm to exit the domestic market, but does not enable the domestic firm to charge the full monopoly price and c) to set the tariff so high that it allows the domestic firm to obtain an unfettered monopoly position. However, in order to ensure the existence of the first stage of the game (in which the Southern government picks the IPR level), we must establish the conditions under which duopoly is the welfare maximizing market structure and the "duopoly" tariff dominates the other options.

Recalling that the social welfare function is represented as the sum of consumer surplus, domestic firm profit and tariff revenue, marginal social welfare is given by

$$\frac{dW^*(t)}{dt} = \frac{\partial S^*(t)}{\partial x}\frac{dx_c^*}{dt} + \frac{\partial S^*(t)}{\partial t} + \frac{\partial \Pi^*(t)}{\partial t} + t\left(\frac{\partial q_s^*}{\partial x}\frac{dx_c^*}{dt} + \frac{\partial q_s^*}{\partial t}\right) + q_s^*. \qquad (17)$$

The first thing to note is that the optimal tariff is positive[20] which, in turn, requires $dW^*(0)/dt > 0$. To see this it is only necessary to compare marginal profit with the direct effect of tariff on consumer surplus. Summing these two effects gives $\partial\Pi^*/\partial t + \partial S^*/\partial t = (f(x^*)(1-\beta)+t)/3 > 0$. Since the indirect consumer surplus effect, $\partial S^*/\partial x \; dx^*_c/dt$, and q_s are always non–negative, marginal social welfare is unambiguously positive at $t = 0$ implying that the positive tariff is welfare improving.

This result is related to the standard conclusion in strategic trade theory which claims that, given duopoly Cournot competition between the foreign and the domestic firm, imposing a "low" tariff is beneficial in terms of social welfare under fairly general conditions (see Helpman and Krugman, 1989). A sufficient (but not necessary) condition for this result to hold

[20] A sufficient condition to have optimal positive tariff is a not "too convex" demand function. A linear demand function surely satisfies this requirement. For a full discussion of the sign of an optimal tariff, see Brander and Spencer (1984).

is that there be a "positive terms of trade effect," which, in this context, means that the new equilibrium price rises by less than the increase in tariff. This is surely the case with a linear demand function.

The specific context of the problem, however, suggests that positive social welfare effects may not be limited to situations where tariffs are low, but may also be present at a level of tariff high enough that duopoly is not a viable market form. In other words, the optimal tariff may be so high that it induces the foreign firm leaving the market. Such "non–standard" result is the consequence of the distinctive feature of our model that the domestic firm is a type of "natural monopoly" due to scale economies caused by tariff. Namely, tariff in duopoly boosts domestic output both directly by shifting the reaction curve of the competitor inwards and indirectly through increase in R&D investment. An increase in R&D, in turn, reduces marginal costs, C, and all these effects reduce the average costs, $C[x(t)] + x(t)/(q_n[x(t),t])$, of the Northern firm despite the increase in x (see Footnote 16). Thus, it makes sense to increase the tariff more than it would otherwise be increased. The only opposing force which may preserve duopoly as the optimal market form is tariff revenue. This occurs only if the benefits from tariff revenue are higher than the losses from lower R&D, higher appropriation of the R&D output and, finally, losses of having more than one firm (with natural monopoly characteristics) in the market. Clearly, such a situation arises only if the R&D efficiency is in some sense "low".[21] Nevertheless, even in this situation the optimal tariff is, as illustrated in the next subsection, still higher than in the standard duopoly model in which there is no innovative activity and IPR violation.

Technically, the Northern government's optimization problem is defined as $\max W^*(x(t),t)$ s.t. $q_s^*(x(t),t) \geq 0$. However, only an interior maximum is consistent with duopoly. Thus, we assume that there is an interior solution so that the optimal tariff can be obtained by

[21] The R&D efficiency is implicitly captured by the function f(x) and its underlying parameters (and its first and second derivatives).

solving the equation dW*/dt = 0 for t. Denote this solution as t* where[22]

$$t^* = \frac{3\beta f(x^*) + (1+\beta)^2 f(x^*) x^{*\prime} f'(x^*) + (A-\alpha)(3+2(1+\beta)x^{*\prime} f'(x^*))}{9 + (4-5\beta)x^{*\prime} f'(x^*)} \tag{18}$$

and x*' stands for dx_c^*/dt. As already discussed, this assumption requires that the implicit R&D efficiency is "low," implying that the marginal welfare loss net of tariff revenue is equal to the marginal benefit of the additional tariff revenue at some $t^* \leq t_p$. It further implies that the constraint on the R&D production function has to be such that $f(x^*_c)$ is lower than a certain threshold value, B(.), obtained by solving the equation $q_s^*[x^*(t^*)] = 0$. Thus, $f(x^*_c) \leq B[x_c^*(\beta),\beta]$ has to hold where B(.) is given as

$$B[x_c^*(\beta),\beta] \equiv \frac{(A-\alpha)(1-3\beta x_c^{*\prime} f'(x_c^*))}{3-4\beta+(2-3\beta^2+4\beta)x_c^{*\prime} f'(x_c^*)}.$$

Note that t_p is the upper bound of the optimal tariff in duopoly. Similarly, we are able to characterize the lower bound of t*. It is easy to show that the tariff revenue is maximized at the tariff level of $t_p/2$. Since for social welfare function without tariff revenue the optimal tariff has to be at least t_p, it is clear that the interior solution will be in the interval $t^* \in (t_p/2, t_p]$. However, this is only a necessary but not a sufficient condition for t* to be a global (rather than local) maximum. Namely, even if $t^* \in (t_p/2, t_p]$, it may easily happen that welfare from the unconstrained monopoly exceeds the welfare from duopoly if spillovers are large. Thus for t* to be a global optimum, there is an additional condition that $W^*(t) \geq W^*_m$ where W^*_m stands for the welfare generated in an unfettered monopoly ("monopoly welfare" henceforth). The discussion above is summarized in the first Proposition.

[22] Note that (18) gives only an implicit tariff since $x_c^* = x^*(t)$ is an implicit function of the tariff.

PROPOSITION 1.

Duopoly is the optimal, welfare maximizing market form in the post–tariff situation if the R&D efficiency is "low", that is if $f(x) \leq B[x_c^*(\beta),\beta]$ *and* $W^*(t) \geq W^*_m$. *In addition the optimal tariff* $t_{opt} = t^*$ *and* $t^* \in (t_p/2, t_p]$.

The proposition 1 as stated above is rather abstract. What does, for example, "low" R&D efficiency mean? In order to illustrate more concretely the situation where duopoly turns to be the optimal market structure, we again use the explicit R&D production function introduced in subsection 3.4, (that is, $f(x) = (g\,x)^{1/2}$) where the parameter g explicitly captures R&D efficiency (see, for instance, Chin and Grossman 1991 or Žigić 1998a, for use of this functional form). In addition, we restrict g to be such that $g \in (0,4)$[23]. Thus, substituting $(g\,x)^{1/2}$ into equation (4) enables us to get an explicit expression for x_c^* which we label by x^*, where x^* is

$$x^* = \frac{(A-\alpha+t)^2(2-\beta)^2 g}{(9-(2-\beta)^2 g)^2} \,. \tag{19}$$

Substituting further $(g\,x^*)^{1/2}$ into the welfare function, and taking the derivative with respect to t gives us an analogue to (17). The solution of this equation yields an explicit expression for the interior optimum tariff denoted as t^{**} such that

$$t^{**} = \frac{(A-\alpha)(27+(-2+\beta)g(10-2g-\beta(11-5g+4\beta g+\beta^2 g)))}{81+(-2+\beta)g(32-6g-\beta(10-7g+2\beta g))}. \tag{20}$$

Substituting $(g\,x^*)^{1/2}$ and t^{**} into (2.b) gives $q_s^{**}(.)$ in terms of g and β. Solving the equation $q_s^{**}(.) = 0$ for the threshold level of R&D efficiency (denoted g_{cr}) gives the expression (21) which is an analogue to the B function (see Fig 1).

[23] This follows Chin and Grossman (1990). For g = 4 monopoly profit is not defined.

$$g_{cr}(\beta) = \frac{9}{[(2-\beta)(2(2-\beta)+(7-7\beta+4\beta^2))^{1/2}]} \tag{21}$$

Finally, comparison of W*(t*) with W^*_m gives the other critical value g_{cc} (Appendix with the derivation of g_{cc} can be found in Žigić 1996b or obtained upon request from the author). The line g_{cc} is relevant only if $\beta > 1/2$ since it is easy to demonstrate that monopoly welfare is never higher then welfare in duopoly if $\beta < 1/2$.

The set of parameters consistent with post–tariff duopoly as the welfare maximizing market structure is represented by the shaded area in Fig 1. Thus, for $g = g_1$, the highest value of β consistent with duopoly is β_1.

Interpreting the Proposition 1 in the light of the above gives Proposition 1a:

PROPOSITION 1A

Duopoly is the optimal, welfare maximizing market form in the post –tariff situation if $\beta < 1/2$ and $g < g_{cr}(\beta)$. If, on the other hand, $\beta > 1/2$ then in addition to $g < g_{cr}(\beta)$, $g < g_{cc}(\beta)$ must also hold.

Although the shaded area in Fig 1 is our main concern, it is important to note that the unconstrained monopoly yields higher welfare than duopoly and constrained monopoly[24] as long as $\beta > 1/2$ and g is not "too low" (i.e, $g > g_{cc}$). The reason for this is that the R&D expenditures in duopoly and constrained monopoly are suppressed when $\beta > 1/2$ so that the unconstrained

[24] Note that the constrained monopoly cannot be the optimal market form here because when $\beta > 1/2$ a further increase in tariff beyond t_p up to t_m would increase both the Northern firm's profit and Northern consumer surplus.

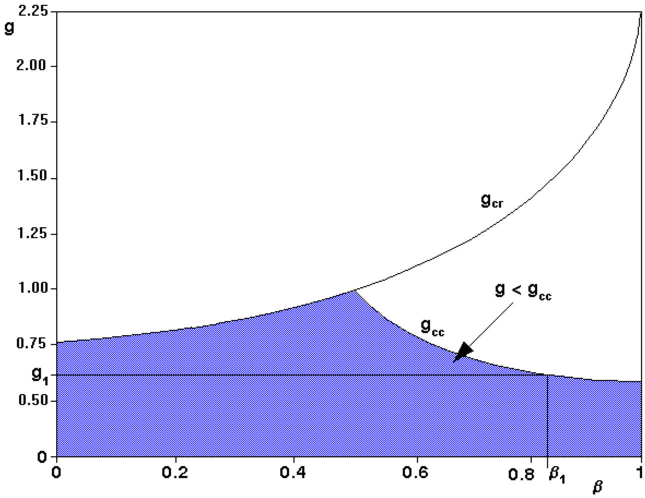

Fig.1. The region of parameters ($g < g_{cr}$ and $g < g_{cc}$) consistent with the duopolistic competition.

monopolist (for whom spillovers do not matter), invests more in R&D than the duopolist or constrained monopolist[25] and since R&D efficiency is not too low, the welfare costs of the lost R&D output (net of tariff revenues) in duopoly exceeds the monopoly distortion. Moreover, the unconstrained monopoly is, in fact, a natural monopoly (despite the fact that the tariff has no influence on R&D expenditures here) since the average costs are always falling in the point of the optimal R&D, x^*_m (the proof is straightforward and can be obtained upon request from the author). However, the policy implication here is not that unfettered monopoly is unconditionally the best solution. Obviously, the government may try to use other instruments (e.g. price caps) to regulate the monopoly, provided that this intervention does not adversely affect R&D.

[25] See Appendix 1 for the proof that $x^*_m > x^*_p$ and therefore $x^*_m > x^*_c$ when $\beta > 1/2$.

4.3. The three roles of the optimal tariff

Before discussing the first stage of the game, we will briefly examine the different roles of tariffs in our setup. As already mentioned, in our specific context tariffs may act not only as a device for profit shifting, but also as an instrument that boosts socially beneficial R&D investments (see Lemma 8), generates economies of scale and finally serves as a buffer that dampens the extent of IPR violation.

In a standard duopoly case when there are neither innovative activities of the domestic firm nor IPR violations by the foreign firm, the optimal tariff[26] is t* = (A - c)/3. This can be easily seen by evaluating t* at $\beta = 0$ and f(x) =0 (or t** at $\beta = 0$ and g = 0) and by recalling that in this case c = α. To account for the second, technological function of tariff, let us for the moment assume that the Northern firm invest in the innovative activity but there is no IPR violation by the Southern firm. The optimal tariff in this case is the special case of t* with $\beta = 0$. In order to get graphical representation of the problem, we use here t** when $\beta = 0$. Thus,

$$t^{**}(0,g) = \frac{(A-\alpha)(27-20g^2+4g)}{81-64g+12g^2}.$$

It is easily seen that the optimal tariff increases with the increase in R&D efficiency. The higher is R&D efficiency, the more it pays to stimulate investment in R&D and the higher is the optimal tariff (see Fig 2).

[26]As Bhattacharjea (1995) nicely demonstrated, the optimal tariff t* =(A-c)/3 is rather robust concept independent from the things like the degree of product differentiation, or the slope of the demand curves. More importantly, this optimal tariff has far less demanding information content than subsidy, since it, among other things, does not depend on the domestic unit costs, and the strategic manipulation by the domestic firm (e.g. costly signalling) is avoided.

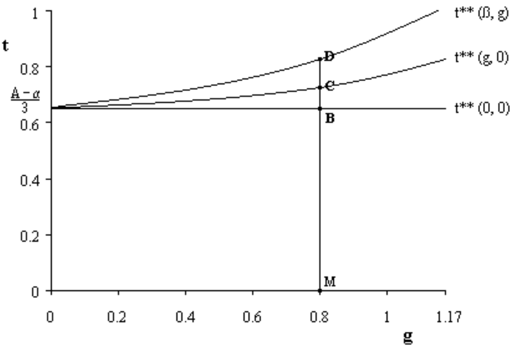

Fig. 2 The decomposition of the optimal tariff on its three roles; A = 10, α = 8

Finally allowing for a violation of IPR (β > 0), the optimal tariff increases even more. As seen from Fig 2, for a given R&D efficiency, g, the total optimal tariff (MD), can be decomposed into three parts. MB is the part of the optimal tariff due to its profit shifting role, BC is due to its technological function, and CD stems from its role in counteracting IPR violation.

PROPOSITION 2

If duopoly is the equilibrium market form then the optimal tariff can be broken up into the three parts: profit shifting, technological, and IPR violation offsetting. Due to latter two roles, optimal tariff is higher than in the standard duopoly case.

5. FIRST STAGE—OPTIMAL IPR PROTECTION

5.1. The Cournot–Nash equilibrium

In the first stage of the game, the Southern government has to decide the level of IPR protection by, for example, adopting patent protection legislature of a particular degree of stringency.[27] For the sake of simplicity, we assumed that the complex phenomenon of the level of IPR protection (or violation) can be condensed into a single parameter, β, scaled from zero to 1.[28]

The underlying assumption is that the Southern government can commit to its choice of IPR strength and that the degree of IPR violation is selected strategically, taking into account its impact on the subsequent choice of the optimal tariff by the Northern government. Nonetheless, let us for the time being assume that the Southern government ignores the impact of its choice variable on the subsequent tariff. In the technical sense, this is equivalent to the situation in which two governments choose their strategic variables simultaneously. The rationale for modelling behaviour in this way might be that the two governments interfere more than once, in which case a pure Nash equilibrium may be the appropriate technical description of the situation. In this case, the welfare function for the South reduces to its firm's profit function, thus:

$$W_s^* = \Pi_s^*[x(\beta),\beta] = \frac{[A-\alpha-2t^*-(1-2\beta)f(x)]^2}{9}. \qquad (22)$$

Given t*, the optimal level of IPR, protection, β*, is determined by maximizing Π_s* with respect to β, subject to β ≤ 1 and W*(t*) > W^*_m. The necessary condition requires $d\Pi_s^*/d\beta \geq 0$ where $d\Pi_s^*/d\beta$ is given by the expression below:

[27] In practice, the Southern governments could manipulate the level of IPR violation not only by adopting, say the appropriate patent law but also through the lax enforcement of the law. In addition, as the evidence in some developing countries shows (see Braga, 1990), governments enable the direct procurement of the important foreign technological pieces of information to its nationals. The government usually acquires these important pieces of information through patent disclosure. Furthermore, the government could by its policy influence the absorption capacity for adopting innovations and, thus, in ultima linea, the level of spillovers.

[28] Some authors (e.g. Rapp and Rozek, 1990), have compared the patent laws of the South and the others and attached a scalar ranging from zero to five, depending how far the particular country's IPR legislature is from conforming with the American one.

$$\frac{d\Pi_s^*}{d\beta} = \frac{\partial\Pi_s^*}{\partial x}\frac{dx_c^*}{d\beta} + \frac{\partial\Pi_s^*}{\partial\beta} = \frac{2(A-\alpha-2t-(1-2\beta)f(x_c^*)(2f(x)-(1-2\beta)(x_c^*)^{\prime}f^{\prime}(x_c^*)))}{9}.$$

Thus, in choosing the optimal level of IPR protection, the Southern government takes into account its impact on the Northern firm's R&D expenditures but, by assumption, not its impact on optimal tariff imposed by the Northern government. It is easy to see that in the case of large spillovers, the Southern firm's profit also increases with R&D investments, thus $\partial\Pi^*_s/dx > 0$ for $\beta > 1/2$ (and vice versa). Also, it is straightforward to prove that $dx^*/d\beta < 0$. Thus, the "strategic effect" above is negative if $\beta > 1/2$. Yet the total effect is always positive since the direct effect, $\partial\Pi_s^*/\partial\beta > 0$, always dominates.

LEMMA 9. *Relaxing IPR protection is always beneficial for the Southern welfare if duopoly is viable market form in the post–tariff situation.*

PROOF. Substituting the value of t_p into the expression above (recall that t_p is the maximal possible "duopoly" optimal tariff leading to $q_s^*= 0$), gives us $d\Pi_s^*/d\beta(t_p) = 0$. Since the function $d\Pi_s^*/d\beta(t)$ is monotonically declining in t, $t^*\in[0,t_p]$, it implies that $d\Pi_s^*/d\beta > 0$ for all values of t^* such that $t^*\in[0,t_p)$.[29]

Applying this conclusion to the specific case when $f(x^*) = (g\ x^*)^{1/2}$, the Southern government has a dominant strategy. It should select the highest level of β that is consistent with duopolistic competition, independent of the erected tariff by the North. That is, by choosing β, it should not induce the Northern government to set $t_p(\beta)$ or $t_m(\beta)$ as its best response, because this will lead to $W_s^*(\beta,t) \equiv \Pi_s^*(\beta,t) = 0$, which is surely not desirable for the South.

If, say, the actual R&D efficiency is $g = g_1$, then (see Fig 1) the optimal level of IPR violation from the point of view of the Southern government is $\beta = \beta_1$ (to be rigorous, it should

[29] Alternatively, note that $\Pi^*_s(\beta) = q^{*2}_s$. Thus, $d\Pi^*_s/d\beta = 2\ q^*_s\ dq^*_s/d\beta \geq 0$ since it is straightforward to show that $dq^*_s/d\beta > 0$.

be slightly less than β_1 since $W^*(t^*) > W^*_m$ has to hold).[30]

5.2. The Stackelberg–Nash game between the governments

Our full–fledged, four–stage game requires, however, that the Southern government takes into account the impact of the selected IPR violation on the optimal tariff chosen by the Northern government. In other words, the Southern government acts as a Stackelberg leader in the policy game and its optimization problem looks now as:

$$\underset{\beta}{Max}[W_s^*] = \Pi_s^*(x[t(\beta),\beta],t(\beta),\beta)$$
$$s.t.$$
$$t = t^*(\beta),\ \beta \leq 1\ \wedge\ W^*(t^*) > W_m^*.$$

Substituting $t^*(\beta)$ for t into the above objective function and taking the derivative with respect to β, gives now

$$\frac{d\Pi_s^*}{d\beta} = \frac{\partial\Pi_s^*}{\partial x}\frac{\partial x}{\partial t}\frac{dt^*}{d\beta} + \frac{\partial\Pi_s^*}{\partial x}\frac{dx_c^*}{d\beta} + \frac{\partial\Pi_s^*}{\partial t}\frac{dt^*}{d\beta} + \frac{\partial\Pi_s^*}{\partial\beta}.$$

The difference from the analysis in the subsection 5.1. is the additional term,

$$\left(\frac{\partial\Pi_s^*}{\partial x}\frac{\partial x}{\partial t} + \frac{\partial\Pi_s^*}{\partial t}\right)\frac{dt^*}{d\beta}, \tag{23}$$

that is apparently negative since Southern government takes now into account the fact that increase in IPR violation leads to the higher tariff, that is $dt^*/d\beta > 0$ (see subsection 4.3). This, in turn, suggests that we might expect to see a lower level of IPR violation than in the case of the simultaneous choice of tariff and IPR. To gain a more intuitive understanding of the problem,

[30] The highest permissible value of g, consistent with the duopoly competition, is g = 1.17, with the corresponding optimal value $\beta^{**} = 1/2$ (see Fig 1). On the other hand, for a value of g smaller than 0.385 the optimal value will be $\beta^{**} = 1$. For all other values of the parameter g between these two values, the optimal β will be in the interval $\beta^{**}\in(1/2,1)$.

we again look at our example using the specific R&D production function $f(x) = (g\ x)^{1/2}$.

The problem can now be written as:

$$\underset{\beta}{\mathrm{Max}}[\Pi_s^*(\beta)],$$

$$\text{s.t. } \beta \leq 1,\ g < g_{cc}(\beta) \text{ and } t = t^{**}(\beta)$$

where $\Pi_s^*(\beta)$ is obtained by the appropriate substitution of $(g\ x^*)^{1/2}$ for $f(x^*)$:

$$\pi_s^*(\beta,t) = \frac{(A-\alpha)^2(3+(1-\beta)(-2+\beta)g)-(6-(2-\beta)gt)^2}{(9-(2-\beta)g)^2}\ . \qquad (24)$$

Substituting $t^{**}(\beta)$ for t in (24), we get $\Pi_s^{**}(\beta)$. Taking the derivative with respect to β gives the value of $d\Pi_s^{**}(\beta)/d\beta$. It is straightforward, but a bit messy, to show that $d\Pi_s^*(\beta)/d\beta > 0$ [31] for all permissible values of g and β. Thus, the optimal level of IPR, denoted as β^{**}, turns out to be the same as in the case when the Northern and the Southern governments simultaneously choose the level of IPR protection and optimal tariff. That is, although in the Stackelberg case the Southern government takes into account the negative impact of increased β on subsequent tariff, within the particular model this additional effect (see expression 23) is not too strong to lead us to the interior solution (see footnote 31).

Finally, before we state Proposition 3, it is important to note that β^* (or β^{**}) reflects only the IPR restriction and ignores the technological restriction that some industries are more susceptible to spillovers than others. Thus β^* represents in some sense the upper bound of the permissible spillover level ($\beta \leq \beta^*$). What matters for the Northern government in imposing a tariff is the actual level of spillovers in particular Southern exporting industries (see expressions 18, and 20) rather than the overall strength of IPR protection that is set for all industries and

[31] Much like in footnote 29, we can again write $\Pi^*_s(\beta,t^*(\beta)) = q^{*2}_s$ but now, $d\Pi^*_s/d\beta = 2\, q^*_s\,(dq^*_s/dt\ \ dt^*_s/d\beta + dq^*_s/d\beta)$ and Sign $[d\Pi^*_s/d\beta]$ = Sign $[dq^*_s/dt\ \ dt^*_s/d\beta + dq^*_s/d\beta]$. When $f(x) = (g\ x)^{1/2}$ then it can be shown that $dq^*_s/d\beta$ exceeds $dq^*_s/dt\ \ dt^*_s/d\beta$ in absolute values for all permissible value of β. Obviously, an interior optimum would require that the negative impact of the tariff on the Southern firm's output exceeds the corresponding positive effect of spillovers at some possibly large values of β.

measured by β^*. This observation yields the empirical prediction that the exported products which are subject to higher spillovers will also be subject to higher tariffs.

PROPOSITION 3.

The Southern government strategically chooses the level of spillovers (that is, the degree of the IPR enforcement) in such way as to keep its firm always (if possible) in a duopoly competition with the Northern firm. In the specific case in which $f(x) = (gx)^{1/2}$ the Cournot–Nash and the Stackelberg level of preferred IPR coincide.

This particular result, is however, the consequence of the assumption that there is no consumption of the good, *z*, on Southern market and therefore, there is no negative implications of IPR violation on Southern consumer surplus. If, however, the consumption of the Southern market is big enough and in addition, the R&D efficiency exceeds certain critical level, then Southern government would prefer rather strict IPR protection (see Žigić 1998a).

6. WORLD WELFARE AND THE OPTIMAL TARIFF

As well known, the standard tariff game is a negative sum game where one country's welfare gain is lower than the other's loss and the change in net total (world) welfare is negative if tariff is imposed. However, in the context in which tariffs have not only a strategic, profit shifting, function but also act as instruments of the technological policy, this conclusion need not hold. To illustrate this point, let us assume that North and South together represent the relevant world market of the good under considerations. Let WTO act as a world central planer and has the power to pick the tariff taking into account the total world welfare. That is, it maximizes the function $W_w^*(t) = W^*(t) + W_s^*(t) = W^*(t) + \Pi_s^*(t)$. For the sake of simplicity we take β as given. Clearly, the level of the optimal tariff will depend now on the importance of its two roles: strategic and technological. If the strategic role dominates, the WTO would prefer to eliminate the tariff and opt for the free trade, while if the technological role is the dominant one, a positive tariff might be desirable outcome. To investigate whether there is a place for such positive tariff, we look at the marginal world welfare evaluated at the zero tariff. Thus, with t = 0, we have now

$$\frac{dW_w^*(0)}{dt} = \frac{\partial S^*(t)}{\partial x}\frac{dx_c^*}{dt} + \frac{\partial S^*(t)}{\partial t} + \frac{\partial \Pi^*(t)}{\partial t} + q_s^* + \frac{\partial \Pi_s^*(t)}{\partial x}\frac{dx_c^*}{dt} + \frac{\partial \Pi_s^*(t)}{\partial t}. \quad (25)$$

Note that this corresponds to (17) when t = 0 with the additional component, $\partial\Pi_s$*(t)/∂x dx*/dt + $\partial\Pi_s$*(t)/∂t, that captures the total effect of the tariff on the Southern firm's profit. Since this total effect, dΠ*(t)/dt, is negative (at least when $\beta < 1/2$), the sign of dW_w*(0)/dt is ambiguous. However, recalling the intuition above regarding the Northern government's choice of the optimal tariff, we expect here again that in case of "high" R&D efficiency, the technological role of tariff may be so important as to overcome its negative impact on the Southern firm's profit, so that the optimal tariff is positive. In the same light, "low" R&D efficiency may easily require zero tariff since the distortional effect of tariffs dominates. Also note that, unlike the Northern government, the World planner does not necessarily consider the appropriation of the R&D output by the South as something bad since it helps the diffusion of innovation worldwide. If the benefits of the diffusion of technology exceed the costs in terms of dampened incentives to conduct R&D, then the tariff will be put to zero (Region I in Fig 3) or rather low level like $t^\circ <$ t* (Region II in Fig 3).

Since, unlike in (17), we cannot tell anything *a priori* on the bases of the general expression (24), we now turn to the example in which $f(x) =(g x)^{1/2}$. Evaluating W_s*(t) for f(x*) $=(gx^*)^{1/2}$, taking the derivative with respect to t, and evaluating it at the zero tariff gives

$$\frac{dW_w^*(0)}{dt} = \frac{(A-\alpha)(-9+(-2+\beta)g(-8+\beta+2g-\beta g-2\beta^2 g+\beta^3 g))}{(9-(-2+\beta)^2 g)^2}.$$

It is easy to prove that whenever $g > g_b(\beta)$ we have $dW^*_w/dt\,(0) > 0$. Thus, $g_b(\beta)$ represents the border line between "low" and "high" R&D efficiency in this context (see Fig 3) .

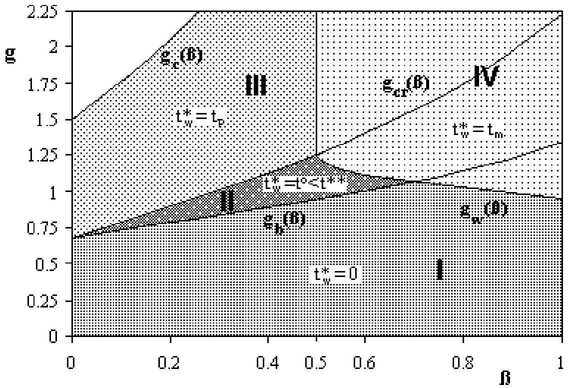

Fig 3. The optimal tariff from the world welfare point of view as a function of g and IPR violation

Another interesting situation is when $dW^*_w/dt(t_p) > 0$. If this is the case, the optimal world tariff will (depending whether β is bigger or lower than 1/2) be t_p or t_m[32]. In other words, the importance of R&D efficiency will be so large that it would require t_p or t_m as the optimal choice despite its obvious negative implications for the Southern firm's profit. Interestingly enough, $dW^*_w/dt(t_p) > 0$ requires that $g > g_{cr}(\beta)$ (see Fig 3). Thus for $g > g_{cr}(\beta)$ the optimal tariff will be t_p or even t_m. In this case, the choice of tariff by the Northern government coincides with that of the world planner. Finally, since welfare in unfettered monopoly can easily exceed the welfare in duopoly when spillovers are large, we have to work out the border line similar to $g_{cc}(\beta)$ line by identifying the parameter space for which $W^*_m > W^*_w(t)$. This gives the $g_w(\beta)$ line (see Fig 3).

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[32] Recall from Lemma 4 that for $\beta < 1/2$ an increase in tariff above t_p reduces socially beneficially R&D investment and thus harms welfare despite its positive impact on profit. Thus, the optimal tariff will be t_p. If, on the other hand, spillovers are large,($\beta > 1/2$), an increase in tariff beyond t_p boosts the R&D spending, hence, the optimal tariff will be t_m. The formal proof can be found in Žigić 1996b.

To summarise, there are 4 distinct regions relating the impact of tariffs on world welfare. In region I, R&D efficiency is not high enough to justify a positive tariff. Note, however, that unlike the world planner, a "rent shifting" Northern government would impose a positive tariff even in this region. In region II, both the world planner and Northern government will impose positive tariff, however, the World planer takes into account the Southern firm's profit and its optimal tariff is lower than the one chosen by the Northern government. In region III, the world planner selects $t^*_w = t_p$ and finally in region IV, $t^*_w = t_m$. In these last two cases both the world planner and the Northern government choose the same optimal tariff. [33]

7. CONCLUDING REMARKS

In this chapter, we have examined the interaction between the Northern strategic trade policy and Southern government incentives to set the level of IPR protection in the situation when there are IPR violations by the Southern firm. As for the " Northern" side, we show that the optimal tariffs have some additional roles besides their traditional role as a device to shift foreign profit to the domestic treasury and to domestic profit. Tariffs act as an instrument that may reduce IPR violations and, therefore, stimulates the domestic firm to invest in socially beneficial R&D that in turn leads to better exploitation of the scale economies. In this setup, optimal tariffs are higher than in the standard duopoly model without R&D investment and IPR violations.[34] As for the "Southern" side, the Southern government sets the IPR policy strategically by anticipating the Northern firm’s R&D decision and Northern government

[33] All of the above analysis assumes that β was given exogenously. If the WTO simultaneously chooses both β and the tariff, things become more complicated. It can be shown that depending on the R&D efficiency, both optimal IPR, β^*_w, and optimal tariff, t^*_w can be positive.

[34] It is important to stress that all our results have been derived assuming no export of the domestic firm to the South and therefore passive Southern government's policy. However, our analysis will not change in a fundamental way if the domestic firm also exports to the foreign market and the Southern government imposes a tariff on its export. The Southern government will solve the analogous problem like (17) and the set of optimal tariffs will be determined in this interactions as a Nash equilibrium. Thus, as Brander (1995) noted, the erection of the tariff by the foreign government does not offset the incentives of the domestic government to impose a tariff.

decision on tariffs. The Southern government would prefer to set maximal lax in IPR protection but it cannot do this (unless the R&D efficiency "very low") since such IPR violation triggers a prohibitive (that is, predatory or monopoly) tariff. [35]

Since the appropriation of R&D output by the South is a form of informal technology transfer, it is not *a priori* clear that the world planner should discourage it. The world planner would have to weigh carefully the benefits of innovation diffusion and the costs of diminished incentives and decreased R&D investment in the North. Such considerations will urge a zero or low tariff if R&D efficiency is low (see Fig 3), but it will require a prohibitive (t_p or t_m) tariff if R&D efficiency is high.

The subsequent research on the North–South interaction of strategic trade policy and IPR protection concentrated on the on Southern strategic trade policy and consequently on the competition in Southern market. Thus, Naghavi (2002) focuses on the incentive for Southern government to protect IPR when the competition is on the Southern market and consequently there is Southern consumer surplus to care about. Building upon Žigić (1998a) duopoly model and allowing for the Northern firm to penetrate the Southern market either by a export or FDI, he shows that stringent IPR policy is always chosen in the South in order to motivate technology transfer, which in turn improves social welfare. Qui and Lai (2004) analyse both the Southern and Northern tariffs. Much like Žigić (2000), they show (in somewhat different oligopoly model with differentiated products and product innovation) that, besides profit–shifting considerations, there is another rationale for a Northern tariff: incentives to innovate. Second, while a Northern tariffs are pro–innovative, a Southern tariffs are in contrast, "anti–innovative". This differentiates the

[35] This outcome is the consequence of the fact that by assumption there is no consumption on Southern market and therefore, there is no negative implications of IPR violation on Southern consumer surplus. If, however, there is “enough” consumption of the good in question on the Southern market and in addition, the R&D efficiency exceeds certain critical level, then Southern government may prefer rather strict IPR protection (see Žigić 1998a) or Naghavi, 2002). Another situation when we do not observe IPR violation in equilibrium is when the Northern government erects a tariff only if it observes the violation of intellectual property rights by the Southern government. Such a tariff is called a punitive tariff (see Žigić 1998c).

two tariffs in an important way: a Southern tariff is a beggar–thy–neighbour policy, but a Northern one may not be. Third, global welfare declines as the South raises its tariff rate, but like in Žigić (2000) under some circumstances global welfare rises as the North increases its tariff rate. Vishwasrao et al.(2005) investigate Southern country's choice of optimum tariffs and patent length in which like in Naghavi (2002), a Northern firm can penetrate the Southern market either by a export or FDI. The absence of patent protection requires high tariffs to induce FDI. This reduces welfare when the good is imported. A combination of patent length and tariffs can be used to reduce this loss and induce FDI. Thus Southern countries may have an incentive to protect patents, although never to the same extent as Northern countries.

A P P E N D I C E S

Appendix 1

Monopoly profit is given by (A.1.1)

$$\Pi^m(x) = \frac{(A-\alpha+f(x))^2}{4} - x \tag{A.1.1}$$

and is maximized at the value of x^*_m. Thus, the derivative of (A.1.1) with respect to x is

$$\partial\Pi/\partial x = \frac{(A-\alpha+f(x))f'(x)}{2} - 1 \tag{A.1.2}$$

with

$$\frac{[A-\alpha+f(x_m^*)]f'(x_m^*)}{2} - 1 = 0. \tag{A.1.3}$$

However, when predation is an optimal strategy, x^*_m is not feasible and the level of R&D expenditures x^*_p is in general different than x^*_m. To show this, note that the "predatory price" has to be such that $p = \alpha - \beta f(x) + t$ holds. Taking this into account, the predatory profit can be written as

$$\Pi^p(x_p) = \frac{(A-\alpha+f(x_p))(t+(1-\beta)f(x_p))}{2} - x_p \tag{A.1.4}$$

with $t \in [t_p, t_m]$. Differentiating (A.1.4.) with respect to x_p and evaluating the derivative at t_s where $t_s \in [t_p, t_m]$, gives the following expression:

$$\partial\Pi/\partial x|_{t=t_s} = \frac{(A-\alpha+f(x_p))f'(x_p)}{4} + \frac{(1-\beta)(A-\alpha+f(x_p))f'(x_p)}{2} - 1. \qquad (A.1.5)$$

Note (by comparing A1.5 with A.1.3) that the value of (A.1.5) is lower than zero for $\beta < 1/2$ implying $x^*_p > x^*_m$ and that the opposite is true for $\beta > 1/2$. For $\beta = 1/2$ the two values coincide, implying $x_p = x_m$.

Appendix 2

Here we compare t_s with t_m for both small and large spillovers where:

$$t_s = \frac{A-\alpha-(1-2\beta)f(x_p^*)}{2} \wedge$$
$$t_m = \frac{A-\alpha-(1-2\beta)f(x_m^*)}{2}$$

and $t_s \in [t_p, t_m]$.

If $\beta < 1/2 \Rightarrow x^*_m < x^*_p \Rightarrow f(x^*_m) < f(x^*_p) \Rightarrow t_m > t_s$ because the last member of the above expression, $-(1-2\beta)f(x) < 0$.

If $\beta > 1/2 \Rightarrow x^*_m > x^*_p \Rightarrow f(x^*_m) > f(x^*_p) \Rightarrow t_m > t_s$ because now $-(1-2\beta)f(x) > 0$.

Finally, when $\beta = 1/2 \Rightarrow t_m = t_s = (A - \alpha)/2$.

Appendix 3

R&D Indicators

Countries	Applied R&D /GDP (x 100) All Sectors		Applied R&D / Value Added (x 100) Agriculture		Scientists & Engineers Engaged in R&D in 1986		Basic Science /GDP (x 100)
	1970	1986	1970	1986	Total	Per 1000 workers	1986
Industrial Economies							
United States	165	185	196	216	785	656	42
United Kingdom	156	171	395	527	86.5	332	31
France	158	194	78	152	72.889	309	46
Germany	203	260	294	283	128.162	462	50
Japan	184	275	328	254	531.612	880	37
Planned Economies	260	300	75	100	–	–	–
Recently Industrialized Economies							
Spain	2	5	21	81	15.299	119	7
Greece	2	2	32	63	3	77	6
Portugal	2	4	89	61	3.475	71	8
Israel	11	25	293	447	3.35	232	90
Newly Industrialized Economies							
Korea, Republic of	5	18	38	56	32.117	205	19
Singapore	1	5	–	–	2.401	195	15
Middle-Income Developing Economies							
Venezuela	2	4	195	118	4.568	97	8
Argentina	5	4	68	44	10.5	87	8
Mexico	2	6	11	63	16.679	76	10
Brazil	2	7	50	95	32.508	75	6
Chile	1	4	89	121	1.6	43	10
Colombia	0	2	61	64	1.083	12	2
Turkey	1	2	44	41	7.747	49	4
Thailand	3	3	91	60	n/a	n/a	6
Egypt	8	2	39	40	19.939	161	4
Philippines	2	2	41	18	4.816	23	3
Low–Income Developing Economies							
Indonesia	1	3	29	45	24.895	45	6
Pakistan	2	3	5	31	9.325	41	3
Kenya	1	1	134	81	n/a	n/a	2
India	4	8	16	35	28.223	12	12
Bangladesh	1	2	15	34	n/a	n/a	20

SOURCE: Evenson, 1990.

Chapter III

Strategic Trade Policy and the (In)Ability of the Government to Precommit to Its Policy: Social Welfare Implications

1. INTRODUCTION

We argued in chapter II that in the particular case where free trade leads to unilateral violations of intellectual property rights (IPR) via, say, R&D spillovers, efficiency and welfare losses may be large due to the well known appropriability problem as well as to the somewhat less known failure of the Northern firm to fully exploit economies of scale (see also Žigić, 2000). This makes the use of strategic trade to be strictly superior to free trade. More specifically, we showed that when Northern and Southern firms compete in quantities on the Northern market and there are IPR violations by the Southern firm, a strategic tariff may reduce or completely eliminate illegally appropriated research output and thus thwarts IPR violations and enhances investment in R&D. However, these findings were obtained under the recently challenged assumption that the government can commit to its policy instrument before the Northern firm chooses its strategy. As Neary and Leahy, (2000) pointed out,"... governments and firms are likely to differ in their ability to commit to future action". Thus, the government may lack credibility with the firms whose behaviour it tries to influence or there may be a time lag between the announcement and the implementation of strategic trade policies. As a consequence, the government may be forced to select its policy only *after* the strategic choice of domestic firms has taken place.[1] This gives a strategic motive to the domestic firm to influence

[1] Carmichael (1987) was the first to refer to empirical evidence showing that in practice the government often sets its policy only after it observes firms' action. See also Gruenspecht (1988) and Neary (1991).

(or manipulate) the government's policy response. In these circumstances, it has been claimed, implementing the strategic trade policy can cause inefficiencies and consequently can lead to lower social welfare compared to the corresponding social welfare under free trade (see for instance, Goldberg, 1995, Karp and Perloff, 1995, Neary and O'Sullivan,1997, Maggi and Grossman, 1998, Neary and Leahy, 2000, Ionaşcu and Žigić, 2005).

The primary goal of this chapter is to show that when R&D spillovers (or unilateral IPR violations) prevail and the Northern government cannot commit *ex ante* to the level of its policy instrument, the benefits of strategic trade policy measured in terms of social welfare are generally larger than social welfare under the corresponding commitment regime. In other words, we claim that the inability of the Northern government to commit to a tariff policy before the Northern firm's strategic decision does not weaken the case for strategic trade policy in the above setup. On contrary, this inability generally reinforces it. Related to this finding is the observation that the optimal tariff in the commitment regime is always larger (and therefore more distortional) than the corresponding optimal tariff in the non–commitment regime. The intuition is that tariffs in the commitment regime have the role of a policy instrument that stimulates R&D effort and due to this additional function, are in equilibrium higher than tariffs in the non–commitment regime. Thus, tariffs act here as imperfect substitutes for R&D subsidy imposing side effect in form of consumption distortion that could have been avoided by using appropriate subsidy scheme.

Another contribution of the recent strategic trade literature, primarily due to Neary and Leahy (1996, 1997, 1999, 2000), stresses the distinction between "first–best" and "second–best" policy. The "first–best" versus "second–best" policy issue arises in the context of dynamic games where Northern firms have more than one choice variable (e.g. level of R&D and level of output). In this setup the first best policy in principle includes more than one policy instrument in order to induce socially desirable levels of all choice variables. However, in many circumstances the government may be constrained to a smaller number of instruments or even only one instrument (say an R&D subsidy). Such constrained policies are usually termed "second–best" (or even "third–best "). One of the interesting results from this literature is that, in the case of Cournot competition, the R&D subsidy, which is generally positive in the "second–best" policy setup, turned out to be negative (an R&D tax) when the "first–best" policy was implemented. We show that this is not the case in our model and that the R&D subsidy is always positive in both the "first–best" and "second–best" policy.

2. THE MODEL

2.1. Assumptions

Much like in chapter II, the core model is assumed to be a Cournot type duopolistic competition between a Northern (or "domestic") and a Southern (or "foreign") firm competing on the Northern market where the Northern firm undertakes the innovation effort in reducing unit costs while the Southern firm benefits from this innovation via spillovers (or IPR violations).The Northern firm is assumed to have constant unit variable costs of production $C = \alpha - f(x)$, where x stands for R&D expenditures and f(x) is an "R&D production function" with properties, $f(x) \leq \alpha$, $f(0) = 0$, $f'(x) > 0$ for $x > 0$ and $f''(x) < 0$. However, in order to simplify the analysis and also to make it directly comparable with the dominant approach in modelling process innovation (see, for instance, d'Aspermont and Jacquemin, 1988, Leahy and Neary, 1997, Hinloopen, 1997,.etc), we introduce the following transformation: $y \equiv f(x)$ and $x \equiv f^{-1}(y) \equiv h(y)$. Thus,"y" denotes the reduction in the Northern firm's unit variable costs and represents the first–stage choice variable while h(y) can be interpreted as "R&D cost function" with the ensuing properties that $h(0) = 0$, $h'(y) > 0$ for $y > 0$ and $h''(y) > 0$. Consequently the post–innovative unit[2] cost of the Northern firm now writes as $C = \alpha - y$ whereas the unit (pre–tariff) cost function of the Southern

[2]In the rest of the article we use the term "unit costs" instead of the more correct "unit variable costs".

competitor is $c = \alpha - \beta y$ where $\beta \in[0,1]$ denotes the level of spillovers (or, equivalently, level of the strength of IPR protection). Parameter α can be thought of as pre–innovative constant unit costs describing an old technology initially accessible to both the Northern and the Southern firms. We assume that α is always big enough so that $y \leq \alpha$ holds in equilibrium. The Southern firm that exports its production to the Northern country pays a specific tariff *t* per unit of output.

The inverse demand function in the Northern market (assumed to be linear with units chosen such that the slope of the inverse demand function is equal to one) is $P = A - Q$ where $Q = q_d+q_f$ and $A > \alpha$. The parameter *A* captures the size of the market, whereas q_d and q_f denote the choice variables, that is, the corresponding quantities, of the Northern and the Southern firms.

Social welfare (W) is defined as the sum of consumer surplus (S), the Northern firm's profit (Π_d) and the revenue from tariffs (R). The consumer surplus is defined as

$$S(q) = \int_0^q P(z)dz - qP(q)$$

that in the case of a linear demand reduces to $S_d = (½)(q_f+q_d)^2$, the tariff revenue is given as $R = t\, q_f$ and, finally, the Northern and Southern firms' profits are respectively given as[3]:

$$\Pi_d = (A - Q)q_d - Cq_d - h(y) \text{ and } \Pi_f = (A - Q)q_f - cq_f - tq_f .$$

As for the other model assumptions and restrictions, they are primarily concerned with the issue of well defined maximisation problems and the existence and viability of duopoly that in turn requires several constrains on R&D cost function, h(y), and on underlying model parameters.

As for h(y), we postulate that

(i) $h'(0) = h(0) = 0$

(ii) $h''(y^*) \geq B(\beta) \equiv 2/9\,(2 - \beta)\,(4 - 2\beta + (7-\beta(7 -4\beta))^{½})$

[3]Subscript "d" will be omitted further on since we will concentrate only on Northern variable.

and

(iii) $h'''(y^*) \geq 0$.

While the assumption (i) is rather standard one, the requirement (ii) is a key existence assumption and it requires some discussion. Namely, (ii) is a necessary condition for duopoly to be viable market structure in both commitment and non–commitment regime[4]. It ensures that a strategy leading to the elimination of the Southern competitor— "strategic predation"— would be too expensive and is never optimal for the Northern firm. More specifically, the marginal cost of the unit cost reduction, h'(y), has to be "steep enough" so that its intersection with the accompanied marginal benefit occurs at a level of y* such that $0 < y^* < y^p \leq \alpha$ where y* is optimal unit cost reduction in duopoly and y^p is the level of unit cost reduction that leads to the zero output of the Southern firm in the equilibrium. Moreover, condition (ii) is more restrictive than any other second– order conditions in the optimisation problems under considerations. So when (ii) holds, all second order conditions in our analysis are automatically satisfied. Finally, note that $B(\beta)$ is monotonically declining in β indicating that, ceteris paribus, the Southern firm can survive easier if the spillovers are higher. Alternatively, the higher is β, the higher can be R&D efficiency of the Northern firm (or, equivalently, lower h''(y*)), for a duopoly to be a viable market structure.

The assumption (iii) is kind of sufficient condition that ensures "enough steepness" of the marginal cost of the unit cost reduction, h'(y) .[5]

As for the restrictions on the model parameters, they will be discussed at the appropriate place in the text.

In order to focus on strategic interactions, most authors use a "third market" assumption,

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[4]See Appendix 3 for the derivation of (ii).

[5] Note that there is a whole class of exponential and power functions, h(y), that appropriately describe the cost function of innovation and that verify the condition $h'''(y^*) \geq 0$. See, for instance, Ronnen, (1991) or Zhou, et al. (2002) for a similar requirement on the third derivative of the cost function to be nonnegative in order to ensure the sufficiency for the existence of equilibrium in a somewhat different set–up.

whereby Northern and Southern firms compete on a common export market. As a consequence, only the Northern firm's profit (net of subsidy) enters the social welfare function (see for instance, Karp and Perloff, 1995, Neary and O'Sullivan,1997, Leahy and Neary, 2000). Our welfare function is more comprehensive and the task of the Northern government is not constrained to only strategic interactions but also takes into account the impact of the domestic firm's strategic choices on consumer surplus and tariff revenue.

The key assumption, as has been made clear, is that the government imposes the tariff only after it observes the domestic firm's choice of unit cost reduction. We call this government policy the "non–commitment" regime and the associated variables have the attached subscript "nc". On the other hand, the "commitment regime" implies that government is capable of committing inter–temporally to a tariff prior to the domestic firm's choice of unit cost reduction and the associated variables carry the subscript "c". Note that both "nc" and "c" regimes are in fact "second–best" policies, since there is only one policy instrument and two choice variables (unit cost reduction and quantities).[6]

2.2. The game

We consider a sequential (three–stage) game. In the first stage, the Northern firm strategically chooses its innovation effort and consequent unit cost reduction. In the second stage the non–committed government sets the tariff on imports after it observes the firm's choice of y. Finally, in the last stage, the firms select quantities, and consequently, profits and welfare are realised. Alternatively, we can, following Neary and Leahy (2000) adopt a two stage framework in which the government in the second stage of the game is able to commit only intra–temporally, setting its policy instrument, tariff, before the firms choose the quantities. Then, in the first stage the domestic firm selects the unit cost reduction.

[6] For the whole spectrum of possibilities of commitment patterns between the firms and the government in a dynamic games setting, see Leahy and Neary, 1996.

Much like in Chapter II, we concentrate on the Northern market (alternatively, we may impose a segmented market hypothesis), in which duopoly is assumed to be a viable market form both before and after the tariff is set. In order to ascertain the subgame perfect equilibrium, we proceed by solving the game backwards. In the last (third) stage, the firms choose the equilibrium quantities. The Northern firm maximizes

$$\underset{q_d}{Max}[\Pi_d] = (A-Q)q_d - C(y)q_d - h(y) \tag{1.a}$$

given q_f and $Q = q_d + q_f$.

The first–order condition for an interior maximum is $\partial\Pi_d/\partial q_d = 0$ and yields $A - 2q_d - q_f - C = 0$.

The maximisation problem for the Southern firm yields:

$$\underset{q_f}{Max}[\Pi_f] = (A-Q)q_f - c(y)q_f - tq_f \tag{1.b}$$

given q_d and t. The first–order condition is: $A - 2q_f - q_d - c - t = 0$. Solving the reaction functions yields the Cournot outputs as a function of y:

$$q_d(y,\ t) \ = \ \frac{(A+c(y)-2C(y)+t)}{3}, \tag{2.a}$$

$$q_f(y,\ t) \ = \ \frac{(A-2c(y)+C(y)-2t)}{3}. \tag{2.b}$$

Substituting (2.a) and (2.b) into (1.a) yields the Northern firm's profit function expressed in terms of y, R&D investment costs, h(y), and tariff:

$$\Pi_d^*(y,\ t)\ =\ \frac{(A+c(y)-2C(y)+t)^2}{9}\ -h(y). \tag{3}$$

In the second stage of the game, the Northern government selects the optimal tariff given the unit cost reduction of the domestic firm. Its objective function is given by the expression

$$W^*(t) = \Pi^*(t) + S^*(t) + R^*(t) \tag{4}$$

where consumer surplus, S*(t) and tariff revenue, R*(t) are respectively given by

$$S^*(t)\ =\ 1/2(q_d^*+q_f^*)^2\ =\ \frac{(2(A-\alpha)-t+(1+\beta)y)^2}{18} \tag{5}$$

and

$$R^*(t)\ =\ t\ q_f^*\ =\frac{t\ (A-\alpha-2t-y(1-2\beta))}{3}\ . \tag{6}$$

Note that Northern profit monotonically increases in tariff (the higher the tariff the larger the effective unit cost difference and, consequently, the higher the Northern firm's profit) while consumer surplus monotonically declines in tariff. Finally, the function R(t) initially increases in t as t goes above zero, reaches its maximum at t = 1/4 (A - α - y(1-2β)), but eventually falls to zero as t reaches the prohibitive tariff, t_p, a tariff that causes the exit of the Southern firm. Thus, the function W(t) is strictly concave in t with $d^2W(t)/dt^2 = -1 < 0$ while the whole tariff domain on which duopoly is defined is given by the interval $t \in [0,t_p]$.

The assumption (ii) ensures an interior maximum such that $t_{nc}^* < t_p$ and the optimal tariff, t_{nc}^*, is obtained by solving ∂W/∂t = 0, yielding[7]:

[7] Strictly speaking, (ii) is only the necessary condition for the equilibrium, The sufficient condition for t^*_{nc} to be the optimal government strategy requires that the setting a monopoly tariff, t_m, (where $t_m \geq t_p$) is never optimal. So we assume that this holds, that is, $W^*(t^*(\beta),\beta) \geq W^*_m(t_m)$ where W^*_m stands for social welfare generated when the Northern firm acts as monopolist. This requirement may further reduce the parameter space (see example in the Appendix 4). Finally, note that, t_{nc}^*, is, in fact, an

$$t_{nc}^{*}(y) = \frac{A - \alpha + \beta y}{3}. \tag{7}$$

Finally, in the first stage of the game the Northern firm selects the optimal level of marginal costs reduction, y, taking into account its subsequent impact on both its Southern rival's behaviour (strategic effect) and on the government's choice of tariff (manipulation effect). By substituting t_{nc}* into (3) we obtain

$$\Pi_d^{\circ}(y,\ t_{nc}^{*}(y)) = \Pi_d^{\circ}(y) = \frac{4(2(A-\alpha)+(3-\beta)y)^2}{81} - h(y). \tag{8}$$

Maximising (8) with respect to y gives the first order condition[8] and (implicitly) the optimal y_{nc}*:

$$\frac{8[2(A-\alpha)+(3-\beta)y_{nc}^{*}](3-\beta)}{81} = h'(y_{nc}^{*}). \tag{9}$$

Note that the optimal reduction in unit costs could be obtained more elegantly and more intuitively by comparing the marginal costs and benefits of an increase in y. A small increase of y positively affects the subsequent government tariff by $\partial t^*/\partial y$. This, in turn, increases Northern operational profit, $\pi^* = 1/9\ (A - \alpha + t_{nc}^* + y(2-\beta))^2$, (that is, the profit before the costs of innovation were subtracted) by $\partial \pi^*/\partial t$. In addition, a given increase in y also increases the Northern firm's operational profit directly by $\partial \pi^*/\partial y$. The associated cost of such a marginal increase is h'(y). Thus, the optimal y_{nc}* is found at the point where the marginal benefit of a decrease in unit costs equals its marginal costs, that is, where $\partial \pi^*/\partial t\ \partial t/\partial y + \partial \pi^*/\partial y = h'(y)$ holds. This expression describes the same first order condition (9).

optimal time–consistent tariff (see Goldberg,1995).

[8] The second order condition requires h''(y) > (8 (3- β2)/81 and (ii) is sufficient for this second order condition to hold.

3. TARIFFS, R&D AND WELFARE IN TWO REGIMES

3.1. Optimal tariffs in two regimes

After calculating the optimal tariff in the non–commitment regime, we now briefly characterize the optimal tariff in the commitment regime and then make the tariff comparison across the two regimes.

In the commitment regime, the first two stages are reversed; the government commits to the tariff in the first stage and then domestic firm chooses its optimal R&D for a given tariff. Since the last stage is the same in both regimes, we proceed with the second stage of the game in which the Northern firm choses optimal R&D effort. Maximisation of (3) with respect to y gives the first order condition that implicitly determines the optimal y (but now as function of tariff). Label it as y_c^* (t).

$$\frac{2}{9}(2-\beta)(A-\alpha+t+(2-\beta)y) = h'(y_c^*). \tag{10}$$

Substituting y_c^* (t) in (4) gives the government objective function, $W_c^*(y_c(t_c),t_c)$ to be maximised in the first stage. Setting $dW_c^*/dt = 0$ yields[9]:

$$t_c^* = \frac{(A-\alpha) + \beta y_c^* + (2(A-\alpha) + y_c^* (3 - (2-\beta)\beta - 3h'(y_c^*))y')}{3 - \beta y'} . \tag{11}$$

Again, the restriction (ii) makes sure that the tariff, t_c^*, lies between zero and corresponding predatory tariff, t_p, and, much like in the non–commitment case (see footnote 8 and Appendix 4), we require that $W_c^*(t^*(\beta),\beta) \geq W_m^*(t_m)$ for t_c^* to be the government's equilibrium strategy.

The tariffs are generally different in the two regimes due to the somewhat different functions that they perform. Namely, a distinctive characteristic of the tariff in the commitment

[9] Note that (11) gives only an implicit tariff since $y_c^* = y^*(t)$ is an implicit function of the tariff.

regime is that it possesses a "technological function". The committed government that sets the tariff, t_c*, takes into account the tariff's impact on the subsequent choice of domestic firm's R&D. Thus, t_c*, besides its profit shifting role, also has the function of stimulating R&D investment. In the absence of an R&D subsidy, the tariff, t_c*, assumes part of the R&D subsidy's role and acts not only as a trade policy but also as an industrial or technological policy instrument.[10] This additional role of the tariffs in the commitment regime indicates that their optimal values may exceed the optimal values of their counterparts in the non–commitment regime since in the non–commitment regime R&D investment is already in place when the tariff, t_{nc}*, is set . So t_{nc}* has no direct impact on the firm's choice on R&D.

LEMMA 1

The optimal tariff in the commitment regime always exceeds the optimal tariff in the non–commitment regime.

Proof: See Appendix 1

Finally, we note here that the result from Lemma 1 generalizes to the case with horizontal product differentiation within both Cournot and the Bertrand type of conduct (see Ionaşcu and Žigić, 2005b).[11]

An Example

In order to illustrate the relationship between the tariffs in the two regimes more transparently, we make use of the specific "R&D cost function" which is derived from the

[10] For the three roles of the tariff in the commitment regime, see Chapter II or Žigić, 2000.To the extent that parameter β captures the size of IPR violation, both t_{nc}* and t_c* have a role to counter IPR violation (see the example below).

[11] The relation between the level of optimal tariffs in the two regimes seems to be robust since it also holds in a rather different trade model of vertical product differentiation (see Herguera, et al. (2002).

following "R&D production function": $y = (g\ x)^{½}$ (see Chin and Grossman,1991, and Žigić, 1998a, for applications of this R&D production function). The appropriate transformation yields, $x = h(y) = y^2/g$. The parameter g captures R&D efficiency so that a bigger g implies an easier reduction in unit costs. (Note that the assumption (ii) imposes now the upper bound on the parameter g).

The corresponding levels of tariffs in the two regimes are now given by:

$$t_{nc}^{*} = \frac{(A-\alpha)(27-4g(1-\beta)(3-\beta))}{81-4g(3-\beta)^2} \qquad (12)$$

and

$$t_{c}^{*} = \frac{(A-\alpha)(27+g(10+g(-2+\beta)(1-\beta)^2-11\beta)(-2+\beta))}{81-g(32-g(3-2\beta)(2-\beta)-10\beta)(2-\beta)} \ . \qquad (13)$$

The straightforward comparison between (12) and (13) reveals that $t_{nc}^* < t_c^*$ for all permissible values of $g > 0$ and for all $\beta \geq 0$.

Proof: See Appendix 2.

When spillovers are strictly positive, the tariff, t_{nc}^*, among other things, serves as an instrument to counteract IPR violation. However, without spillovers ($\beta = 0$), (12) collapses to (12.1)

$$t_{nc}^{*}(\beta=0) = \frac{(A-\alpha)}{3} \qquad (12.1)$$

and the optimal tariff becomes a pure, profit shifting tariff (see Bhattacharjea 1995). Thus, the tariff, t_{nc}*, can have two roles at best: profit shifting and countering IPR violation if $\beta > 0$.[12]

As for the optimal tariff, t_c*,when the government can make commitment, this tariff, as we already showed, has an additional technological function aimed at boosting R&D investment. This role is clearly seen if we evaluate (13) at $\beta = 0$ to get

$$t_c^*(\beta=0) = \frac{(A-\alpha)(27-20g+4g^2)}{81-64g+12g^2} \tag{13.1}$$

and observe that $dt_c^*/dg > 0$.

Finally, both (12) and (13) reduce to pure, profit shifting tariffs, when $\beta = g = 0$.

3.2. Marginal cost reduction in two regimes

A comparison of the marginal cost reductions and consequently the underlying innovating efforts in the two regimes is not only interesting *per se* but even more importantly, is crucial for the comparison of social welfare in the two regimes as we will see in the next section.

LEMMA 2

The unit cost reduction in the non–commitment regime exceeds the unit cost reduction in the commitment regime as soon as R&D spillovers are above the critical level of β^r. That is, $y^*_{nc} > y^*_c$ when $\beta > \beta^r$. Moreover, $\beta^r < 0.10335$.

Proof: See Appendix 5

The presence of spillovers is crucial for the above result[13]. In other words, when spillovers are zero or very small, $y_c^* > y_{nc}^*$, but as soon as a certain low level of $\beta = \beta^r < 0.10335$ is

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[12] The fact that $dt_{nc}^*/dg > 0$ for $\beta > 0$ should not be interpreted as implying the technological function of the tariff, t_{nc}*, since this is only a passive increase of tariff due to the increase in the R&D output, y*, as g gets larger.

[13] In the absence of spillovers, Ionaşcu and Žigić (2005b) showed that $y_c^* > y_{nc}^*$ holds in a more general setup that allows for horizontal product differentiation and both Cournot and Bertrand type of market conduct.

reached, the reverse becomes true, implying that y_{nc}* declines more slowly than y_c* as the level of spillovers increases.[14]

The relationship between y_c* and y_{nc}* is not obvious *a priori*. On the one hand, the government in the commitment regime can affect via tariff the socially insufficient level of unit cost reduction, stimulating the investment in R&D that leads to a higher reduction in unit costs[15]. However, this "technological function" of tariff is of a limited power due to its offsetting, negative side: an increase in tariff leads to a price increase in equilibrium and thus, has an adverse direct effect on the consumer surplus. On the other hand, in the non–commitment regime the technological function of tariff is absent, but the domestic firm has an incentive to invest in unit cost reduction in order to manipulate the government and induce a higher tariff on imports. This additional motive to invest in R&D and in unit cost reduction is not present in the commitment regime so this, so called, "manipulating" incentive leads to the comparably higher investment in R&D and, consequently, a higher unit cost reduction as soon as the spillover level exceeds a certain low level, $\beta^r < 0.10335$.

The clue for this result lies in the lower sensitivity of y_{nc}* with respect to the change in spillovers level as compared to corresponding sensitivity of y_c* to spillovers. To understand the intuition behind the lesser sensitivity of unit cost reduction on spillovers in the non–commitment regime, we briefly review the characteristics of the firm's strategic behaviour in the context under consideration. First, it is well known that in dynamic Cournot duopoly models, where the domestic firm exhibits "limited leadership", the domestic firm (incumbent) "over-invests" in its strategic variable in order to gain advantage over its competitor. In other words, it pursues a so called "top dog" strategy that makes the domestic firm "tough" (see Fudenberg and Tirole, 1984,

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[14] Both y_c* and y_{nc}* decline monotonically in β on the whole range of $\beta \in [0,1]$. This implies the faster decline of y_c* in β starts already at the level of $\beta = 0$.

[15] Reitzes (1991) was probably the first to demonstrate the positive impact of strategic tariff on R&D.

Tirole, 1991). The notion of over-investment is defined with respect to the non–strategic benchmark in which the Northern firm selects its strategic variable ignoring its impact on the subsequent stage variable of the competitor. However, this "top dog " strategy becomes more and more "diluted" with an increase in spillovers. In fact, the higher the spillovers, the more the foreign firm appropriates the innovative output of the domestic firm and consequently the higher are the disincentives to invest in R&D. Thus, after a certain threshold level of β a disincentive effect of spillovers starts to dominate so that the "top dog " strategy turns into a "lean and hungry look " strategy leading to under-investment vis–à–vis the non–strategic benchmark (see subsection 3.2.1 for an example and graphic representation). In other words, since this strategic investment is aimed directly at the competitor, it is very sensitive to spillovers.

On the other hand, in the non–commitment regime, there is an additional, "manipulating" motive that the Northern firm faces on top of the standard strategic investment motive described above. Namely, the domestic firm has an incentive to manipulate the government decision on the tariff because in the non–commitment regime a higher unit cost reduction induces a higher tariff, that in turn benefits the domestic firm's profit. This additional motive for over-investment is not present in the commitment regime and it is targeted towards the domestic government and not directly towards the foreign firm. Thus the "manipulating" investment is therefore less vulnerable to spillovers. Consequently, the overall R&D investments in the non–commitment regime (that can conceptually be broken up into two parts: strategic and manipulating R&D investment) are less sensitive to spillovers than the corresponding R&D (and unit cost reduction) in the commitment regime.

An example

When we put again $y = (g\,x)^{1/2}$, yielding $x = h(y) = y^2/g$, the corresponding optimal unit cost reduction in the two regimes are given by the expressions (14) and (15) below:

$$y_c^* = \frac{(A-\alpha+t_c^*)(2-\beta)g}{9-g(2-\beta)^2}, \tag{14}$$

$$y_{nc}^* = \frac{8(A-\alpha)(3-\beta)g}{81-4g(3-\beta)^2}. \tag{15}$$

The lower sensitivity of y^*_{nc} to spillovers compared to y^*_c is easy to observe in Figure 1. First note that in the benchmark case (Northern firm acts non–strategically), labelled y^*_{ns}, unit cost reduction is clearly the least sensitive to spillovers due to its non–strategic nature. The threshold level of β after which an over-investment (the "top dog" strategy) in the commitment regime turns into an under-investment ("lean and hungry look " behaviour) is labelled β^c and $\beta^c = ½$. Note that due to the lower sensitivity of y^*_{nc}, the analogue critical value of β in the non–commitment regime (labelled β^{nc}) is higher than ½, that is $\beta^{nc} > \beta^c = 1/2$.

The expression for the threshold level of spillovers, β^r, is a bit messy since it depends on g (see Appendix 6). Nevertheless, it suffices for spillovers to be such that $\beta > 0.09$ for $y^*_{nc} > y^*_c$ to hold irrespective of the value of g that is consistent with the duopoly competition (see Appendix 6).

3.3. Welfare in two regimes

The above discussion of the optimal tariffs, optimal unit cost reduction and of the implied R&D levels in the two regimes serves as a prelude, to the key comparison of relative social welfare. As a corollary of Lemma 1, we put forward the following proposition.

PROPOSITION 1

The sufficient condition for social welfare in the "non–commitment" regime to exceed social welfare in the "commitment" regime is that $y^*_{nc} > y^*_c$. *Consequently, it suffices for R&D*

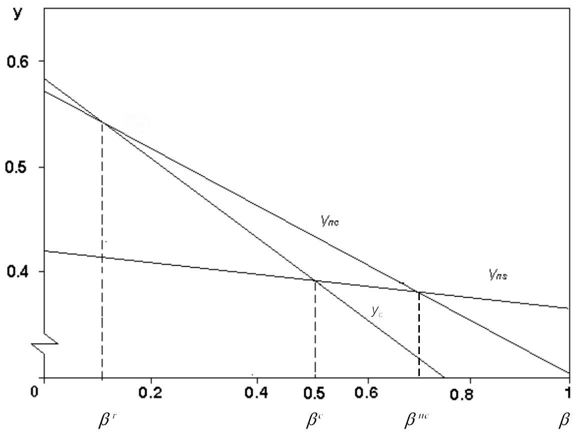

Figure 1

spillovers to be above the critical threshold level, $\beta = \beta^r < 0.10335$ *in order for* $W_{nc}^* > W_c^*$ *to hold. Finally, for* $\beta > \beta^r$*, social welfare in the "non–commitment" regime is always higher than social welfare in the corresponding free trade world.*

The socially optimal level of unit costs reduction, (labelled y**), does not coincide with the Northern firm's unit cost reduction in either of the two regimes, since the Northern firm does not take into account the beneficial impact of its marginal cost reduction on the consumer surplus and its impact on tariff revenue. To verify the claim that y** > y* (where "y*" stands for either y_{nc}* or y_c*), it suffices to show that dW*(y*)/dy > 0 and to realize that the social welfare function is strictly concave in y by assumption (ii). Thus, a "small" more social welfare by increasing consumer surplus than the resulting social welfare loss due to the fall in the firm's profit and a possible decline in tariff revenue.[16] Note that a positive marginal social welfare requires that the

[16]It is easy to check that tariff revenue increases in y provided that β is large enough.

marginal impact of y on consumer surplus and tariff revenue at point y* must be positive. In other words, $dS^*(y^*)/dy + dR^*(y^*)/dy > 0$ must hold in both regimes in order to have $dW^*(y^*)/dy > 0$. (Note that $d\Pi^*(y^*)/dy = 0$ by the first order condition of profit Maximising in each regime.) Thus, in the non–commitment regime we get

$$\frac{dW^*_{nc}\ (y^*_{nc})}{dy} = \frac{(A-\alpha)(6+25\beta)+(9-6\beta+28\beta^2)y^*_{nc}}{81} > 0. \qquad (16)$$

By the same token, $dW_c^*\ (y_c^*)/dy > 0$ holds as well (see chapter II).

As can be seen from (16) this result holds even in the absence of spillovers. However, the presence of spillovers aggravates the departure from the social optimum since the Northern firm experiences disincentives to invest in unit cost reduction due to inability to fully appropriate all of the benefits of its innovating activity. In other words, the gap between y** and y* is lower in the absence of spillovers.[17]

The fact that the domestic firm, regardless of the regime, under-invests in R&D from the social point of view and therefore has a lower than socially optimal unit cost reduction, should not be confused with the firm's strategy which we call "over-investment" (which is optimal up to certain level of spillovers as we show in section 3.2). The notion of "over-investment" is defined in relation to the domestic firm's non–strategic behaviour in which it ignores the strategic effect of unit cost reduction on the foreign firm's second stage variable (that is, on its output) and has nothing to do with the socially optimal level of R&D investment, h(y**). However, there is an important case when "top dog" behaviour and "manipulative" over-investment in R&D also imply "over-investment " from the social point of view. This appears in so called "third market" models where the social welfare function coincides with domestic firm profit (net of

[17] Technically, the derivative, $dW_{nc}^*\ (y_{nc}^*)/dy$ reaches its lowest value when $\beta = 0$ as seen from (16). The same is valid for $dW_c^*\ (y_c^*)/dy$.

subsides/taxes) and where the domestic government (assuming the foreign government is passive and also assuming dynamic Cournot duopoly with "small" or zero spillovers) faces potentially three types of strategic considerations: the standard "profit shifting" motive, the government's motive to counteract the domestic firm's strategic over-investment and the government's motive to offset the domestic firm's manipulative investment (see Neary and Leahy, 2000). Transferring it in our framework, if the government cares only about the firm's profit net of taxes and subsidies (which is natural in the third market case), it would seek to provide the profit shifting instrument on its own, as a tariff or export subsidy, and then by means of an R&D tax try to prevent the domestic firm's socially wasteful over-investment associated with both the "top dog" behaviour and (in the case of non–commitment regime) with the manipulative behaviour.

An Example

Once again applying the same functional form for R&D effort, that is, $h(y) = y^2/g$, we calculate the corresponding social welfare levels in the two regimes:

$$W^*_{nc} = \frac{(5103-8g(129-6g(1-\beta)^2(3-\beta)-97\beta)(3-\beta))}{2(81-4g(3-\beta)^2)^2},$$

$$W^*_c = \frac{(63+g(16+g(-2+\beta)(1-\beta)^2-14\beta)(-2+\beta))}{2(-81+g(-2+\beta)(-32+10\beta+g(2-\beta)(3-2\beta)))}$$

and then look for the critical value of spillovers, $\beta^w(g)$, beyond which $W^*_{nc} > W^*_c$. While this critical value as a function of innovation efficiency is a rather messy expression, it is sufficient for spillovers to be such that $\beta > 0.03$, regardless of the value of g for social welfare in the non–commitment regime to dominate the social welfare in the non–commitment regime[18] (see Appendix 7). The summary of the empirical work on spillovers by Griliches (1992) finds that typical values of β range between 0.2 and 0.4, far above any possible value of $\beta^{w}(g)$.

4. THE "FIRST–BEST" POLICY

Since in our "second–best" setup the key strategic variable— R&D investment— is under–supplied, the principle objective of the "first–best" policy is to remove this inefficiency with some other policy instrument. The natural policy tool for this purpose would be an R&D subsidy to the domestic firm.

Before we proceed, it should be made clear at the outset that the term "first–best" is not completely appropriate in this setup (a more correct name would be "constrained first best policy"). The "true" first best policy would involve three policy instruments: import tariff, output subsidy and R&D subsidy or tax. However, the optimal output subsidy would in our setup induce the Northern firm to produce at the point where marginal costs equal price, which in turn would imply that the Northern firm serves the whole Northern market. That is, the optimal market structure would be domestic monopoly. Moreover, the optimal tariff would be zero. Since the duopoly interaction between the Northern and Southern firms and strategic tariff are at the core of our analysis, the issue of optimal output subsidy naturally has to be disregarded. More generally, output subsidy is considered to be an unrealistic (Dixit, 1988) and due to its heavy informational content often infeasible and impractical instrument (Bhattacharjea,1995).

Despite the above cautions, we nonetheless stick with the term "first–best" policy to distinguish it from the one–instrument, "second– best" policy (which, by the above logic would be the "third–best policy ") and also to be in line with Neary and Leahy’s (2000) terminology who

[18]Note that it is possible that $W_{nc}^* > W_c^*$ even when $y^*_{nc} < y^*_c$. The reason for this is that $t_c^* > t_{nc}^*$ and so there are comparatively larger distortion in social welfare at even very low levels of spillovers.

(although in their setup fully correctly) called the combination of two instruments like output and R&D subsidies the "first–best" policy.

The relevant framework is now a four–stage game that adds one initial stage to the game considered in the previous section: government commitment to a level of R&D subsidy. Again, we can, following Neary and Leahy (2000), consider this game as basically a two stage game where in both stages the government is restrained to committing intra–temporally; thus, in the first stage the government selects the R&D subsidy before the domestic firm chooses R&D, whereas in the second stage the government commits to the tariff before the firms choose their quantities. Since the rest of the game is already solved, we turn immediately to the first stage and the government's choice of the optimal subsidy.

The objective function of the government that implements the "first–best" policy is now given by the expression (17):

$$W^{*}_{fb}[y^{*}(s),t^{*}(y^{*}(s),s),s] = \Pi^{*}(\cdot) + S^{*}(\cdot) + R^{*}(\cdot) - sh(y^{*}) \tag{17}$$

where "fb" stands for the" first–best" and "s" denotes the subsidy. The domestic firm's profit now has an additional term stemming from its subsidy income, $I \equiv s\,h(y)$. The social marginal cost of raising a unit of subsidy is assumed to be one, and so the cost of subsidy payment for the government is $T \equiv s\,h(y)$.

Differentiating (17) with respect to the subsidy and equating it to zero while using the domestic firm's first order condition (envelope theorem) and noting that $\partial\Pi^*/\partial s = h(y^*)$ yields (implicitly) the optimal "first–best" subsidy:

$$s^{*} = \frac{1}{h'(y)}\left(\frac{\partial S^{*}}{\partial y} + \frac{\partial R^{*}}{\partial y} + \left(\frac{\partial S^{*}}{\partial t} + \frac{\partial R^{*}}{\partial t}\right)\frac{\partial t}{\partial y}\right). \tag{18}$$

A positive optimal subsidy requires that the positive impact of unit cost reduction on consumer surplus (the first expression in (18)) dominates the negative impact of the optimal tariff on the consumer surplus and tariff revenue as well as any possible negative impact (which occurs only if $\beta < ½$) of unit cost reduction on the tariff revenue. In other words, the right hand side of (18) has to be positive. Indeed, substituting the relevant values obtained by the differentiation of the expressions (5) and (6) into (18) gives

$$s^* = \frac{(A-\alpha)(6+25\beta)+(9-6\beta+28\beta^2)y_s^*}{81h'(y_s^*)} > 0 \ . \qquad (19)$$

Clearly, the optimal "first–best" R&D subsidy is positive, stimulating investments in R&D, removing the distortion between the privately and socially desirable R&D investment levels and ensuring the unit cost reduction to be at the socially optimal level, y_s*.

We now turn to a "second–best" policy that we coin "R&D subsidy only". Our look at this policy will be brief since this issue is discussed at length elsewhere (see for instance, Spencer and Brander, 1983, Bagwell and Staiger, 1994, Maggi, 1996, and Leahy and Neary, 1997, Hinloopen, 1997). In the absence of tariff, the expression (18) characterizing the optimal subsidy reduces to:

$$s_{sb}^* = \frac{\partial S^*}{\partial y} = \frac{(1+\beta)(2(A-\alpha)+(1+\beta)y_{sb})}{9h'(y_{sb})} > 0. \qquad (20)$$

By comparing (20) with (18), it is easy to show that the sum of remaining effects in (18) is negative, yielding the expected relation between the first and second best subsidy, namely $s^*_{sb} > s^*$. This is in line with findings emphasising the robustness of the R&D subsidy (see for instance, Brander,1995, Bagwell and Staiger,1994, and Leahy and Neary, 1997, Hinloopen,1997, and Neary and Leahy, 2000) since R&D subsidy has to boost inefficient R&D investment and act as a surrogate for the unavailable tariff. Interestingly, the level of spillovers and consequently, "toughness" or "softness" of strategic R&D investment has no impact on the sign of the optimal instrument (R&D subsidy) in either "first" or "second–best" setup. We summarise these observations in the proposition 2.

PROPOSITION **2**

Both the "first–best" and "second–best" R&D subsidies are always positive with $s^* < s_{sb}^*$ irrespective of the level of spillovers and consequently, irrespective of whether R&D investment makes the Northern firm "tough" or "soft".

The difference from the standard results in Cournot competition where the "first–best" subsidy is negative (i.e., an R&D tax is optimal) stems primarily from the different specification of the welfare function. If we neglect consumer surplus and tariff revenue, then it is clear from (18) that the optimal subsidy will be zero.[19] The reason for this is that in such a situation both the firm and the government have the same ability to commit so the firm can achieve the most advantageous strategic position on its own (see also Neary and Leahy, 2000).

As for the "first–best" tariff, it is given by

$$t_{fb}^* = \frac{A - \alpha + \beta y_s^*}{3}. \qquad (21)$$

It obviously has the same functional form as the tariff in the non–commitment regime, since the tariff is no longer an instrument supporting R&D investment. However, note that as long as β > 0, the optimal "first–best" subsidy exhibits (at least indirectly) a profit shifting role by affecting the optimal tariff through its influence on the optimal level of unit cost reduction. (Note that when

[19] However, this is no longer the case if the foreign firm also invests in R&D.

$\beta = 0$, R&D has no impact on the optimal tariff and once again the tariff has only a profit shifting role.) Thus, in the presence of spillovers the division of labour between the two instruments is somewhat blurred. This seems to be a robust finding since a similar phenomenon was also noticed by Leahy and Neary (1999) in a different framework with spillovers and international competition.

An Example

We now turn to the calculation of the optimal, "first–best" subsidy and tariff when h(y) $= y^2/g$. Substituting it into the expressions (19) and (21) respectively, we obtain the expressions for the "first–best" optimal subsidy and tariff:

$$s^* = \frac{6+\beta(25-4g(1-\beta)(3-\beta))}{9(6+\beta)}, \tag{22}$$

$$t_{fb}^* = \frac{(A-\alpha)(6-g(1-\beta)(3-\beta))}{18-g(9-6\beta+4\beta^2)}. \tag{23}$$

It is interesting to note that the optimal subsidy increases in the level of spillovers. This may seem counterintuitive at first glance, since as β and y increase, so do the spillover benefits appropriated by the foreign firm. R&D subsidies are, however, an industrial policy instrument with the primary role of enhancing socially insufficient R&D investment while the other instrument (the optimal tariff) has (among other roles), an IPR violation offsetting role (note that $\partial t_{fb}^*/\partial\beta > 0$). Since the optimal R&D subsidy increases with spillovers, it also triggers an increase in the tariff (see expression 23) that thwarts the spillover benefit appropriated by the foreign firm, defined as $F[y_s^*(s),t] \equiv \beta\, y_s^* q_f^*(y_s^*, t)$ through the negative impact of the tariff on foreign output. Moreover, as long as spillovers are "not too high," the investment in R&D makes the Northern firm "tough" and the increase in R&D induced by R&D subsidy also reduces the output of the Southern firm[20] and thus additionally decreases the spillover benefit of the foreign firm. Larger spillovers require larger R&D subsidies, even if the beneficiaries are foreign, not because the home government cares about foreign profits, but because, firstly, it wishes to offset the negative disincentives to investment arising from non–appropriability (see Leahy and Neary, 1999) and, secondly, because it aims to spur better exploitation of scale economies by the Northern firm.

5. CONCLUSION

In this chapter, we analysed the effect of different degrees of government commitment on social welfare in a duopoly game where Northern and Southern firms compete in quantities on an imperfectly competitive Northern market and where there are R&D spillovers from the Northern to the Southern firm. More specifically, we distinguished between "committed" and "non–committed" policy regimes where a "committed" government selects the policy instrument before the strategic choice of the domestic firm while its "non–committed" counterpart sets the policy instrument only after the strategic variable of the domestic firm is already in place. The latter presumes only intra–temporal commitment on the part of government (and consequently, the absence of inter–temporal commitment).

Concerning government policy, we made a distinction between "first–best" and "second–best" policies. The "first–best" policy in principle includes more than one policy instrument in order to induce a socially desirable level of strategic choice variables whereas strategic choice variable in our set up is unit cost reduction and consequently, investment in R&D. In many circumstances, however, the government may be constrained to a smaller number of policy instruments. In this "second–best" policy environment, there may be only one instrument

[20] Recall that when spillovers exceed a certain critical level, the investment in R&D makes the Northern firm "soft" calling for a "lean and hungry look" strategy (see Fig 1 and see Fudenberg and Tirole, 1984).

at the government's disposal. Since, in our context, the Northern firm has two choice variables—the level of R&D investment and the quantities to be produced—the "second–best" policy implies either R&D subsidy or the import tariff (but not both of them).

As for the "second–best" policy when import tariffs are the only instrument, we showed that when R&D spillovers prevail, social welfare in the non–committed regime is higher than social welfare in the commitment regime and, consequently, higher than the corresponding welfare under a free trade regime. The reason for this result is that the optimal tariff in the non–committed regime is lower than the optimal tariff in the committed regime, creating a smaller distortional effect on consumer surplus and tariff revenue. The benefits of the latter exceed the forgone benefits in the Northern firm's profit due to the higher tariff as soon as a small critical level of spillovers is surpassed. A sufficient condition for social welfare in the non–commitment regime to dominate is that the Northern firm's strategic variable— unit cost reduction — be higher than in the commitment regime. In effect, the Northern firm in the non–committed regime has an additional motive to over-invest in order to induce a higher tariff from the government and this additional motive makes it less sensitive to R&D spillovers. Its R&D investment and unit cost reduction, therefore decrease more slowly as spillovers rise, exceeding the R&D investment from the commitment regime as soon as a certain low spillovers threshold level is exceeded.

We demonstrated that the optimal subsidy is always positive in both the "first–best" and "second–best" policy setup irrespective of the level of spillovers and consequently regardless of whether the investment makes the Northern firm soft or tough. The reason for this is the socially inefficient level of private R&D due to the appropriability problem that subsidy aims to correct and due to the scale economies that larger R&D investment brings about. The role of the optimal subsidy in the "first–best" setup is somewhat blurred due to R&D spillovers since, besides its primary role of correcting for socially insufficient R&D, the "first–best" subsidy also affects the optimal tariff and thus, at least indirectly, has a profit shifting role.

APPENDICES

Appendix 1: Comparison of the tariffs in the two regimes

In order to prove that $t_c^* - t_{nc}^* > 0$ for all $\beta \in [0,1]$ and for duopoly being a viable market form, it is sufficient to show that $t_c^* - t_{nc}^{up} > 0$ where t_{nc}^{up} is an appropriately defined upper bound of t_{nc}^*. To obtain t_{nc}^{up} we first derive the upper bound of y_{nc} (labelled as y_{nc}^{up}) as a function of y_c. The most challenging and the relevant case is when $y_{nc} > y_c$. (If on the other hand, $y_c > y_{nc}$, the proof is straightforward by direct comparison of the t_c^* and t_{nc}^* evaluated at the same level of y.) Thus $y_{nc} > y_c \Rightarrow h'(y_{nc}) > h'(y_c)$ or

$$h'(y_{nc}) - h'(y_c) > 0. \qquad \text{(A1)}$$

By the mean–value theorem (A1) can be expressed as

$$h'(y_{nc}) - h'(y_c) = h''(z)\,(y_{nc} - y_c). \qquad \text{(A2)}$$

Since we assume that $h'''(y) \geq 0 \Rightarrow h''(z) \geq h''(y_c) \Rightarrow$

$$h'(y_{nc}) - h'(y_c) \geq h''(y_c)\,(y_{nc} - y_c). \qquad \text{(A3)}$$

To get y_{nc} explicitly we substitute the Northern firm's first order conditions from both commitment and non–commitment regimes in (A3). The corresponding first–order conditions are respectively given by:

$$h'(y_c) = 2\,(2 - \beta)\,(A - \alpha + t_c + (2 - \beta)\,y_c) / 9 \qquad \text{(A4)}$$

and

$$h'(y_{nc}) = 8\,(3 - \beta)\,(2\,(A - \alpha) + (3 - \beta)\,y_{nc}) / 81. \qquad \text{(A5)}$$

To simplify the notation we rearrange the above first order conditions in the following form:

$h'(y_c) = B_c + D_c\, y_c$ and $h'(y_{nc}) = B_{nc} + D_{nc}\, y_{nc}$, where

$$B_c = 4\,(A - \alpha)\,(2 - \beta)\,(6\,\eta - (2 - \beta)^2) / X,$$

$$D_c = 4\,(2 - \beta)\,(3\,(3 - \beta)\,\eta - 2\,\beta^2 + 7\,\beta - 6) / X,$$

$B_{nc} = 16 (A - \alpha) (3 - \beta) / 81,$

$D_{nc} = 8 (3 - \beta)^2 / 81,$

$\eta = h''(y_c)$ and $X = 81 \eta - 4 (2 - \beta) (7 - 2\beta).$

In constructing B_c and D_c, we use the fact that

$$t_c^* = ((A - \alpha) (27\eta - 2 (2 - \beta) (4 - 5\beta)) + (27\beta \eta + 4 - 2\beta (3 - 2\beta)^2) y_c) / X, \qquad \text{(A6)}$$

where (A6) is nothing else but slightly rearranged expression (11) from the main text. More precisely, the expression $y'(t)$ from (11) is expressed in terms of η, and model parameters obtained through differentiation of the first order condition (A4).

Combining these two equations the upper bound of y_{nc} writes now as

$$y_{nc}^{up} = (B_{nc} - B_c) / (\eta - D_{nc}) + ((\eta - D_c) y_c) / (\eta - D_{nc}) \geq y_{nc}.$$

Then $t_{nc}^* = (A - \alpha + \beta y_{nc}) / 3 \leq (A - \alpha + \beta y_{nc}^{up}) / 3 = t_{nc}^{up}$, the upper bound on t_{nc}.

Thus, the difference between the tariffs is bounded from below by $t_c^* - t_{nc}^{up}$, which can be represented as a function of β, $\eta = h''(y_c)$, and y_c, i.e., $t_c^* - t_{nc}^{up} = \Phi(\beta, \eta, y_c)$. It is possible to show that $\Phi(.)$ increases in y_c. To evaluate the sign of the function $\Phi(.)$ we now introduce the lower bound of y_c that we label y_c^{low} to get $\Phi(\beta, \eta, y_c^{low}) = \Psi(\beta, \eta)$, a lower bound on $\Phi(\beta, \eta, y_c)$.

The lower bound of y_c is obtained again by relying on the mean–value theorem. Namely,

$$h'(y_c) - h'(0) = h''(z) (y_c - 0) => h'(y_c) = h''(z) y_c$$

since $h'(0) = 0$ by assumption and finally, since $h'''(y) \geq 0$,

$$h'(y_c) = B_c + D_c y_c \leq h''(y_c) y_c,$$

whence

$$y_c - y_c^{low} = B_c / (\eta - D_c).$$

Thus, to complete the proof it suffices to demonstrate that $\Psi(\beta, \eta) \geq 0$ for all $\beta \in [0,1]$ and for all η such that duopoly is sustainable. After some arithmetical transformations, it is possible to show that $\Psi(\beta, \eta)$ has the same sign as $\Theta(\beta, \eta)$, namely

$\Psi(\beta, \eta) = 2 (A - \alpha) X \Theta(\beta, \eta) / (81\eta^2 + 4 (2 - \beta)^2 (3 - 2\beta) - 4\eta (2 - \beta) (16 - 5\beta))$, where

$$\Theta(\beta, \eta) = 27\eta^2(4 + 20\,\beta - 15\beta^2) - 2\eta(2 - \beta)^2(12 + 116\beta - 85\beta^2) + 16\beta(1 - \beta)(2 - \beta)^3(3 - \beta).$$

It is easy to show that $\Theta(\beta, \eta)$ increases in η when $\eta \geq 8 / 9$ (see (2)) regardless of β. Thus,

$$\Theta(\beta, \eta) \geq \Theta(\beta, 8 / 9) = 16\,\beta\,(40 + 210\,\beta^2 - 266\,\beta^3 + 90\,\beta^4 - 9\,\beta^5) / 9,$$

and the graph of $9\,\Theta(\beta, 8 / 9) / (16\,\beta)$ is displayed in Figure 1A below. Thus, $t_c^* - t_{nc}^* \; ^3 \; t_c^* - t_{nc}^{up}$ $= \Phi(\beta, \eta, y_c) \geq \Psi(\beta, \eta)$, and $\Psi(\beta, \eta)$ is positive as $\Theta(\beta, 8 / 9)$ is positive.

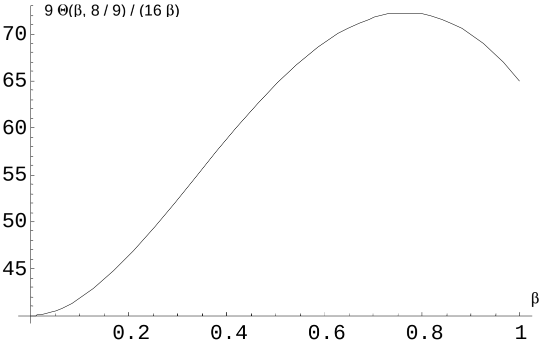

Figure 1A

Appendix 2: Comparison of the tariffs in the two regimes when h(y) = y^2/g

Solving $t_c^* - t_{nc}^* = 0$ for the critical value of $g_t(\beta)$ yields

$$g_t(\beta) = \frac{24+\beta(220+\beta(-286+85\beta))}{8(1-\beta)(2-\beta)^2(3-\beta)\beta}$$

$$-\frac{\sqrt{(2-\beta)}\sqrt{(288-\beta(-240+\beta(-1040+\beta(-1416+5\beta(78+149\beta)))))}}{8(1-\beta)(2-\beta)^2(3-\beta)\beta},$$

where $g_t(\beta)$ represents an upper bound below which $t_{nc}^* < t_c^*$. However, as seen from Figure 2A, $g_t(\beta) > g_{cr}(\beta)$ for all $\beta \in [0,1]$ where

$$g_{cr}(\beta) = \frac{9}{(2-\beta)(4-2\beta+\sqrt{(7-(7-4\beta)\beta)})} .$$

delineates the upper border of the duopoly's feasability region when $\beta < ½$ and it is obtained by solving the equation $q_f^*(.) = 0$ (see Appendix 4). Consequently, the whole feasibility region for the duopoly market structure is a proper subset of the region $g(\beta) \leq g_t(\beta)$, implying $t_c^* - t_{nc} > 0$ will hold in the whole duopoly region.

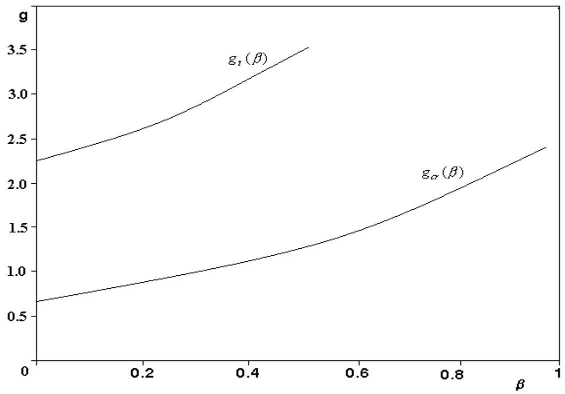

Figure 2A

Appendix 3: Viability of Duopoly

For the duopoly to be a viable market form the best response of the foreign firm should be such that $q_f^* > 0$ holds in equilibrium. We start with the more complicated commitment case. The optimal output of the foreign firm expressed as the function of y_c (t) and t_c is given by

$$q_f^* = \frac{1}{3}(A - \alpha - 2t_c^* - y_c(1 - 2\beta)) \tag{A1}$$

where

$$t_c^* = \frac{2(A-\alpha)(4-5\beta) - y(1-2\beta)^2(2-\beta) - 27(A-\alpha+y\beta)h''(y)}{4(7-2\beta)(2-\beta) - 81h''(y)}. \tag{A2}$$

By substituting (A2) in (A1) and setting it to zero, we obtain the upper bound of y_c, that we label as y_c^{up}:

$$y_c^{up} = \frac{(A-\alpha)(4(2-\beta)(1+\beta) - 9h''(y))}{8(1-2\beta)(2-\beta) - 9(3-4\beta)h''(y)}.$$

To obtain the lower bound, we use the mean–value theorem, and the fact that

$$h''(y_c)\,(y_c - 0) > h'(y_c) - h'(0) \Rightarrow h''(y_c)\, y_c > h'(y_c)\,.$$

Thus, the lower bound is obtained by turning the above inequality into the equation and rearrange it to obtain:

$$y_c^{low} = h'(y_c)\,/h''(y_c). \tag{A3}$$

The explicit expression for h' (y_c) is obtained from the corresponding first–order condition:

$$h'(y_c) = 2\,(2 - \beta)\,(A - \alpha + t_c + (2 - \beta)\, y_c)\,/\,9. \tag{A4}$$

We then substitute (A2) in (A4) and subsequently substitute so obtained expression into (A3) to get the lower bound, y_c^{low}:

$$y_c^{low} = \frac{4(A-\alpha)(2-\beta)((2-\beta)^2-6h''(y))}{4(16-5\beta)(2-\beta)h''(y)-81h''(y)^2-4(3-2\beta)(2-\beta)^2}.$$

Finally, setting $y_c^{up} > y_c^{low}$ yields (A5) that is identical to (ii) from the main text:

$$h''(y) > \frac{2}{9}(2-\beta)(4-2\beta+\sqrt{(7-(7-4\beta)\beta)}). \qquad \text{(A5)}$$

The same exercise can be repeated for the non–commitment case yielding

$$h''(y) > \frac{8}{9}(1-\beta)(3-\beta), \qquad \text{(A6)}$$

but (A6) is less restrictive than (A5) (see Fig A3). So the intersection of the two is just the parameter space determined by (A5).

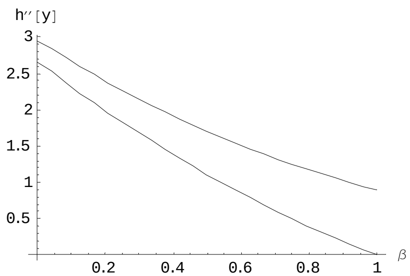

Figure 3A

Appendix 4: Viability of Duopoly– regions of parameters g and β when $h(y) = y^2/g$

We start with the commitment regime. For the duopoly to be a viable market form the best response of the Southern firm should be such that $q_f^* > 0$ holds in equilibrium. This requirement is summarised in the key assumption (ii) in the main text. When $h(y) = y^2/g$ the condition (ii) transforms into the following specific expression imposing the upper bound on the innovating efficiency parameter g (see Figure 4A):

$$g_{cr}(\beta) = \frac{9}{(2-\beta)(4-2\beta+\sqrt{(7-(7-4\beta)\beta)})} .$$

Moreover, sufficient condition requires that $W^*_c(t^*(\beta),\beta) \geq W^*_m$, that is, social welfare in duopoly, W^*_c, be higher than the corresponding social welfare, W^*_m , generated when the Northern firm acts as monopolist. For $h(y) = y^2/g$, this yields another upper bound on parameter g described by the function $g_{cc}(\beta)$ in Figure 4A. (The explicit expression for $g_{cc}(\beta)$ is extremely messy and therefore will not be reproduced here.) Thus, if $g < g_{cc}(\beta)$, social welfare in duopoly exceeds the welfare from monopoly. The curve g_{cc} is relevant only if $\beta > ½$ since it is easy to demonstrate that welfare in a monopoly is never higher than welfare in a duopoly if $\beta < ½$. A similar procedure was performed for the non–commitment regime, but since it yields the broader regions of the parameters, the intersection of the two feasible regions coincides with the feasibility region of the commitment regime.

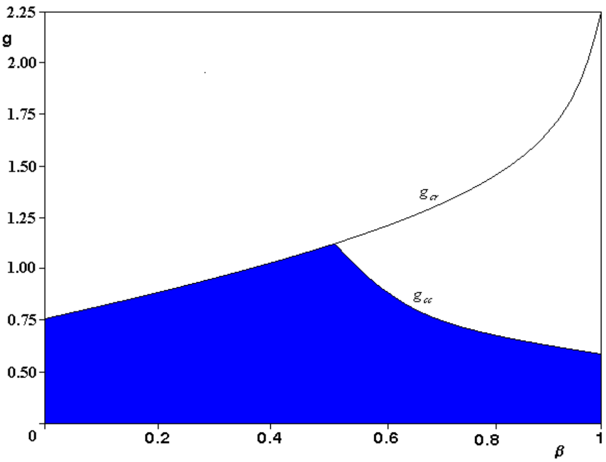

Figure 4A

Appendix 5: Comparison of the unit cost reductions in the two regimes

The optimal unit cost reductions are determined from the first–order conditions, namely

$$h'(y_c) = 2\,(2 - \beta)\,(A - \alpha + t_c + (2 - \beta)\,y_c) / 9 \qquad \text{(A1a)}$$

in the commitment case and

$$h'(y_{nc}) = 8\,(3 - \beta)\,(2\,(A - \alpha) + (3 - \beta)\,y_{nc}) / 81 \qquad \text{(A1b)}$$

in the non–commitment case. Also recall that the sustainability of duopoly (assumption (ii) in the main text) requires that

$$h''(y^*) \geq 2\,(2 - \beta)\,(4 - 2\beta + (7 - 7\beta + 4\beta^2)^{1/2}) / 9 \qquad \text{(A2)}$$

under both regimes.

If the R&D levels are the same ($y_c^* = y_{nc}^*$), then from (A1a) and (A1b) it follows that the commitment tariff should equal

$$t_c^{eq} = ((6 + \beta)\,(A - \alpha) + (12\beta - 5\beta^2)\,y_c) / (9\,(2 - \beta)).$$

If the actual level of t_c^* is less (greater) than t_c^{eq}, then y_c is less (greater) than y_{nc}. This actual level, obtained by setting $dW(y_c(t_c),t_c) / dt_c = 0$, is

$$t_c^* = ((A - \alpha)(27\eta - 2(2 - \beta)(4 - 5\beta)) + (27\beta\eta + 4 - 2\beta(3 - 2\beta)^2) y_c) / X, \qquad \text{(A3)}$$

where again

$$\eta = h''(y_c) \text{ and } X = 81\eta - 4(2 - \beta)(7 - 2\beta).$$

The difference $t_c^* - t_c^{eq}$ can be written as $2Y/9Z$, where

$$Y = (A - \alpha)(24+\beta(220+\beta(49\beta-214)-62\eta)) + y_c(36 + \beta((2\beta - 3)(8\beta^2+\beta-52) + 81(\beta-3)\eta))$$

and $Z = (2-\beta)X$. The condition (A2) yields

$$X \geq 2(2 - \beta)(22 - 14\beta + 9(7 - 7\beta + 4\beta^2)^{1/2})$$

which is obviously positive. Hence $Z > 0$.

Now it remains to show that $Y < 0$ for $\beta > 0.10335$. Condition (A2) yields an upper bound on Y which can be written as $f_1(\beta)(A-\alpha)+f_2(\beta)y_c$, where

$$f_1(\beta) = 12 + 23\beta^2 - 4\beta(7 + 9(7 - 7\beta + 4\beta^2)^{1/2}) \text{ and}$$

$$f_2(\beta) = 18 + \beta(2\beta(85 - 26\beta + 9(7 - 7\beta + 4\beta^2)^{1/2}) - 3(43 + 18(7 - 7\beta + 4\beta^2)^{1/2})).$$

The figure 5A shows the graphs of the functions $f_1(\beta)$ and $f_2(\beta)$. Each of them has a unique zero point in [0,1] which can be approximated numerically as 0.10334 and 0.071512, respectively. Therefore, for $\beta > 0.10335$, both $f_1(\beta)$ and $f_2(\beta)$ are negative, which implies that $Y < 0$ and hence $t_c^* - t_c^{eq} < 0$ and $y_c < y_{nc}$.

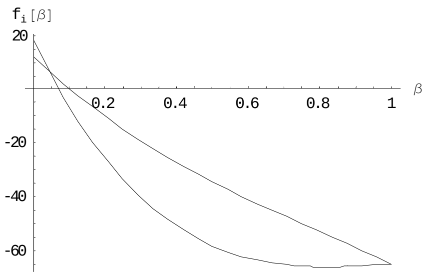

Fig 5A

Appendix 6: Comparison of the unit cost reduction in the two regimes when h(y) = y^2/g

Solving $y_{nc}^* - y_c^* = 0$ for the critical value of $g_r(\beta)$ yields:

$$g_r(\beta) = \frac{648\beta}{24+\beta(220-\beta(214-49\beta))+\sqrt{(2-\beta)^2(144+\beta(2784-\beta(3272-(9368-2783\beta)\beta)))}},$$

where $g_r(\beta)$ represents an upper border below which $y_{nc}^* > y_c^*$. Adding the upper contour of the duopoly feasibility region, $g_{cr}(\beta)$, shows that there is a non–empty intersection for which (shaded area in Figure 6A) $y_c^* > y_{nc}^*$. The critical value of the $\beta_r(g)$ is obtained by inverting the function $g_r(\beta)$. Note that irrespectively of the value of g, $y_{nc}^* > y_c^*$ for any β such that $\beta > \beta_1^r$ where the value of $\beta_1^r = 0.0909$.

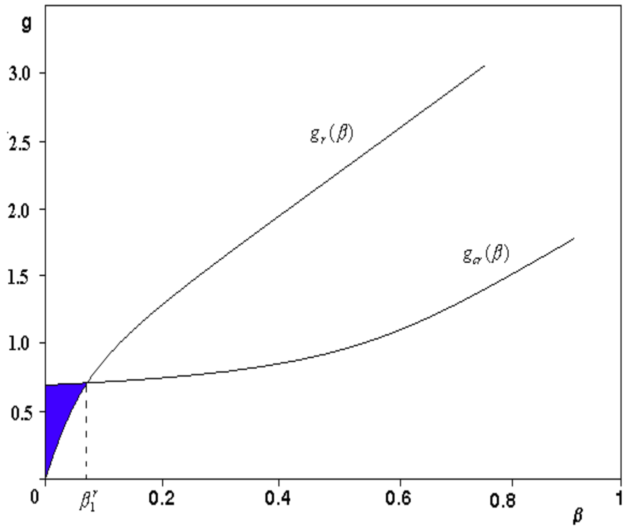

Figure 6A

Appendix 7: Comparison of the social welfare in the two regimes when h(y) = y^2/g

Solving $W_{nc}^* - W_c^* = 0$ for the critical value of $g_w(\beta)$ implies

$$W_{nc}^* - W_c^* = \frac{(5103 - 8g(129 - 6g(1-\beta)^2(3-\beta) - 97\beta)(3-\beta))}{2(81-4g(3-\beta)^2)^2} + \frac{(63 + g(16 + g(-2+\beta)(1-\beta)^2 - 14\beta)(-2+\beta))}{2(-81 + g(-2+\beta)(-32+10\beta + g(2-\beta)(3-2\beta)))} = 0.$$

To get the critical value $g_w(\beta)$ that depicts the upper border below which $W_{nc}^* > W_c^*$, it is necessary to solve the following equation for g:

$$16g^3(1-\beta)^2(2-\beta)^2(3-\beta)^2\beta^2 - 648\beta(6+29\beta) - 8g^2(1-\beta)(2-\beta)(3-\beta)\beta(12-\beta(-116+49\beta)) + g(144+\beta(2784+\beta(16168+\beta(-19144+4993\beta)))) = 0.$$

Since the solution is extremely messy, it will not be reproduced in the text. The intersection of the areas of $g(\beta) \geq g_w(\beta)$ and $g(\beta) \leq g_{cr}(\beta)$ yields a small shaded area for which $W_c^* > W_{nc}^*$ (see Figure 7A1).

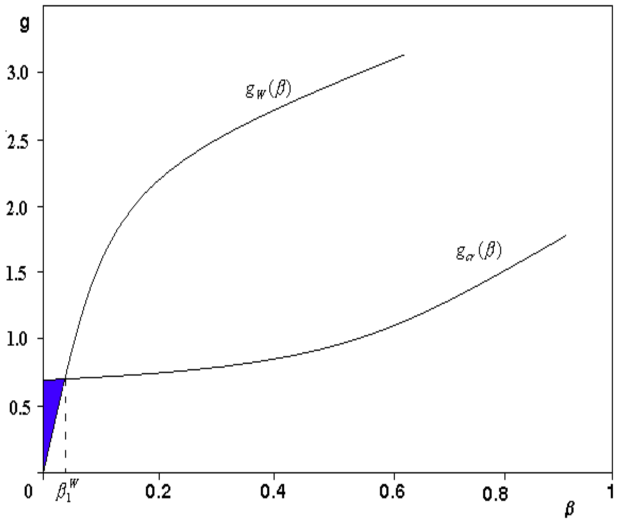

Figure 7A1

The critical value of $\beta^w(g)$ is obtained by inverting $g_w(\beta)$. Note that irrespective of the value of g, $W_{nc}^* > W_c^*$ for any β such that $\beta > \beta_1^w$ where $\beta_1^w = 0.03909$. The graphical representation of W_{nc}^*, W_c^* and W_{ft}^* (social welfare in a free trade regime) is given in Figure 7A2 below.

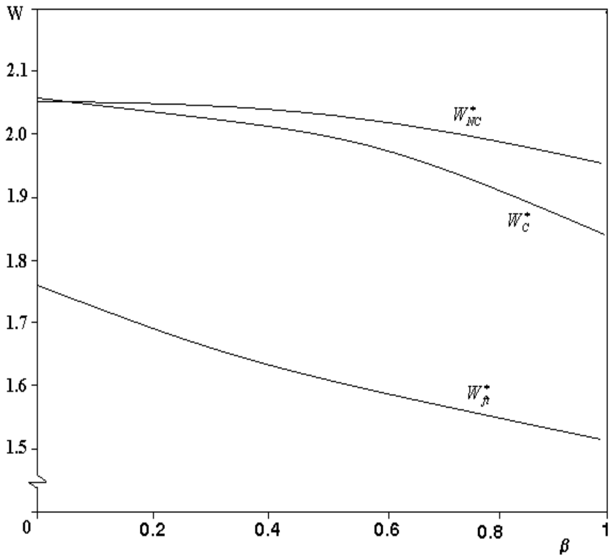

Figure 7A2

Chapter IV

Strategic Tariff Protection, Market Conduct, and Government Commitment Levels in the South

A Symmetric versus Asymmetric Information Analysis

1. INTRODUCTION

In this chapter, we change the perspective, and focus on the Southern market as the centre of action. As consequence, the key normative part of our analysis deals extensively with some trade policy issues and concerns of the Southern policy makers.

The conventional wisdom originating from, for example, the Washington consensus, states that a prerequisite for a developing (or transition) country to achieve a stable growth path is, among other things, to liberalize its trade. However, a recent study by Rodriguez and Rodrik (2001) casts doubt on this previously unchallenged "truth". The authors show that the countries that initially follow a trade protection policy and other import substitution policies, display respectable economic growth per capita for a substantial period of time. They also demonstrate that the subsequent economic crises in some of these countries are not necessarily due to the pursued trade polices, but rather are consequences of bad macro management and adverse external shocks. Rodrik (2001) concludes that trade liberalization is an outcome rather than a precondition for successful economic development.

The above considerations suggest that it might be desirable for a developing economy to protect some of its industries that are believed to have a long–run perspective. Thus, delicate issues here are which industries should be protected and when and how the government may try to assist them. Without entering too much into details of these issues, it could be expected that the selected industry or firm should be one that is capable of narrowing the technological gap *vis–à–vis* its counterparts in developed countries. This in turn would require that the developing country firm is able to invest efficiently in innovation, or more likely, to closely imitate the advanced technology. Moreover, the initial technological level of the developing country firm should not lag too far behind its developed country counterpart so that it is unable to innovate or directly compete with the developed country's firm given an adequate protection policy.

A variety of policy instruments would protect the domestic market and enhance domestic innovation or imitation. However, as far as the policy choice is concerned, our aim here is rather modest: The criterion for policy selection is not a first–best possible policy mix, but a simple and transparent policy that enhances social welfare.

The standard tools for import protection used in developing countries are tariffs. Tariffs are known to enhance both the innovative effort of the domestic firm and the social welfare[1] of the country (see, for instance, Reitzes, 1991; Žigić, 2000; Bouët, 2001; and Qiu and Lai, 2001). The optimal level of tariff protection is not likely to be prohibitive, since the presence of the foreign competitor on the market in the form of imports might also be beneficial for consumers, for the domestic firm's incentive to innovate or imitate[2], and for the state treasury as a source of funds. Yet, foreign firms might "jump over" the tariff by establishing affiliates in the domestic market making, therefore, the tariff policy ineffective (see Motta, 1992). We exclude this case by assuming that it is not optimal for foreign firms to enter the domestic, developing country market due to, for example, prohibitively high entry (sunk) costs in this market. Alternatively we may assume that there is a ban on foreign direct investment. One reason for a ban on foreign direct investment, may, for instance, be that it

[1] The link between tariffs and the innovative (or imitative) activity of the domestic firm is often considered the core of the infant industry argument.

[2] Žigić (2000) shows that the incentives to innovate in a duopoly are higher than in a monopoly in the absence of unilateral R&D spillovers from the innovative firm to the receiving firm.

leads to a crowding out of domestic entrepreneurship in a particular industry (see Das, 2002). Thus, in our setup, another "policy tool" that complements tariffs is the competition of the foreign firm in terms of domestic imports. Unlike tariff protection, we treat this former policy as exogenously given.

Although R&D subsidies are another standard policy tool that enhances the innovative or imitative effort of the domestic firm, the typical developing country usually does not have the financial resources to subsidize R&D investment. In addition, implementing a subsidy might be troublesome for numerous reasons arising from the high information content required to implement the optimal subsidy to the distorting effects of taxes necessary to finance the subsidy (Bhattacharjea, 1995). Moreover, as Krugman (1989) notes, less developed countries are often unable to commit to future subsidies. Therefore, we discount the possibility of subsidization in our analysis.

This chapter is motivated by the potential importance of this "tariffs *cum* foreign competition" policy which should enable developing economies to start the catch–up process for those of its industries that exhibit the greatest comparative advantage. We analyze plausible variants of the above policy set–up in terms of social welfare generated, and in terms of the informational requirements for their implementation. We also check whether these policies are prone to time consistency problems and the strategic behaviour (manipulation) of the domestic firm. We then compare the polices with free trade and with other relevant benchmark polices, like the hypothetical case in which the domestic government can set the domestic firm's innovative level in addition to setting the tariff.

The "plausible variants" of our trade policy arise due to several factors. The first and the most familiar of these is that the market under consideration is likely to be oligopolistic. In practice, it is often the case that there are only one or a few domestic firms in the industry to be protected by the domestic government and a few foreign competitors. As is well known, even in such a seemingly simple framework, both policy implementation and policy conclusions might be rather sensitive to factors like underlying oligopoly conduct (see Eaton and Grossman, 1986). For example, depending on the type of market competition, levying both tax and subsidy can be an optimal trade policy when domestic and foreign firms compete in a third market.

The second source of possible variations in our policy set–up lies in the (in)ability of the domestic government to commit to its policy (see, for instance, Karp and Perloff 1995; Neary and Leahy; 2000, and Žigić, 2003). This idea can be traced to Carmichael's (1987) observation that governments often set the level of their policy instrument only after firms have already chosen the level of some strategic variable. In this context, a domestic firm might influence (or manipulate) the government's policy response through the level of their variable. This strategic behaviour of the domestic firm against the local government causes inefficiencies that may lead to lower social welfare compared to the corresponding social welfare under free trade.

The third and last factor that we consider as a potential cause of policy variation stems from asymmetric information between the firms and the government. As Qiu (1994) points out "... it is reasonable to expect that policymakers have less information than firms concerning production and markets" (p 334). Unlike the majority of existing literature on asymmetric information in strategic trade which assumes cost or demand parameter uncertainty (Qui, 1994; Grossman and Maggi, 1998; Maggi 1999; Bhattacharjea, 2002, among others), we focus here on the particular information asymmetry that arises from the government's uncertainty about the mode of competition (Maggi, 1996 and Ionaşcu and

Žigić, 2005).[3] The relevance of such uncertainty is caused by the fact that the optimal intervention policy might vary with the type of market conduct. If the domestic government does not have full information on the type of market conduct it might set a suboptimal trade instrument that could lead to a lower social welfare than the *laissez faire* level (Ionaşcu and Žigić, 2005).

In modelling the above set–up, we rely on a multistage game where we allow for strategic investment in technology catch–up by the domestic firms that may exhibit the features of industries in developing countries. This investment may take the form of technological upgrading or costly imitation undertaken by the domestic firms in order to acquire the developed country's technology. We consider two polar types of market conduct (Cournot versus Bertrand), and two different timings of government intervention (before investment in technological upgrading occurs and after it). With this model, we test the robustness and the informational requirement across different competition types, as well as different government commitment levels. Moreover, since strategic policies are often criticized for their sensitivity to the type of market competition, we assess how the presence of information asymmetry may affect domestic social welfare. We consider a set–up with asymmetric information in which firms are fully informed about the type of market conduct while the domestic government may only hold some rational beliefs about it.

It is important to stress at the outset that our approach is distinct from the "infant industry protection" analysis. The latter is explicitly concerned with the economic consequences of trade liberalization, or the removal of the tariff barriers about to take place in

[3] Klemperer and Meyer (1986) and Maggi (1996) point out that the type of market competition might be endogenously determined by the nature and severity of demand uncertainty and by the perceived costs of expanding production above the installed capacities, respectively. In principle, by analyzing these factors the government can infer the nature of market competition. Yet, these factors are difficult to measure as they are of a subjective nature. Even when these difficulties can be surpassed and an adequate measure can be computed, a government from a less industrialized country might lack the necessary resources or might be unwilling to cover the costs of gathering the necessary information. In addition, when the marginal cost is constant, the presence of uncertainty does not reveal the type of market competition, and therefore, both Cournot and Bertrand outcomes are equally plausible (Klemperer and Meyer, 1986).

a specific time horizon (see infant industry papers like Wright, 1995; Leahy and Neary, 1999; Miravete, 2001). In our approach, the issue of removing tariff barriers is beyond the scope of the analysis. We assume that the protection lasts "for a substantial period of time", as Rodrik (2001) has demonstrated, and that if trade liberalization is ever to happen, it would take place during an uncertain, very long period so that the protected firms do not take this into account in their economic calculations.

Furthermore, our analysis is linked to the work of Bhattacharjea (1995) who also analyses tariff policy on the domestic market in the context of developing countries. He comes to the conclusion that tariffs are robust in different market conducts, and that the informational requirement necessary for identifying their optimal level is not too large compared with, say, investment or output subsidies. In addition, the agency problem does not arise in Bhattacharjea‘s analysis. However, he considers neither prior strategic R&D investment by firms nor the assumption of possible information asymmetries. Furthermore, he does not analyze the situation when the government can commit in advance to its policies.

Bhattacharjea's result, in which tariffs are robust instruments with respect to the market competition type, carries over fully in our more complex set–up. In addition, we prove that these results hold for different government commitment levels. Regardless of the government's ability to commit to its policy and regardless of the type of market conduct, the foreign rent extraction effect, the reduction in domestic oligopoly distortion effect, and the beneficial effect on domestic innovative (imitation) activity, are strong enough to justify a positive tariff, so that social welfare under protection is always higher than under free trade.

The presence of asymmetric information might have a beneficial effect on domestic social welfare in our set–up. In the first case, in which the government is assumed to be unable to update its prior beliefs about the type of market conduct, a non–committed domestic government will in some cases choose tariff levels that are higher than the symmetric information tariffs and thus generate higher social welfare than in the case of symmetric information. In the second case, where information is asymmetric, the government is allowed to update its beliefs after it observes the firm's R&D effort. Since the firm with a Cournot conduct may have an incentive to signal its type and differentiate itself from the Bertrand firm, it would invest more in R&D, possibly generating higher social welfare as compared to the corresponding perfect information case.

With regard to the information requirements for the implementation of the optimal policy, the information burden in the case of the government commitment regime is higher compared to the non–commitment case, and is, in addition, prone to the manipulative behaviour of the domestic firm. The committed government sets the tariff level to enhance domestic innovation effort and needs to know the domestic technology and production parameters.

The remainder of the chapter is organized in seven sections. In the second section, we define the model that is followed by a description of the "first–best" optimal R&D and tariff protection choice. Sections four, five, and six establish the equilibria in the government "non–commitment" regime, free trade and the government "commitment" regime, respectively. In section seven, we introduce asymmetric information concerning the competition type. The last section summarizes the main findings of the chapter IV.

2. THE MODEL

We focus on the domestic country. We assume that in this country three different goods are consumed. Two of them are differentiated products produced in an oligopolistic sector while the third one, the *numeraire*, is produced domestically in a competitive sector.

The first two varieties are supplied by a domestic and a foreign firm that compete either in prices or in quantities in the domestic country.[4]

Domestic consumers are of the same type and their preferences are continuously and uniformly distributed on the unit interval. In addition, we assume that the representative consumer has a separable utility function, linear in the *numeraire* good. Thus, there is no income effect on the consumers' consumption of differentiated goods. The representative consumer's maximization problem can be written as

$$\max_{q^d, q^f} \left\{ U(q^d, q^f) - p^d q^d - p^f q^f \right\}$$

(q^d and q^f denote the consumption of differentiated goods produced by the domestic and the foreign firm, respectively, p^d and p^f are their respective prices, and $U(\cdot,\cdot)$ stands for the consumer's subutility function of consuming the differentiated goods). Moreover,

$$CS(q^d, q^f, p^d, p^f) = U(q^d, q^f) - p^d q^d - p^f q^f$$

is an exact measure of consumers' surplus. Like Singh and Vives (1984), we assume that $U(\cdot,\cdot)$ is a quadratic and strictly concave function given by

$$U(q^d, q^f) = \alpha_d q^d + \alpha_f q^f - \frac{1}{2}[\beta_d (q^d)^2 + 2\gamma q^d q^f + \beta_f (q^f)^2],$$

where $\alpha_i > 0$. From the strict concavity assumption, it follows that $\beta_i > 0$ and $\beta_d \beta_f - \gamma^2 > 0$, for $i = d, f$. Also, to ensure the existence of direct demands we assume that $\alpha_i \beta_j - \alpha_j \gamma > 0$ for $i \neq j$, $i = d, f$. The parameter γ quantifies the type and the degree of differentiation between the two varieties. We assume that the two differentiated varieties are substitutes, so $\gamma \geq 0$.

Following the utility maximization problem the inverse demands are linear and are given by

$$p^d(q^d, q^f) = \alpha_d - \beta_d q^d - \gamma q^f \qquad (1)$$

[4] We assume that there is no consumption of the differentiated variety in the foreign country. Alternatively, we can assume that the foreign and the domestic market are segmented.

$$p^f(q^d, q^f) = \alpha_f - \beta_f q^f - \gamma q^d. \quad (1')$$

The original technology of the domestic firm lags behind that of the foreign firm. It requires a pre–innovation unit cost of *c*, while the corresponding value for the foreign firm, c_f, is lower than *c* and, for simplicity, is set to zero. To catch up with its rival before facing its competitor in the market the domestic firm engages in process R&D activities. The decrease in marginal cost due to the innovative effort is denoted by *x*. To obtain an *x* (≤ *c*) decline in the unit production cost, the domestic firm has to incur $k{\cdot}i(x)$ costs, where $i(0) = 0$, $i'(x) \geq 0$, and $i''(x) \geq 0$, for any *x* on [0, *c*]. Any innovative effort aiming to decrease the marginal cost below 0 brings the R&D costs to infinity. The parameter *k* describes the efficiency of the innovative process and so *k* can be viewed as the indicator of the domestic's firm ability to narrow the technological gap. We further assume that the technology of the foreign firm is mature enough and does not require any R&D efforts.

The government in the domestic country considers raising the innovative activities of the local firm and social welfare by introducing a tariff. We assume a benevolent government that cares about all the agents in the domestic economy (consumers, the local producer, and its own revenue). In what follows, the variable *t* stands for the specific tariff level ($t = 0$ when there is no tariff protection).

Depending on the government's ability to commit to its policy, we consider two related three–stage games. If the government can commit in advance, the actual level of tariff is set before the domestic firm sets its innovate efforts. Then, in the first stage of the game, the domestic government announces the tariff protection level (0 if there is no intervention). In the second stage, the domestic firm invests in R&D. Finally, in the third stage, the two firms meet in the domestic market where they compete either in prices or in quantities. We refer to this game as the government "commitment" case. When the optimal tariff is chosen after the R&D is already in place but before competition takes place, the first and the second stages of the game are reversed. So, first the domestic firm chooses its level of innovation, then the domestic government sets the level of tariff protection. At the end, the competition in the market takes place. We call this game the government "non–commitment" case.

Using the above notations, we can write the firms' profits in the domestic market as

$$\pi^d(s^d, s^f; x) = q^d[p^d - (c - x)] - ki(x) \tag{2}$$

$$\pi^f(s^d, s^f; t) = q^f[p^f - t], \tag{2'}$$

where s stands for q if the firms compete in quantities and for p when they compete in prices. However, running a separate analysis for the quantity competition and for price competition is arduous, cumbersome and messy. In order to avoid this, we put both the Bertrand and Cournot analyses under a common umbrella. Namely, we assume that each firm has an explicit conjecture about its competitor output choice (see e.g. Eaton and Grossman, 1986; Dixit 1988 or Martin, 1993). These conjectures are defined by parameters v_d, v_f and by means of them we can easily reproduce both the Cournot and Bertrand equilibria since $v_d = v_f = 0$ for Cournot competition and $v_d = -\frac{\partial p^f/\partial q^d}{\partial p^f/\partial q^f} = -\frac{\gamma}{\beta_f}$, $v_f = -\frac{\partial p^d/\partial q^f}{\partial p^d/\partial q^d} = -\frac{\gamma}{\beta_d}$ for Bertrand competition. We can regard now the last stage of the game as a quantity decision subgame, but depending on the choice of parameters v_d and v_f, we actually get either the Cournot set–up or the Bertrand set–up.[5] To simplify the notations and the formulas, we set $V_d = \beta_d + \gamma\, v_d$ and $V_f = \beta_f + \gamma\, v_f$ (a possible interpretation of V_d and V_f will be given later). It is straightforward to verify that for both the Bertrand and Cournot conjectures, the property $V_d\beta_f - V_f\beta_d = 0$ holds.

In what follows we assume that under tariff protection (with or without government commitment), the cost and demand parameters are such that the equilibria are characterized by interior solutions for the product competition stage and levels of innovation higher than

[5] See Maggi (1996) for a different unified treatment of Bertrand and Cournot competition where choice variables are prices and where the capacity constraint determines the equilibrium outcome (Cournot or Bertrand). Apart from conjectures describing the Bertrand and Cournot equilibria, we do not use here a full–fledge conjectural variation model (see Dixit (1988) on the strengths and limits of this approach).

zero. Using the above notations, these requirements impose the following constraints on parameters:

$$c < \alpha_d . \tag{A1}$$

$$ki'(0) < \frac{2V_d(V_f+\beta_f)^2}{[(V_d+\beta_d)(V_f+\beta_f)-\gamma^2]^2}\left[\alpha_d - c - \frac{\gamma}{2V_f+\beta_f}\alpha_f\right]. \tag{A2}$$

$$ki''(x) > \frac{2V_d(V_f+\beta_f)^2}{[(V_d+\beta_d)(V_f+\beta_f)-\gamma^2]^2},\ \forall x \in (0,c). \tag{A3}$$

The first constraint, (A1), requires the home firm to be a viable monopoly, even without innovating. The second condition, (A2), guarantees R&D levels larger than zero in the case of tariff intervention (with or without government commitment). It ensures that the domestic firm benefits from its first unit of innovation. The last assumption, (A3), ensures that the second order conditions for the profit maximization problems are satisfied. Note that the assumptions (A2) and (A3) implicitly determine the lower and the upper bound of the R&D efficiency parameter, *k,* in general. Namely, (A2) requires *k* to be sufficiently low so that the domestic firm is efficient enough and has a good R&D potential to benefit from its R&D, for its given market size. On the other hand, *k* in general, needs to have the lower bound for the problem under consideration to be nontrivial. That is, (A3) calls for *k* high enough for domestic social welfare to be a strictly concave function in *t*.

When necessary, to distinguish both the firms' and government's choices between the two different types of competition, we will use superscript *C* for variables in Cournot competition and superscript *B* to denote Bertrand values.

3. THE "FIRST–BEST" EQUILIBRIUM

We begin the social welfare analysis by deriving and discussing the hypothetical socially optimal equilibrium in which the government, besides the tariff, would be able to choose directly the level of its firm's innovative (or R&D) effort.[6] For convenience, we label this equilibrium the "first–best" optimum[7]. In this case, tariff and innovation levels are chosen at the same time, and the game is solved (like all other games under consideration) backwards in order to find the subgame perfect equilibria. The first order conditions associated with the profit maximization problems are

$$p^d - (c - x) - V_d q^d = 0 \tag{3}$$

$$p^f - t - V_f q^f = 0 \tag{3'}$$

(where V_d and V_f could be interpreted as the slopes of the perceived inverse demands for the home and foreign firm respectively; see Singh and Vives, 1984). The optimal quantities that solve the system of equations (3) and (3') are given by

$$q^d(x,t) = \frac{1}{(V_d + \beta_d)(V_f + \beta_f) - \gamma^2}\left[(V_f + \beta_f)(\alpha_d - c + x) - \gamma(\alpha_f - t)\right] \tag{4}$$

$$q^f(x,t) = \frac{1}{(V_d + \beta_d)(V_f + \beta_f) - \gamma^2}\left[(V_d + \beta_d)(\alpha_f - t) - \gamma(\alpha_d - c + x)\right]. \tag{4'}$$

Taking into account the first order condition (3), the domestic firm's profit (2) can be rewritten as

$$\pi^d(x,t) = V_d (q^d(x,t))^2 - ki(x) \tag{5}$$

where $q^d(x, t)$ is given by (4).

We can now solve for the "first–best" values of R&D and tariff. Since we assumed that the domestic government cares about all the agents in the economy, its social welfare function is given by

$$W = CS + \pi^d + t\,q^f = U(q^d, q^f) - [(c - x)q^d + ki(x)] - [p^f - t]q^f. \tag{6}$$

It follows that an infinitesimal change in the subgame perfect equilibrium produces a

[6] Note that in terms of social welfare this is equivalent to assuming that the government can set an optimal R&D subsidy (tax).

[7] However, the usage of the term "first–best" is not completely correct here since the true "first–best" policy in our set–up would also involve an output subsidy to correct for oligopoly distortion (see also footnote, 10). Nevertheless, we use the term "first–best" to distinguish it from polices where only tariff is available.

social welfare effect

$$dW = (p^d - c + x)dq^d - q^f d(p^f - t) + tdq^f + (q^d - ki'(x))dx\,, \qquad (7)$$

that is a combination of four different effects: (i) a domestic oligopoly distortion effect: from a social point of view, domestic output produced in equilibrium is too small since its marginal utility ($p^d dq^d$) exceeds its marginal cost ($(c-x)dq^d$); (ii) a positive terms of trade effect: a tariff causes the net foreign price ($p^f - t$) to fall when the demand function is linear; (iii) a volume of trade effect: a decrease in the quantity of imported goods has a negative impact on the tariff revenue; (iv) a cost reduction effect: an increase in innovation has a positive effect on the domestic firm's profit. While the first three effects were present in Dixit (1988) and Cheng (1988)[8], the fourth effect is new and is specific to this set–up with R&D innovation.

Using the foreign firm's first order condition (3') we can rewrite the total social welfare effect (7) as

$$dW = (p^d - c + x)dq^d - [V_f q^f - t]dq^f + (q^d - ki'(x))dx\,. \qquad (8)$$

When we employ in (8) the home firm's first order condition (3) and the inverse demand (1) we obtain

$$dW = \left(V_d q^d + V_f \frac{V_d + \beta_d}{\gamma} q^f - \frac{V_d + \beta_d}{\gamma} t \right) dq^d + \left(q^d - ki'(x) - V_f \frac{1}{\gamma} q^f + \frac{1}{\gamma} t \right) dx\,. \qquad (9)$$

From (4) and (4') we see that q^d can be expressed independently of x as a function of q^f, t, and the model's parameters. Thus, q^d and x are linearly independent variables. In this situation, to have $dW = 0$ for arbitrary values of dq^d and dx (not both zero) as the social welfare maximization problem requires, it is necessary and sufficient that the values of both parentheses in (9) equal zero.

When we equate the first parenthesis of formula (9) to zero, that is

[8] Cheng (1988) calls the third effect an "import consumption distortion effect". See a more detailed description of these first three effects in that paper.

$$V_d q^d + V_f \frac{V_d + \beta_d}{\gamma} q^f - \frac{V_d + \beta_d}{\gamma} t = 0, \tag{10}$$

we obtain the "first–best" value of tariff

$$t_{so} = V_f q^f + \gamma \frac{V_d}{V_d + \beta_d} q^d. \tag{11}$$

The optimal tariff serves to extract foreign duopoly rents and to eliminate part of the domestic oligopoly distortion by enhancing the home firm's market share.[9] This latter role, however, could be more efficiently performed by an output subsidy/tax, and therefore, an optimal policy mix would also incorporate an output policy (see Dixit, 1988).[10]

By replacing in the optimal tariff formula (11) the actual quantities q^d and q^f from formulas (4) and (4'), and by exploiting the fact that $V_d \beta_f - V_f \beta_d = 0$ for both Bertrand and Cournot conjectures, we obtain a simplified form of this tariff

$$t_{so} = \frac{\alpha_f}{2 + \frac{\beta_f}{V_f}}.^{11} \tag{12}$$

The level of this tariff depends only on the intercept of the foreign inverse demand function and on the ratio between the foreign firm's elasticity of inverse demand and its perceived elasticity. It does not depend on the innovation level x. Consequently, social welfare (6) seen as a function of t and x is separable with respect to these two variables.

To find the "first–best" innovation level, we equate the second parenthesis of formula (9) with zero, and we obtain

$$q^d - ki'(x_{so}) - V_f \frac{1}{\gamma} q^f + \frac{1}{\gamma} t = 0, \tag{13}$$

[9] When tariff and innovation levels are chosen simultaneously (as is the case in this section) a change in tariff has a direct impact on q^d, q^f, and $p^f - t$ but not on x, so only the first three effects from (7) are present.

[10] Actually in this set–up which includes an R&D choice, a combination of three policies forms the first–best policy: a tariff, an output subsidy (tax for price competition), and an R&D subsidy.

[11] Based on Dixit (1988), more parameters would be included in formula (12) (Dixit, 1988 uses slightly different notations than ours). However, for all conjectures that verify $V_d \beta_f - V_f \beta_d = 0$, thus for all conjectures for which there is the same ratio between the firms' elasticity of demand and their perceived elasticities, formula (12) holds. In the case of Cournot conjectures, this was previously noted by Bhattacharjea (1995).

alternatively, in the case of corner solutions for the R&D level, $dx = 0$.

The government would use the innovation effort of its firm as an imperfect substitute for the output subsidy. That is, part of the domestic oligopoly distortion would be reduced through higher R&D investment, since a higher level of innovation would bring about a higher domestic production, thereby reducing the gap between the price and the marginal cost.[12] The government then faces a trade–off between the social benefits from a reduced domestic oligopoly distortion and the associated costs (the costs of innovation and the negative impact on the volume of trade). Therefore, when we employ the "first–best" tariff (11) in (13) we obtain

$$ki'(x_{so}) = q^d(x_{so}, t_{so})\frac{2V_d + \beta_d}{V_d + \beta_d}.^{13} \qquad (14)$$

As we said, the discussion of the "first–best" social welfare and its accompanied optimal values (like unit cost reduction and tariffs), in the hypothetical case when the domestic government can directly and simultaneously determine both R&D effort of its firm and specific tariff, will serve as a benchmark for the comparison with the social welfare and the corresponding optimal values in "more realistic" equilibria. These more realistic equilibria are those in which the government is constrained only to the choice of tariffs or free trade. In the subsequent analysis we will continue to refer to t_{so} and x_{so} as "first–best" socially optimal values and compare them with the corresponding values of t and x in situations when the firm itself chooses unit cost reduction and the government only sets the tariff (either after or before the strategic choice of the domestic firm).

[12] However an output subsidy would still enhance the domestic welfare, since it eliminates the domestic oligopoly distortion that persists even at lower marginal costs.
[13] In the case of corner solutions for R&D investment ($x = c$), this equality becomes inequality: $ki'(x_{so}) < q^d(x_{so}, t_{so})(2V_d + \beta_d)/(V_d + \beta_d)$. This will be the case for all the first order conditions for the R&D level. We derive and prove here all the results considering interior solutions for R&D. However, all the results still hold for corner solutions in innovation. The proofs are available on request.

4. THE "NON–COMMITTED" DOMESTIC GOVERNMENT

We first analyze the situation where the domestic government cannot commit in advance to its policy. If a tariff is introduced, its level is chosen only after the local firm has already selected the level of its R&D effort.

4.1. Tariff policy

The level of the optimal tariff maximizes the social welfare function (6). As we noticed in the previous section, social welfare as a function of x and t is separable, so the optimal tariff will be equal to the "first–best" value described by (12), namely

$$t^* = t_{so} .$$

This is a quite remarkable and somewhat unexpected result. The optimal tariff in a simple set up where the domestic government is not able to commit in advance coincides with the "first–best" tariff. The reason for this is that the optimal tariff does not depend on the innovation effort, since R&D investment in our set–up affects only the domestic marginal cost, which has no effect on the optimal tariff level.[14] However, the independence of the optimal policy instrument on domestic R&D breaks down in the case of subsidies. In a similar set–up but with output subsidies rather than tariffs, we proved that the government's policy depends on the level of R&D investment and therefore is subject to manipulative behaviour from the domestic firm (see Ionaşcu and Žigić, 2005). Another situation where the innovation effort influences the level of the optimal tariff arises when there are spillovers from the innovating to the non–innovating firm (see Žigić, 2003). However, in our set–up, R&D spillovers from domestic to the foreign firm are clearly not an issue at all.

One should note that, t^*, is, in fact, a time–consistent tariff (see Goldberg, 1995). This

[14] In fact, in contrast to the output subsidies, the optimal tariff depends only on the foreign firm's unit cost. If the foreign firm has a c_f marginal cost, then the level of the optimal tariff is $(\alpha_f - c_f)/(2 + \beta_f / V_f)$.

is particularly important in the developing country context, since the governments of such countries often fail to ensure in advance the credibility of their policies (see also Bhattacharjea, 1995, on this issue).

When we replace the values of V_f corresponding to the two types of product competition, the optimal tariff in the Cournot competition case is given by

$$t^{*C} = \frac{\alpha_f}{3}$$

and in the case of Bertrand competition by

$$t^{*B} = \frac{\alpha_f}{3 + \frac{\gamma^2}{\beta_d \beta_f - \gamma^2}}.$$

In the case of Cournot competition the policymakers need to know only the market size of the foreign firm, while in the Bertrand case some extra information regarding the sensitivity of prices to demand and the degree of differentiation is required. Nevertheless, since in both cases no information on domestic costs and R&D investment is required, the agency problem is precluded.

Thus, tariffs as policy instruments prove to be robust and not too demanding in terms of informational requirements and seem to be a good alternative to the first–best policies – a mix of tariffs and output and R&D subsidies/taxes – so often criticized for their sensitivity to market conduct and extensive informational requirements. Nevertheless, there is a greater informational requirement in the Bertrand than in the Cournot type of market interaction. The optimal tariff in Cournot competition is also higher than that in Bertrand. The reason for these differences lies in the role that the domestic tariff performs. The tariff helps to extract rents from the foreign firm, to raise revenue for the domestic treasury and to reduce the consumption distortion induced by the oligopolistic competition. The tariff accounts for the latter effect directly, by enhancing domestic production and, indirectly, through its effect on innovation: Domestic firms expecting that the imports will be subject to a tariff invest more in R&D than under free trade.

The extent to which the tariff protection could be used to extract foreign rents and to reduce the oligopoly distortion is determined by the ratio between the foreign firm's elasticity of inverse demand and its perceived elasticity [see expression (12)], which is in fact a measure of market competitiveness.[15] When markets are less competitive (a low ratio), as is the case with the Cournot type of market competition, there are more foreign profits to be extracted and there is a higher domestic oligopoly distortion to correct for. Therefore, $t^{*C} > t^{*B}$. To compute the ratio between true and perceived elasticity, more information is needed in the case of price competition.[16]

4.2. Optimal R&D effort

Anticipating that the domestic government will adopt the tariff t^*, the domestic firm chooses an R&D level that satisfies the first order condition associated with the maximization problem for the profit (5) evaluated in t^*, namely

$$ki'(x^*) = 2V_d q^d(x^*,t^*)\frac{\partial q^d}{\partial x}(x^*,t^*)\,. \qquad (15)$$

When we replace the first derivative of the quantity q^d given by (4) with respect to x in (15) we get

$$ki'(x^*) = \frac{2V_d(V_f+\beta_f)}{(V_d+\beta_d)(V_f+\beta_f)-\gamma^2}q^d(x^*,t^*)\,. \qquad (16)$$

From the "first best" point of view, this R&D investment level is too low. As (A3)

[15] A firm producing in a less competitive market perceives its demand as being less elastic to changes in prices than a firm performing in a more competitive environment. Consequently, it produces less at higher prices and accrues higher profits.

[16]One should note that the tariffs' formula remains the same for the most general R&D investment cost function. The essential restrictions that support these results are the assumptions of only one firm investing in R&D and constant unit cost.

holds, the right hand side of the equation (16) and the curve $ki'(x)$ have a single crossing property. In addition

$$t^* = t_{so} \text{ and } \frac{2V_d(V_f+\beta_f)}{(V_d+\beta_d)(V_f+\beta_f)-\gamma^2} < \frac{2V_d+\beta_d}{V_d+\beta_d},$$

so x^* is smaller than x_{so} (its implicit formula is given by 14). Moreover, the Cournot competition yields higher R&D levels than its Bertrand counterpart does, thus $x^{*B} < x^{*C}$ (see Appendix 1 for a proof).

The important findings from this section are summarized in Proposition 1 below.

PROPOSITION 1

1. The generated social welfare is below the "first–best" level in both types of market conduct.

2. Both Cournot and Bertrand types of firm under–invest in R&D, x, from the social point of view.

3. The optimal R&D effort (or marginal cost reduction) in Cournot type of competition, x^{*C}, always exceeds the optimal R&D effort in Bertrand type of competition, x^{*B}, for any level of product differentiation, γ, that is, $x^{*C} > x^{*B}$.

4. The optimal tariff in Cournot competition is higher than its counterpart in Bertrand competition, that is, $t^{*C} > t^{*B}$.

Thus, regardless of the market conduct, the social welfare is below the "first–best level". The same is true for R&D investment. Protected by a tariff policy, the domestic firm would find an innovative effort that results in a x_{so} decrease in marginal cost too expensive since it ignores the fact that at the margin the gains in consumer surplus still offsets the losses in profits and tariff revenue for x levels slightly above x^*. In addition, the possibility of socially wasteful over–investment in R&D is precluded by the fact that the optimal tariff in the non–commitment regime does not depend on the level of innovation, x, so there is no potentially damaging manipulative behaviour of the domestic firm.

The third part of proposition 1 is consistent with the Schumpeterian tradition suggesting that more monopolistic markets generate more innovation. The intuition behind these results is that in Cournot competition there are more profits to be gained, and therefore, there are higher returns from a decrease in marginal cost. Technically, the impact of the market conduct on the level of R&D effort can be quantified by treating V_f as a continuous variable that measures the degree of market power. An increase in V_f implies a more monopolistic market, and it is easy to show that $dx^*/dV_f > 0$ in our set–up (see Appendix 1). Alternatively, the expected ranking between x^{*C} and x^{*B} might be roughly predicated by referring to the famous Fudenberg–Tirole (1984) taxonomy of business strategies, where, in the Bertrand case, the firms competing in prices (being strategic complements) pursue a (so–called) "puppy dog" strategy that asks for "underinvestment" in the strategic variable, which is in our case unit cost reduction, x. On the other hand, Cournot competition requires a so–called "top dog" strategy that implies "overinvestment" in the strategic variable (see Tirole, 1991).[17]

The presence of the optimal tariff proves to be crucial in determining the ranking of R&D investment in the respective market conduct. A higher anticipated tariff in Cournot competition provokes larger investment in R&D compared with Bertrand competition. As Bester and Petrakis (1993) have shown, in the absence of tariff protection, with high levels of γ, the ranking is reversed so that $x^{*B} > x^{*C}$.

[17] However, the notion of "under–" and "over–" investment" in the Fudenberg–Tirole (1984) approach is defined with respect to the non–strategic firm's behaviour and not relative to the "first–best" social optimum.

Finally, the higher optimal tariff in the Cournot type of conduct is a consequence of the higher oligopoly distortion in a Cournot setting that requires larger correction.

5. FREE TRADE

Free trade equilibrium serves as an important general benchmark for comparison with other policy options. In our case, the comparison of free trade with the "non–commitment" policy regime is of special interest given the critique that the government's inability to pre–commit to its policy may lead to lower social welfare compared with free trade (see, for instance, Karp and Perloff, 1995; Grossman and Maggi, 1998; Neary and Leahy, 2000; Ionaşcu and Žigić, 2005).

If the domestic government commits to free trade, the level of R&D investment maximizes the profits given by (5) for a zero tariff. Therefore, the optimal level of innovation is implicitly defined as

$$ki'(x_{ft}) = 2V_d q^d(x_{ft},0)\frac{\partial q^d}{\partial x}(x_{ft},0),$$

or after appropriate substitution

$$ki'(x_{ft}) = \frac{2V_d(V_f+\beta_f)}{(V_d+\beta_d)(V_f+\beta_f)-\gamma^2}q^d(x_{ft},0). \tag{18}$$

Regardless of the type of competition in the market, the level of R&D induced by the anticipated tariff protection is always higher than the optimal level of innovation under free trade. To show this, we first recall from (4) that $q^d(x, t)$ is increasing in t. Then for x^*,

$$ki'(x^*) - \frac{2V_d(V_f+\beta_f)}{(V_d+\beta_d)(V_f+\beta_f)-\gamma^2}q^d(x^*,0) > 0.$$

When we take the first derivative with respect to x of the function on the left hand side we get

$$ki''(x) - \frac{2V_d(V_f + \beta_f)^2}{[(V_d + \beta_d)(V_f + \beta_f) - \gamma^2]^2} > 0,$$

which is positive (due to the assumption A3). Therefore, x should decrease to reach equality again.

The optimal levels of R&D effort across the different regimes are displayed in Figure 1 (RHS_{so}, RHS, RHS_{ft} stand for the right hand side of the equations (14), (16), and (18) respectively). Note that as k decreases, innovation becomes cheaper, the optimal R&D levels increase and it is more likely to have corner solutions as shown by the dashed line in Figure 1.

The above results are consistent with the infant industry argument in favour of tariff policies. Indeed, the anticipation of tariff protection enhances the innovative efforts of the domestic firm and therefore positively impacts the domestic firm's production costs.

The above considerations suggest that the domestic firm's profit and social welfare in a non–commitment regime are larger than their counterparts in free trade. The comparison of the relevant equilibrium values in free trade and in the non–commitment regime is given in Proposition 2 below (see Appendix 2 for a proof)

PROPOSITION 2

Regardless of the type of the market conduct:

1. Social welfare in the non–commitment regime is higher than in the free trade regime.

2. The optimal R&D effort (or unit cost reduction) in the non–commitment regime, x^*, is always bigger than the optimal cost reduction under free trade, x_{ft}.

3. The domestic firm earns a higher profit under such tariff protection than under free trade.

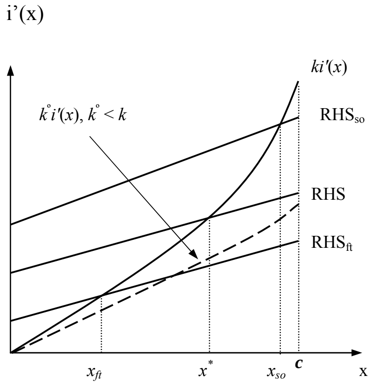

Figure 1. The innovation levels chosen under "first–best", free trade and non–commitment regime

The intuition for the above findings is straightforward; the anticipation of the optimal tariff motivates the domestic firm to enhance its R&D effort compared to free trade, since the tariff enables the domestic firm to capture a higher market share and gain a higher profit. Thus it has increased incentives to invest in marginal cost reduction. Finally, appearance of the tariff brings revenue to the domestic treasury and the joint impact of increased domestic firm profit and tariff revenue exceeds potential losses in consumer surplus and thus, leads to the increase in social welfare.

6. THE "COMMITTED" DOMESTIC GOVERNMENT

When the domestic government is able to commit in advance to the precise value of its policy choice, it announces the level of the tariff protection before the domestic firm invests in R&D. The quantities that the domestic and the foreign firm will produce are given by (4) and (4') respectively. If a tariff is announced in stage one, the domestic firm chooses an innovation level that maximizes (5). Thus, the optimal R&D choice $x(t)$ for a given t, which we will denote as X, satisfies

$$ki'(X) = \frac{2V_d(V_f + \beta_f)}{(V_d + \beta_d)(V_f + \beta_f) - \gamma^2} q^d(X,t). \tag{19}$$

Regardless of the type of market conduct, the level of innovation increases when the tariff increases. To see this, we take the first derivative of the above equation (19) with respect to t:

$$\frac{dX}{dt}\left(ki''(X) - \frac{2V_d(V_f + \beta_f)^2}{[(V_d + \beta_d)(V_f + \beta_f) - \gamma^2]^2} \right) = \gamma \frac{2V_d(V_f + \beta_f)}{[(V_d + \beta_d)(V_f + \beta_f) - \gamma^2]^2}. \tag{20}$$

Since the term in brackets is positive due to assumption (A3), and since the sign of the right hand side is the same as the sign of γ, the impact of an increase in tariff protection on the R&D level is positive. Therefore, for a given tariff, the R&D investment under tariff protection is higher than in the case of free trade.

When, for instance, the domestic government chooses t^*, that is, the optimal tariff in the "non–commitment" regime, equation (19) gives a level of R&D $X(t^*)$ equal to x^* (see also equation 16). Thus, in the commitment regime, from the domestic social welfare point of view, the government can do at least as well as without commitment (simply by choosing a tariff equal to t^*). Consequently, social welfare when the government can commit in advance to its policy is never lower than the optimal social welfare under a non–commitment situation.[18]

The domestic government chooses a level of tariff protection T^* that maximizes (6). Since the first order condition (3') still holds, for an infinitesimal change in the Nash equilibrium in quantities, equation (9) is still valid. Plugging it into the domestic firm's first order condition with respect to innovation (19), we obtain

[18] As Žigić (2003) shows, this is generally not true when there are R&D spillovers from the innovating to the non–innovating firm. However, R&D spillovers are not a real possibility in our set–up.

$$dW = \left(q^d V_d + \frac{(V_d + \beta_d)(V_f q^f - T)}{\gamma} + \frac{2V_d (V_f + \beta_f)(\gamma q^d - \gamma k i'(X) - (V_f q^f - T))}{\gamma k i''(X)((V_d + \beta_d)(V_f + \beta_f) - \gamma^2)} \right) dx . \qquad (21)$$

The government then chooses a level of tariff T^* such that the value in the brackets is zero. So T^* is given by

$$T^* = V_f q^f + \gamma \frac{V_d}{V_d + \beta_d} q^d +$$

$$+ \gamma \frac{2V_d (V_f + \beta_f)[q^d (2V_d + \beta_d) - ki'(X)(V_d + \beta_d)]}{(V_d + \beta_d)[ki''(X)(V_d + \beta_d)((V_d + \beta_d)(V_f + \beta_f) - \gamma^2) - 2V_d (V_f + \beta_f)]} . \qquad (22)$$

By using $ki'(X)$ given by (19), the values for q^d and q^f given by (4) and (4'), and the fact that for Bertrand and Cournot conjectures $V_d \beta_f - V_f \beta_d = 0$ we obtain

$$T^* = t^* + \gamma \frac{2\beta_f^2 V_f [\beta_d (V_f + \beta_f)^2 - \gamma^2 (2V_f + \beta_f)] q^d}{(2V_f + \beta_f)[\beta_d (V_f + \beta_f)^2 - \gamma^2 \beta_f][ki''(X)(\beta_d (V_f + \beta_f)^2 - \gamma^2 \beta_f) - 2V_f \beta_f]} . \qquad (23)$$

As in the non–commitment case, besides extracting foreign rents, the optimal tariff should correct for domestic oligopoly distortion. Moreover, now that the tariff is chosen before the home firm decides on its innovation level (and no R&D subsidy is considered), the tariff has an additional role; it has to correct for the level of innovation that, as we saw in the

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[19] To underline this new role of tariff as a direct instrument for enhancing the innovation level, we look at what happens when the domestic government uses R&D subsidies to correct for suboptimal levels of innovation. When the government chooses an R&D subsidy, r, together with the level of tariff protection, the welfare becomes

$$W = CS + \pi^d + t q^f - r k i(x) = U(q^d, q^f) - [(c - x) q^d + ki(x)] - [p^f - t] q^f .$$

Since there is no change in the home and the foreign firm's first order conditions (3) and (3'), the equations (7), (8) and (9) still hold. With an R&D subsidy in place, a^d and x become again independent variables, so once more we get the first order conditions of the welfare maximization problem (commitment case) by setting the values in the parentheses to zero. The first parenthesis = 0 gives us again formula (10), and consequently formula (12) for the tariff level. The second parenthesis of (9) = 0 gives (13). When we replace in (13) the formula (12) for the tariff level, and domestic firm's first order condition with respect to R&D, $ki'(x) = 2V_d q^d (V_f + \beta_f) / ((1 - r)((V_d + \beta_d)(V_f + \beta_f) - \gamma^2))$, we find that the optimal subsidy is $r = k[\beta_d - 2V_d \gamma^2 / ((2V_d + \beta_d)((V_d + \beta_d)(V_f + \beta_f) - \gamma^2))]$ >0 for both Bertrand and Cournot conjectures.

non–commitment case, tends to be sub–optimal. To enhance the innovation level, a higher tariff is required[19]. Hence, the optimal tariff, T^*, exceeds its corresponding counterpart, t^*, without government commitment. (It is straightforward to check that the second part in expression (23) is positive.)

The optimal level of R&D effort, X^*, calculated from (19) when the tariff, T^*, given by (23) is considered, is higher than the optimal level of innovation, x^*, for a non–committed government, but still below the "first–best" optimal level. These results are presented in the following proposition (see the Appendix 3 for a proof).

PROPOSITION 3

Regardless of the type of the market conduct:

1. The optimal tariff protection in the "commitment" regime is higher than the optimal tariff protection in its "non–commitment" counterpart, that is, $T^* > t^*$.

2. Consequently, the domestic firm exhibits greater R&D effort in the "commitment" regime, that is, $X^* > x^*$ *and higher social welfare, that is,* $W^*_{com} > W^*_{ncom}$.

3. The R&D efforts in both the "commitment" and "non–commitment" regimes are below the "first–best" value, that is, $x^* < X^* < x_{so}$.[20] .

7. ASSESSMENT OF THE CONSIDERED POLICIES

Before moving to the policy analysis under asymmetric information, first, we briefly

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[20] Although it is not the primary goal of our analysis, comparing the corresponding Cournot and Bertrand equilibria, as we did in a previous section, would be of some interest. However, the expressions are prohibitively complex so that it is not possible to have an analytical comparison leading to close form solutions. Using simulations, we found out that for a specific functional form for the R&D effort, $f(x) = x^2/2$, and for $\alpha_d = \alpha_f = 1$ and $\beta_d = \beta_f = 1$, $T^{*C} > T^{*B}$ and, consequently, $X^{*C} > X^{*B}$.

discuss the pros and cons of the three policies with respect to four criteria:

a) the social welfare that they generate;

b) the information requirement for their implementation;

c) the time consistency issue; and

d) the agency problems.

The policies in question are government commitment regime (GCR), government non–commitment regime (GNCR) and free trade (FT). The ranking and the characteristics of the policies are given in Table 1.

Table 1. Rank (Characteristics) of discussed policies according to various criterions

Policy\Criterion	Social welfare	Inform. requirement	Time consistency	Agency problems
GCR	1 (largest)	3 (high)	3 (credibility problem)	3 (prone to agency problems)
GNCR	2 (second–largest)	2 (low)	1 (time consistent)	1 (no agency problem.)
FT	3 (lowest)	1 (zero)	3 (credibility problem)	1 (no agency problem.)

Table 1 shows that the only strength of the government commitment regime is that it yields the highest social welfare. The information requirement for its implementation is likely to be prohibitively high, and consequently, such a policy is susceptible to all kinds of agency problems between the domestic firm and governments. In addition, the capability of the Southern country government to pre–commit to a given level of tariff is questionable at best, so the time consistency issue may arise.

The government non–commitment regime on the other hand has a rather low information requirement, and is not prone to the agency problems and manipulative behaviour of the domestic firm. Moreover, the optimal tariff in this regime is time consistent. The social welfare that it generates is lower than in the commitment regime but higher than in free trade.

Finally, free trade is the most convenient policy as far as the information constraint is concerned, but the worst one from the social welfare point of view. The free trade regime is also not void of time consistency problems. The government's announcement of free trade may not be credible since it would be optimal to intervene *via* tariff *ex post* (that is, after innovation takes place).

So the above short discussion suggests that a "middle–of–the–road" policy – government non–commitment regime – fairs best in the above qualitative assessments, with two–second ranks (social welfare, information requirement) and two first ranks (time consistency, no manipulation). However, these rankings are probably not enough to proclaim the government non–commitment regime as the champion. If the social welfare that government non–commitment regime generates is only slightly above that of free trade, then it may be better to stick to free trade due to its zero information content requirement if the government can somehow commit to it. On the other hand, if the difference in generated social welfare between the government commitment regime and the government non–commitment regime is "very large", then it might be worth investigating how to overcome the problems associated with the former policy regime. Thus, in addition to a comparative qualitative assessment, we also need a comparative quantitative assessment of the social welfare that the three policies generate. As we show in Appendix 6, this quantitative analysis only reinforces the virtues of the government non–commitment regime.

For the purpose of the explicit quantitative analysis, we stick to the specific functional form of the investment function that is assumed quadratic and is given by $i(x) = \frac{1}{2}kx^2$. To simplify the calculation, we set $\alpha_d = \alpha_f = \beta_d = \beta_f = 1$, and $k = 2$. In order to avoid underestimating the overall gains from introducing a tariff, we rule out the possibility of having corner solutions for the innovation levels. Therefore, apart from satisfying the (A1) – (A3) assumptions, parameters c and γ should also be such that the reduction in marginal costs, x, are smaller than c.

7.1. Free Trade versus the Non–Commitment Policy Regime

The optimal levels of increase in efficiency under a non–committed government, x^{*B} and x^{*C}, are implicitly given by formula (16). Having a quadratic investment function, we can explicitly solve equation (16). When we substitute the corresponding levels of V_d and V_f in this equation and solve for x we find that the level of increase in efficiency in the case of Bertrand competition ($V_d = V_f = 1-\gamma^2$), x^{*B}, equals

$$x^{*B} = \frac{2(2-\gamma^2)^2\left[(1-c)((3-2\gamma^2)-2\gamma^2)\right]}{(3-2\gamma^2)\left[k(1-\gamma^2)(4-\gamma^2)^2-2(2-\gamma^2)^2\right]}$$

while the level of increase in efficiency for Cournot competition ($V_d = V_f = 1$), x^{*C}, is given by

$$x^{*C} = \frac{8[3(1-c)-\gamma]}{3k(4-\gamma^2)^2-24}.$$

The fact that these levels of x should be smaller than c adds to the (A1) – (A3) assumptions lower bound restrictions on c. In Bertrand competition, the marginal cost, c, should be at least as high as

$$c > \frac{(3+2\gamma)(2-\gamma^2)^2}{(1+\gamma)(3-2\gamma^2)(4-\gamma^2)^2} \qquad \text{(A4)}$$

while in Cournot competition it should be no lower than

$$c > \frac{4(3-\gamma)}{3(4-\gamma^2)^2} \qquad \text{(A5)}$$

in order to have interior solutions for R&D investment.

The percentage gains in social welfare from having an optimal tariff protection set by a non–committed government with respect to the free trade outcome is given in Table 2.1 and Table 2.2. In Table 2.1, we consider the case when firms choose prices, and we assume that (A1) – (A4) hold. To generate Table 2.2, we assume that firms set quantities and conditions (A1) – (A3), (A5) hold.

From the tables below we can infer several interesting properties. First of all, the gains from tariff protection are roughly between 10 and 32 percent in Bertrand competition and between 10 and 57 percent in Cournot competition. Thus, the introduction of a tariff has a significant, positive impact on the domestic country's social welfare.

Table 2.1. Percentage differences between domestic social welfare under free trade and non–commitment when firms compete in prices*

γ / c	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
0.05	9.99	11.00	12.14	13.43	14.89	16.52	18.34	20.33	22.47	24.71	26.96	29.09	30.94	32.34
0.15	10.85	11.94	13.17	14.56	16.12	17.85	19.74	21.80	23.95	26.14	28.23	30.09	31.55	
0.25	11.63	12.79	14.09	15.56	17.18	18.97	20.89	22.93	25.00	27.01	28.81	30.24	31.15	
0.35	12.34	13.56	14.92	16.42	18.08	19.86	21.74	23.66	25.51	27.18	28.51	29.36		
0.45	13.02	14.27	15.65	17.16	18.78	20.48	22.20	23.84	25.30	26.43	27.10			
0.55	13.70	14.96	16.31	17.75	19.23	20.70	22.06	23.21	24.01	24.34				
0.65	14.49	15.68	16.91	18.13	19.26	20.21	20.87	21.12						
0.75	15.70	16.63	17.43	17.99	18.18	17.91	17.11							
0.85	19.22	18.50	16.79	14.08										

* $(100\frac{W_{nc}^{*B}-W_{ft}^{*B}}{W_{ft}^{*B}})$

Table 2.2. Percentage differences between domestic social welfare under free trade and non–commitment when firms compete in quantities*

γ / c	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
0.05	10.01	11.02	12.17	13.47	14.93	16.56	18.38	20.38	22.53	24.78	27.04	29.18	31.04	32.45
0.15	11.04	12.16	13.43	14.85	16.45	18.23	20.19	22.31	24.54	26.81	29.00	30.94	32.47	33.41
0.25	12.18	13.42	14.82	16.39	18.15	20.09	22.20	24.44	26.75	29.00	31.06	32.73	33.84	
0.35	13.45	14.83	16.39	18.13	20.07	22.19	24.47	26.84	29.19	31.39	33.24	34.54		
0.45	14.89	16.44	18.19	20.14	22.29	24.62	27.08	29.58	31.96	34.03	35.57	36.37		
0.55	16.54	18.30	20.28	22.49	24.90	27.49	30.16	32.78	35.13	36.98	38.07			
0.65	18.47	20.50	22.78	25.31	28.07	30.97	33.89	36.62	38.87	40.35				
0.75		23.14	25.83	28.80	32.02	35.34	38.57	41.39	43.42	44.31				
0.85		26.41	29.68	33.30	37.18	41.11	44.76	47.65	49.28					
0.95		30.57	34.74	39.40	44.39	49.35	53.70	56.69						

* $(100\frac{W_{nc}^{*C}-W_{ft}^{*C}}{W_{ft}^{*C}})$

Second, in the case of Cournot competition, the performance of a tariff protection regime with respect to free trade increases with an increase in the initial domestic firm's marginal cost level, *c*, and with a decrease in the level of product differentiation. Similar relations hold in the case of Bertrand competition when products are not very similar ($\gamma \leq 0.65$).

Third, at least for medium and low levels of γ ($\gamma \leq 0.65$), and values of *c* that satisfy both (A4) and (A5) restrictions, we can see that the percentage gains from tariff protection relative to free trade are quite similar in both types of market conduct.

7.2. Non–Commitment versus Commitment Regime

As in the above section, we take into consideration only interior solutions for the innovation levels. Thus, as before, besides satisfying the (A1) – (A3) assumptions, parameters *c* and γ should be such that X^{*B} and X^{*C} are smaller than *c*.

To compute the optimal levels of increase in efficiency, we first replace in (19) the quadratic form of the investment function and the formula (4) for $q^d(X, t)$. We find that, given the level of tariff *t*, in the second stage the domestic firm chooses a level of R&D of

$$X(t) = \frac{V_d(V_f + 1)}{[(V_d + 1)(V_f + 1) - \gamma^2]^2 - V_d(V_f + 1)^2}\left[(V_f + 1)(1 - c) - \gamma(1 - t)\right].$$

Next, we derive the optimal tariff levels by replacing the above formula in (23) together with the formulas for Cournot and Bertrand conjectures. The optimal tariff protection for quantity competition is

$$T^{*C} = \frac{1}{3} + \gamma \frac{4k(4 - 3\gamma^2)[3(1 - c) - \gamma]}{3[3k^2(4 - \gamma^2)^3 - 64k(3 - \gamma^2) + 48]}$$

and for price competition

$$T^{*B} = \frac{1 - \gamma^2}{3 - 2\gamma^2} + \gamma \frac{2k(4 - 3\gamma^2)(2 - \gamma^2)[(3 - 2\gamma^2)(1 - c) - \gamma]}{(3 - 2\gamma^2)D_B}$$

where

$$D_B = k^2(4-\gamma^2)^3(3-2\gamma^2)(1-\gamma^2) - 8k(2-\gamma^2)^2(6-6\gamma^2+\gamma^4) + 4(2-\gamma^2)^2(3-2\gamma^2)\ .$$

Finally, we obtain the optimal levels of increase in efficiency, X^{*B} and X^{*C}, by replacing in the formula for $X(t)$ the corresponding levels of V_d and V_f and of tariff protection. The level of X^{*B} is given by

$$X^{*B} = \frac{2(2-\gamma^2)^2[k(4-\gamma^2)-2][(1-c)((3-2\gamma^2)-2\gamma^2)]}{k^2(4-\gamma^2)^3(3-2\gamma^2)(1-\gamma^2)-8k(2-\gamma^2)^2(6-6\gamma^2+\gamma^4)+4(2-\gamma^2)^2(3-2\gamma^2)}$$

and the level of X^{*C} is given by

$$X^{*C} = \frac{8[k(4-\gamma^2)-2][3(1-c)-\gamma]}{3k^2(4-\gamma^2)^3-64k(3-\gamma^2)+48}.$$

These levels of increase in efficiency are below c if

$$c > \frac{(3-\gamma-2\gamma^2)(3-\gamma^2)(2-\gamma^2)^2}{144-364\gamma^2+332\gamma^4-138\gamma^6+27\gamma^8-2\gamma^{10}} \qquad \text{(A6)}$$

in Bertrand competition, and if

$$c > \frac{4(3-\gamma)(3-\gamma^2)}{144-124\gamma^2+36\gamma^4-3\gamma^6} \qquad \text{(A7)}$$

in Cournot competition.

The percentage gains in social welfare from having the optimal tariff protection set by a committed government rather than a non–committed one are given in Table 3.1 for price competition, and in Table 3.2 for quantity competition. In the first case, we assume that (A1) – (A3) and (A6) hold while in the latter case, we assume that conditions (A1) – (A3), and (A7) are satisfied.

From these tables we can see that, regardless of the type of market competition, the percentage loss in social welfare when the government cannot commit in advance to its policy is negligible. The loss ranges between a meagre 0.00002% and an upper rough limit of 1.92% for Bertrand competition and of 0.14% for Cournot competition. Our result does not change significantly when we vary parameter k.

Table 3.1. Percentage differences between domestic social welfare under non–commitment and commitment when firms compete in prices*

γ / c	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
0.05	0.00060	0.00057	0.00053	0.00050	0.00045	0.00041	0.00036	0.00031	0.00025	0.00020	0.00014	0.00009	0.00005	0.00002
0.15	0.00550	0.00519	0.00484	0.00445	0.00403	0.00357	0.00308	0.00257	0.00204	0.00153	0.00104	0.00061	0.00028	
0.25	0.01645	0.01540	0.01423	0.01295	0.01156	0.01006	0.00848	0.00684	0.00521	0.00366	0.00227	0.00114	0.00036	
0.35	0.03674	0.03408	0.03114	0.02793	0.02446	0.02077	0.01694	0.01308	0.00936	0.00598	0.00317	0.00115		
0.45	0.07389	0.06767	0.06086	0.05347	0.04559	0.03737	0.02904	0.02095	0.01353	0.00730	0.00277			
0.55	0.14562	0.13092	0.11493	0.09782	0.07993	0.06179	0.04419	0.02812	0.01475	0.00521				
0.65	0.30081	0.26206	0.22055	0.17721	0.13356	0.09178	0.05461	0.02515						
0.75		0.58953	0.45113	0.31499	0.19068	0.08962	0.02321							
0.85		1.92371	0.96067	0.27264										

*$(100\frac{W_c^{*B}-W_{nc}^{*B}}{W_{nc}^{*B}})$

Table 3.2. Percentage differences between domestic social welfare under non–commitment and commitment when firms compete in quantities*

γ / c	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9
0.05	0.00060	0.00056	0.00053	0.00049	0.00045	0.00041	0.00036	0.00030	0.00025	0.00020	0.00014	0.00009	0.00005	0.00002
0.15	0.00524	0.00494	0.00461	0.00425	0.00385	0.00341	0.00295	0.00246	0.00196	0.00146	0.00100	0.00059	0.00027	0.00007
0.25	0.01435	0.01345	0.01245	0.01136	0.01016	0.00887	0.00750	0.00608	0.00466	0.00329	0.00207	0.00106	0.00036	
0.35	0.02794	0.02601	0.02388	0.02154	0.01899	0.01627	0.01342	0.01051	0.00768	0.00505	0.00281	0.00114		
0.45	0.04614	0.04264	0.03877	0.03454	0.02997	0.02511	0.02010	0.01510	0.01036	0.00617	0.00286	0.00074		
0.55	0.06904	0.06329	0.05694	0.05001	0.04256	0.03475	0.02681	0.01909	0.01205	0.00621	0.00210			
0.65	0.09622	0.08742	0.07771	0.06715	0.05589	0.04421	0.03257	0.02161	0.01212	0.00494				
0.75		0.11312	0.09920	0.08411	0.06814	0.05182	0.03596	0.02165	0.01013	0.00262				
0.85		0.13482	0.11642	0.09653	0.07566	0.05472	0.03504	0.01828	0.00623					
0.95		0.13825	0.11730	0.09469	0.07122	0.04821	0.02751	0.01136						

* $(100\frac{W_c^{*C}-W_{nc}^{*C}}{W_{nc}^{*C}})$

To conclude, the government non–commitment regime now appears decidedly superior to the other policy options (at least within the assumed specific functional forms). What is even more interesting is that this policy set–up is the prevailing one in the developing world and so the often–expressed worries that the Southern country governments are unable to pre–commit to a policy choice do not seem to be well founded, at least where simple tariff policy is concerned.

8. MARKET EQUILIBRIUM WITH ASYMMETRIC INFORMATION

There are many ways in which information asymmetry may appear in the context under consideration. However, much of the critique of strategic trade policy focuses on the government's inability to gather and process all the information necessary for beneficial intervention. Thus, we assume that the player in our setup who lacks relevant information is the domestic government. More specifically, we assume that the government does not know the type of market competition between the domestic and foreign firm. The relevance of such uncertainty is amply described in Eaton and Grossman (1986), although Grossman and Maggi (1998) were the first to call for an explicit analysis of this issue more than a decade later.

Since the government non–commitment regime was the clear champion in the symmetric information setup, we focus on it in this chapter as well. When relevant, we discuss how results change for the government commitment regime.

Even in such a narrowly specified framework, the government's (in)ability to cope with the information asymmetry can vary. In the first and standard situation, the government does not know *a priori* the type of market conduct, but by observing the unit cost reduction of the domestics firm, it may infer the true type of competition. More consequential uncertainty occurs if for some reason the government is unable to learn the type of competition even after the R&D investment is in place. In what follows, we first analyze the latter type of uncertainty, and then we discuss how results change when the government can infer the true type of competition.

8.1 Case 1: No updating of government's prior beliefs

Let us assume that nature chooses the type of market interaction before any firm or government decision takes place. With probability η it chooses price competition and with 1-η it chooses quantity competition. Parameter η is common knowledge. After that, firms learn the type of competition while the domestic government obtains no extra information. In what follows, we assess the impact of the lack of information on the level of tariff policy and domestic social welfare.

In terms of the timing of the game, we add an additional stage to the game; nature now moves first by choosing the type of market competition. Then, as before, the domestic firm selects its R&D effort, and thereafter the government sets the level of tariff protection knowing only the probability distribution of the true conduct parameter V_d: $\Pr(V_d^{B}) = \eta$ and $\Pr(V_d^{C}) = 1-\eta$ where V_d^{B} stands for Bertrand and V_d^{C} for Cournot conduct parameter. In the last stage, the two firms compete in the market.

As was made clear in Proposition 1, the levels of marginal cost reduction might convey information regarding the market type. However, we assume that after the innovation takes place the government does not update its beliefs regarding the type of market conduct. This may be the case when policymakers have bounded rationality, or, alternatively, when it may be too costly for the government to accurately assess the actual levels of R&D investment.

The domestic government now maximizes

$$EW = \eta W^{B} + (1-\eta) W^{C}$$

where W^B and W^C can be computed from (6) by plugging in it the expressions for the optimal domestic firm's output (4); the first order condition (3); and then the corresponding conjectures. By solving the social welfare maximization problem for a given level of x, we find that the optimal tariff level is given by

$$t^u = \frac{\alpha_f}{3 + \eta \frac{\gamma^2}{\beta_d \beta_f - \gamma^2}}. \quad (25)$$

It is easy to verify that as η decreases from 1 to 0, t^u increases from t^{*B} to t^{*C}.

PROPOSITION 4

1. If Bertrand conduct is the true type of competition, then for a "high enough" prior probability η, intervention through an optimal tariff under uncertainty, t^u, raises the social welfare level above that of its symmetric information counterpart.

2. If Cournot conduct is the true type of competition, the intervention through an optimal tariff under uncertainty, t^u, results in social welfare higher than under free trade, but lower than that under intervention with symmetric information.

The complete proof appears in Appendix 5.

When Cournot is true market competition, the level of tariff protection, t^u, is always lower than the optimal tariff with symmetric information ($t^{*C} > t^u$), and therefore, social welfare under symmetric information is always higher than the social welfare under incomplete information. However, since social welfare is increasing in tariff in the interval [0, t^{*C}), the optimal protection, t^u , still generates higher social welfare than free trade.

In the case of Bertrand competition, the presence of uncertainty induces the domestic firm to anticipate levels of tariff protection higher than t^{*B} but lower than t^{*C}. Since, as we saw in Section 6, any increase in the tariff protection level towards T^{*B} enhances the social welfare for high enough levels of η, the expected level of tariff protection will drive innovation and domestic social welfare upward to levels that are higher than the symmetric information social welfare with intervention (see Appendix 5). However, as products become more homogenous and at the same time, the government holds inaccurate beliefs about the true market conduct (that is, η tends to zero), social welfare under uncertainty may decrease to levels lower than both the complete information level with intervention and the free trade level with complete information. As the market becomes highly competitive the drop in profit is drastic, and a high tariff close to the Cournot optimal tariff only distorts consumption without bringing sufficient gains from the added innovation (see Appendix 5).

Thus, if the domestic firm does not try to signal the true type of competition in the market, and the tariff is set only after the R&D phase, the presence of uncertainty might enhance the social welfare level above the social welfare with symmetric information and government intervention. This result does not hold in the case of a committed government. When the government is able to commit to its policy before the local firm engages in innovative activities, with or without symmetric information, the government can "credibly" set any tariff above zero. Therefore, the presence of uncertainty does not alter the set of feasible tariffs. As a result, any departure from the optimal tariff level with symmetric information, T^*, reduces social welfare. Unlike the non–commitment case, the presence of uncertainty here always has an adverse effect on the domestic country's social welfare.

8.2 Case 2: Signalling

Up to now we have assumed that the domestic government was not in a position to distinguish between Cournot and Bertrand types of conduct. However, the fact that the Cournot firm always invests more in R&D than the Bertrand firm (see Proposition 1), means that the level of cost reduction, x, could be used by the government to infer the true type of competition in the market. The problem is that the Bertrand firm might try to mimic the behaviour of a Cournot firm by choosing a higher cost reduction than under the symmetric information scenario to induce a higher tariff. This, in turn, may force the Cournot firm to invest more in marginal cost reduction than under symmetric information in order to signal its type.

The aim of this section is to briefly discuss the situations (conditions) under which the domestic government can distinguish between the two polar types of market competition.

In order to induce the higher tariff, t^{*C}, rather than the low tariff, t^{*B}, a Bertrand firm might have an incentive to mimic the behaviour of a Cournot firm by choosing cost reduction, x^{*C}. This would be the case if

$$\pi^B(x^{*B}, t^{*B}) < \pi^B(x^{*C}, t^{*C}). \tag{26}$$

When the above condition holds, to induce the government to implement a high tariff, a Cournot firm would have to signal its type by investing more than $i(x^{*C})$ in R&D. Since this differentiation action is costly, the Cournot firm will signal its type only if there is some decrease in marginal cost, $\tilde{x}$, high enough to deter the Bertrand firms to opt for the same investment level, that is,

$$\pi^B(x^{*B}, t^{*B}) \geq \pi^B(\tilde{x}, t^C(\tilde{x})), \tag{27}$$

but, at the same time, this decrease in marginal cost must still be low enough that the firm competing *à la* Cournot would be better off by revealing its type through signalling than by being perceived as a Bertrand firm

$$\pi^C(\tilde{x}, t^C(\tilde{x})) \geq \max_x \pi^C(x, t^B(x)) \tag{27'}$$

where $t^{*C}(x) = \arg\max_t W^C(x,t)$ and $t^{*B}(x) = \arg\max_t W^B(x,t)$.

The conditions (26), (27), and (27') define the pair of investment levels $(x^{*B}, \tilde{x})$ that form a separating equilibrium given the appropriate government beliefs.

As in the previous section, we assume that the prior probabilities of the Bertrand and Cournot types of conduct are given by: Pr $(V_f^{B}) = \eta$ and $\Pr(V_f^{C}) = 1\text{-}\eta$. We assume that the government's out–of–equilibrium beliefs are such that any x other than $\tilde{x}$ indicates that the firm is of the Bertrand type, or more formally:

$$\begin{cases} \forall\ x \geq \tilde{x} \text{ - } \textit{Cournot type of competition} \\ \forall\ x < \tilde{x} \text{ - } \textit{Bertrand type of competition} \end{cases}$$

These beliefs support the largest possible set of separating equilibria. Moreover, the government's prior probability distribution and its subsequent updates are assumed to be common knowledge.

As Bhattacharjea (2002) points out, it is usually very difficult to solve analytically for these conditions, and such a task "ultimately relies on numerical simulations to demonstrate the existence and social welfare properties of signalling equilibria, even with linear demands and constant costs". Since our set–up is no exception to this observation, we also choose a numerical simulation, the results of which are summarized below. We assume that the R&D cost function is quadratic and is given by $i(x) = x^2/2$.

In order to characterize the "signalling" separating equilibrium, we first identify the ranges of parameters c, k, and γ for which it is profitable for a Bertrand firm to imitate the behaviour of a Cournot firm by investing $i(x^{*C})$ in R&D so that the condition (26) holds. Our simulations show that for most of the parameter space, a Bertrand firm is better off when it mimics the behaviour of a Cournot firm. Only when the level of unit cost c is almost as high as the highest level of c that can still sustain a duopoly structure (see assumption (A2)), the cost of innovation k is very low, and the level of product differentiation is neither very low nor very high (γ in the (0.2, 0.7) range), will a Bertrand firm invest $i(x^{*B})$ rather than $i(x^{*C})$ [21] .

As for the remaining conditions (27) and (27'), they require that the initial marginal cost c be "high enough" for the signalling to be effective. If, on the contrary, the marginal cost is low, the gap between x^{*B} and x^{*C} is small and a Cournot firm has less room for increasing its innovation for signalling purposes. Therefore, it is advantageous for a Bertrand firm to pretend to be a Cournot firm, even if it chooses R&D levels that bring the marginal cost down to zero.

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[21] Under this parameter constellation, condition (26) does not hold, so a trivial, "non–signalling" separating equilibrium exists which coincides with the equilibrium under symmetric information discussed in section 4.

Given "high enough" marginal costs, *c*, a high level of product differentiation (γ low) increases the likelihood of the existence of a separating equilibrium. If products are highly differentiated, then, on one hand the gap between x^{*B} and x^{*C} is relatively small, as both Cournot and Bertrand firms act almost like monopolists so the mimicking is not too costly. On the other hand, and more importantly, having an almost monopolistic position, the Bertrand firm has much less need for an increase in protection, so even a relatively small deviation from its optimal choice under perfect information may not pay off.

Much like in the no signalling case, the level of social welfare might be higher under asymmetric information than under symmetric information provided that a separating equilibrium exists. This is at least the case when products are highly differentiated. As we have just discussed, when products are not alike, the Bertrand firm has low incentives for increased protection, so the signalling behaviour of a Cournot firm results in a mild increase in the innovation level beyond x^{*C}. As we know from proposition 1, the optimal marginal cost reduction, x^{*C}, under symmetric information, is below the "first–best" level symmetric information, x_{so}, and so the signalling brings it closer to its "first–best" level. Unlike in the no signalling case, the increase in social welfare level above its symmetric information level with government intervention may occur only under Cournot competition. When the true conduct is Bertrand and a separating equilibrium exists, the social welfare levels under symmetric and asymmetric information are equal.[22]

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[22] When condition (26) holds but a signalling equilibrium does not exist either because there is no level of R&D such that the incentive compatibility constraints (27) and (27') are simultaneously verified, or because the government does not have *a priori* beliefs that can sustain a signalling equilibrium, then a pooling equilibrium might arise in the market. In this case it is straightforward to show that the level of tariff protection should be higher than t^{*B} and a Bertrand firm invests in R&D more than x^{*B}, its R&D level under full information. Then the inferences from such equilibrium are similar with the one described in section 7.1 (no signalling case). However, none of the pooling equilibrium survives the Cho and Kreps (1987) intuitive criterion.

9. CONCLUDING REMARKS

The focus of our policy analysis was the simple and, in reality, most frequently used "tariffs *cum* foreign competition" set–up designed to protect a domestic industry and enhance its competitive position. This policy framework can appear in several variants due to reasons such as the mode of the oligopoly conduct; the (in)ability of the domestic government to commit to its policy; and information asymmetry.

In the first part of the chapter IV we assumed a perfect, symmetric information set–up and explored the role of oligopoly conduct and the ability of the domestic government to commit to the level of its policy instrument. We considered three policy options: the government commitment regime, the government non–commitment regime, and free trade. We found that, regardless of the market conduct and the ability of the domestic government to commit in advance to the level of its policy, the optimal tariff protection enhances not only the domestic social welfare but also the innovative effort of the domestic firm. However, free trade, as a policy option *per se,* also has its virtues, since the information requirement for its implementation is virtually zero. Thus, we introduced other policy criteria beyond generated social welfare (i.e., the information requirement, time consistency, and the risk of agency and manipulative behaviour) in order to evaluate the policy options under consideration. We found that the most robust policy choice is the government "non–commitment" regime that has a low information requirement, and in which the optimal tariff is time consistent and the risk of manipulation by the domestic firm is absent. In addition, the social welfare loss *vis–à–vis* the government commitment regime is negligible.

An independent and interesting result of the first part of the analysis is the comparison between the corresponding equilibrium values of the innovative efforts and tariffs. Thus, in the government "non–commitment" regime, the optimal Cournot tariff is higher than the analogous Bertrand tariff, and consequently, the innovative effort of the Cournot type of firm exceeds that of the Bertrand type. (The same relation between R&D efforts and tariffs seems to hold in a commitment regime, but we managed to prove this only in the case of the specific functional form of the innovative cost function.)

In the second part of the chpter, we discuss two kinds of information asymmetry and briefly explored how the most desirable policy under perfect information – a non–commitment regime – fared, in the presence of the government's uncertainty about the market conduct. The first type of uncertainty is deemed the stronger one since the domestic government is presumed not to be able to learn anything about market conduct and has to rely only on its prior beliefs in setting the policy. The second type of uncertainty is the standard one in which the government is able to update its beliefs after observing the R&D effort of the domestic firm that can signal its type.

The asymmetric information set–up is less information intensive but in general `worsens social welfare compared to the analogous symmetric information set–up. Nevertheless, we identified situations when the expected social welfare can be higher than the corresponding social welfare levels under the symmetric information assumption. In the strong kind of information asymmetry, this happens when Bertrand is the true type conduct and the government probability associated with this true conduct is "not too low". In the case of the second type of information asymmetry, this occurs when a separating equilibrium exists under Cournot competition and products are "differentiated enough". In such a situation an increase of the innovative effort due to signalling either approaches the first best innovative effort from below or does not exceed it "too much".

APPENDIX 1: PROOF OF PROPOSITION 1

We have already shown that $t^{*B} < t^{*C}$ and that, from the social point of view, both Cournot and Bertrand types of firm under–invest in R&D. Therefore, it remains only to show that $x^{*B} < x^{*C}$. To prove the relation between R&D levels in different types of market conduct, we first eliminate V_d in equation (16) by using the fact that $V_d \beta_f$ - $V_f \beta_d$ = 0. Then we differentiate the resulted equation with respect to V_f and we get

$$\frac{dx}{dV_f}\left(ki''(x^*)-\frac{2\beta_d\beta_f V_f(V_f+\beta_f)^2}{[\beta_d(V_f+\beta_f)^2-\beta_f\gamma^2]^2}\right)=\frac{2\beta_d\beta_f V_f[\beta_d(V_f+\beta_f)^2-(2V_f+\beta_f)\gamma^2]}{[\beta_d(V_f+\beta_f)^2-\beta_f\gamma^2]^2}q^d +$$

$$+\frac{2\beta_d\beta_f V_f(V_f+\beta_f)}{[\beta_d(V_f+\beta_f)^2-\beta_f\gamma^2]^2}\left((\alpha_d-c+x^*)+\gamma\frac{\alpha_f\beta_f}{(2V_f+\beta_f)^2}\right).$$

Due to assumption (A3), the left hand side parenthesis is bigger than zero. In addition, for both Bertrand and Cournot conjectures $\beta_d(V_f+\beta_f)^2-(2V_f+\beta_f)\gamma^2>0$. Then, the right hand side is positive so dx/dV_f is positive, and since $V_f^C > V_f^B$, we find that $x^{*B} < x^{*C}$.

APPENDIX 2: PROOF OF PROPOSITION 2

The social welfare function (6) is separable in t and x. Its first derivative with respect to t is given by (10) and is a linear function in t, positive in $t = 0$. Consequently, as long as the tariff increases towards $t^* = t_{so}$, the domestic social welfare increases. With respect to x, the first derivative is given by (13) or equivalently, by $q^d(x,t_{so})\frac{2V_d+\beta_d}{V_d+\beta_d}-ki'(x)\geq 0$. Due to assumption (A2) this derivative is strictly positive in $x = 0$. Moreover, the solution of this derivative equal to zero is the socially optimum investment level x_{so}. Consequently, as long as the level of investment increases towards x_{so}, domestic social welfare increases. Since 0 (the free trade level for tariff) < t^* and since for product substitutes, $x_{ft} \leq x^* \leq x_{so}$ (with equality if we have corner solutions for the R&D level), free trade brings lower social welfare than the optimal tariff does.

When we take the total derivative of the domestic profit given by equation (5) with respect to t and use in it the envelope theorem (for the R&D choice), we obtain that $\frac{d\pi^d}{dt} = 2V_d q^d \frac{\partial q^d}{\partial t}$, where q^d is given by (4). Since $\partial q^d / \partial t$ is positive, the domestic profit increases as the tariff increases.

APPENDIX 3: PROOF OF PROPOSITION 3

We use the fact that the social welfare function $W(x,t)$ is separable in t and x and we denote by $\partial W/\partial t = \partial W/\partial t\,(x,t)$ and by $\partial W/\partial x = \partial W/\partial x\,(x,t)$. We recall from the discussion in the proof for Proposition 2 that $\partial W/\partial t$ is positive for $t < t^*$ and negative otherwise, and that $\partial W/\partial x$ is positive for $x < x_{so}$. As we saw from equation (19), it follows that $\partial X/\partial t \geq 0$ (with equality only for corner solutions in R&D).

When the optimal tariff is chosen before the domestic firm decides on its innovative effort, the domestic government solves

$$\frac{dW}{dt} = \frac{\partial W}{\partial t} + \frac{\partial W}{\partial x}\frac{\partial X}{\partial t} = 0 .$$

This will yield a different solution than when the government cannot commit in advance to its policy. In that case it only solves $\partial W/\partial t = 0$ and thus chooses the tariff t^*. However at t^* tariff protection the domestic firm chooses a level of R&D investment equal to x^*, a level which is below the corresponding socially optimal value. Thus at t^* dW/dt is positive. If the government chooses a $t < t^*$ then $\partial W/\partial t > 0$ and moreover $\partial W/\partial x > 0$ (since such a tariff will induce a level of R&D lower than or equal to x^*). Thus at $t < t^*$ dW/dt remains positive. Consequently the optimal tariff should be above or equal to t^* with equality holding for $x^* = c$. If x^* is below c, then, if the tariff is high enough to induce investment levels above or equal to x_{so}, dW/dt becomes negative ($\partial W/\partial t < 0$, $\partial W/\partial x \leq 0$). To conclude, the optimal tariff T^* should be higher than the optimal one without government commitment, but not so high as to induce the socially optimal level of innovation. Thus X^* will be above x^* but below the socially optimal value of innovation, x_{so}.

APPENDIX 4: THE CASE WHEN f(x) = $x^2/2$

When we replace in (19) the quadratic form of the investment function and the formula (4) for $q^d(X, t)$ we find that, given the level of tariff t, in the second stage the domestic firm chooses a level of R&D of

$$X(t) = \frac{2V_d(V_f + \beta_f)}{k[(V_d + \beta_d)(V_f + \beta_f) - \gamma^2]^2 - 2V_d(V_f + \beta_f)^2}\left[(V_f + \beta_f)(\alpha_d - c) - \gamma(\alpha_f - t)\right].$$

To derive the optimal tariff level we replace this formula in (23) together with the formulas for Cournot and Bertrand conjectures, and we obtain

(i) $$T^{*C} = \frac{\alpha_f}{3} + \gamma \frac{4k\beta_f(4\beta_d\beta_f - 3\gamma^2)[3\beta_f(\alpha_d - c) - \alpha_f\gamma]}{3[3k^2(4\beta_d\beta_f - \gamma^2)^3 - 64k\beta_d\beta_f^{\,2}(3\beta_d\beta_f - \gamma^2) + 48\beta_d\beta_f^{\,3}]}$$

for quantity competition and

(ii) $$T^{*B} = \frac{\alpha_f}{3 + \frac{\gamma^2}{\beta_d\beta_f - \gamma^2}} + \gamma \frac{2k\beta_d\beta_f^{\,3}(4\beta_d\beta_f - 3\gamma^2)(2\beta_d\beta_f - \gamma^2)[(3\beta_d\beta_f - 2\gamma^2)(\alpha_d - c) - \alpha_f\beta_d\gamma]}{(3\beta_d\beta_f - 2\gamma^2)D_B}$$

where

$$D_B = k^2(4\beta_d\beta_f - \gamma^2)^3(3\beta_d\beta_f - 2\gamma^2)(\beta_d\beta_f - \gamma^2) - 8k\beta_f(2\beta_d\beta_f - \gamma^2)^2(6\beta_d^{\,2}\beta_f^{\,2} - 6\beta_d\beta_f\gamma^2 + \gamma^4)$$
$$+\ 4\beta_f^{\,2}(2\beta_d\beta_f - \gamma^2)^2(3\beta_d\beta_f - 2\gamma^2)$$

for price competition.

We did not make the comparison between T^{*C} and T^{*B} so one could have conjectured that $T^{*C} > T^{*B}$ as was the case in the non–commitment regime (that is, $t^{*C} > t^{*B}$). However, this is not completely clear since we should recall that in the commitment case, the government influences the level of domestic firm's R&D level and unit cost reduction. To the extent that these levels are more suboptimal in the Bertrand case than in the Cournot case we may expect that the difference, T^{*B} - t^{*B} is bigger than T^{*C} - t^{*C}. In other words, the optimal commitment tariff may increase more in the case of Bertrand competition above its non–commitment counterpart than is the case in Cournot competition. So it is *a priori* unclear whether this impact can be strong enough to drive the optimal Bertrand tariff above the Cournot one in the commitment regime. The expressions for T^{*C} and T^{*B} are rather complex, so we were unable to find the exact relations between T^{*C} and T^{*B}. However, in our example with quadratic investment function, when we considered symmetric demands with $\alpha_d = \alpha_f = 1$ and $\beta_d = \beta_f = 1$, we could show by simulations that T^{*B} is never bigger than T^{*C}.

APPENDIX 5: PROOF OF PROPOSITION 4

A domestic firm that correctly anticipates a tariff protection level of t^u chooses a level of R&D given by (16) with the amendment that t^* is replaced by t^u. Since t^u does not depend on the level of innovation, the corresponding level of R&D equals the R&D choice of a firm facing a committed government that announces a t^u level of tariff protection (see formula 19). Thus, for any given level of tariff t, social welfare in the case of non–commitment regime equals the social welfare under commitment, provided that in the former case the domestic firm *correctly* anticipates the level t of the tariff.

We know from Proposition 3 that as long as the tariff increases towards $T,^*$ social welfare increases as well. In Bertrand competition, t^u is always higher than t^{*B}. In addition, for some values of η that are close enough to 1, the continuity of t^u in η ensures that t^{uB} is smaller than T^{*B}. Thus, for such values of η, social welfare under the protection level, t^u , is always higher than social welfare under t^{*B} (On the other hand, when products are almost homogenous and η is close to 0 so that the tariff level t^u approaches t^{*C}, such a high protection level might drive the domestic social welfare to levels even lower than the free trade level.).

The social welfare function (described by formula (6)) increases in t for $t \leq t^*$ and increases in x for $x \leq x_{so}$. The tariff t^u is above 0, which is the free trade "tariff", but below t^{*C}. Also, the level of R&D chosen by the domestic firm under tariff protection x^* is above the free trade level (but below or equal to x_{so}). Thus, the optimal tariff under uncertainty t^u enhances the domestic social welfare with respect to the free trade outcome, but reduces social welfare to below the symmetric information level.

Chapter V
Strategic Trade Policy and Vertical Product Differentiation in North–South Trade

1 INTRODUCTION

The chapter V brings the vertical product differentiation on the scene. The concept of vertical product differentiation was until recently practically absent in the considerations of strategic trade theorists, since the prevalent benchmark in the field was oligopoly competition with horizontally differentiated products. Thus, for instance, J. Brander did not have a reason to devote more than two sentences to the effects of trade policy on product quality in his famous survey from the mid-nineties (Brander, 1995). The neglected role of vertical product differentiation seems now to have become history and, according to some authors (Ghosh and Das, 2001), this new focus could lead to a revival of the whole subject of strategic trade policy[1].

The inclusion of vertical product differentiation in the context of strategic trade is not a purely theoretical exercise, but has solid empirical underpinnings. Namely, recent empirical trade literature has managed to distinguish between intra-industry trade (IIT) that is based on horizontal product differentiation ("horizontal IIT") from the intra-industry trade based on vertical product differentiation ("vertical IIT"), pointing to the different factors that determine these trade flows. An interesting and somewhat surprising fact is that in general vertical IIT represents a significantly larger share in the total IIT (Greenaway et al., 1994 and 1995). As Schott (2004) has demonstrated, this kind of trade is also consistent with the Heckscher-Ohlin type of specialisation but within

[1] Ghosh and Das (2001) see the main reason for the current stagnation of the field of strategic trade policy in the neglected role of vertical product differentiation in international trade theory.

products (varieties), where the producers from a capital and skill-intensive country use their advantage to produce vertically superior varieties, that is, varieties that are relatively capital or skill-intensive and possess higher quality. The novelty of his approach is that this specialization occurs within products rather than, as previously assumed, across products. This also may explain the empirical fact that firms and workers in North not only produce but also export in industries like apparel and textiles, which are commonly associated with developing countries.

Vertical IIT seems to be an improtant pattern of trade between the North and the South (Clark and Stanley, 1999). In other words, this trade is characterized by the different product qualities that Northern and Southern firms offer in the same market (see Table 3 in Greenaway et al., 1994). Thus, for example, U.S. firms export high-quality (and high-value) products such as hydraulic actuators and high-pressure valve stems and seats to Mexico (U.S. International Trade Commission, 1996) and compete there with the Mexican firms that offer the corresponding product varieties of lower quality. At the same time, Mexican firms export simple low-quality steel and iron valve body housings to the U.S. (U.S. International Trade Commission, 1996), competing with high-quality products of the American firms in the U.S. market.

The same phenomenon holds (or at least used to hold) for transition countries as well. Thus, for instance, Landesmann and Burgstaller (1997) observe quality differences between Western and Eastern European intra–industry trade. Even more striking, Aturupane et al. (1999) find that vertically differentiated intra-industry trade accounts for 80 to 90 percent of the total intra–industry trade between the EU and advanced Central European transition economies. Similarly, Van Berkum (1999) analyses the pattern of intra–industry trade in agricultural products between the EU and Central European countries, and finds that vertical product differentiation dominates this trade.[2] Finally, Greenaway et al. (1995) show that in the United Kingdom over two thirds of all intra-industry trade is vertically differentiated, which seems to be just a mirror image of the above–described empirical findings.

On the one hand, the motivation of this last chpater comes from the above-cited empirical evidence which demonstrates that vertical product differentiation is the *differentia specifica* of IIT between Northern and Southern firms and, on the other hand, from the need to further improve the modelling of the above phenomenon. Since the majority of IIT takes place in imperfectly competitive markets, an adequate theoretical analysis has to take into account the strategic interaction among the competing firms, the market structure that comes out of this interaction, as well as the timing, capability, and incentives of the government to intervene in such a set-up. The strategic choices in our particular context concern the firms' selection of product qualities on the one side and the appropriate government policy on the other side.

To the best of our knowledge, there are few theoretical papers that deal with some of the above issues. Some of the first theoretical papers connecting vertical product differentiation and strategic trade are those by Zhou et al. (2000 and 2002), where the authors analyse endogenous quality choice by the firms. However, the stage of action is not the domestic market but rather the standard "third country market" case. Subsequent contributions concentrate on the domestic market, which is arguably a more insightful and more relevant case for the purpose of our analysis. Thus, the already mentioned Ghosh and Das (2001) emphasise competition in the domestic market, in the context where a Northern firm competes with a Southern firm and where the domestic market can be either in the North or in the South. Quality is set exogenously, whereby the Northern firm

[2] See also Fertő (2002).

produces the commodity of high quality and the Southern firm of low quality. The authors show that the Southern firm may not survive in the Northern market once the optimal trade policy is applied, but the opposite is not true: the Northern firm always sustains itself in the Southern market under the optimal set of strategic trade policies (tariffs or tariffs *cum* output subsides.) As for the timing of the game, they applied standard sequencing where the governments commit in advance to selected policy instruments.

Moraga-González and Viaene (2005) use a structure very similar to that of Ghosh and Das (2001), with the only difference being that the quality choice is now endogenous, which in turn requires an intermediate stage to be added to the Ghosh and Das (2001) two-stage game. However, the addition of the endogenous quality choice may have important consequences since the effect of the domestic government's trade and industrial policy (tariffs and subsidies, respectively) may lead to a change in quality leadership. Moreover, Moraga-González and Viaene (2005) confine their analysis to transition economies, identifying the conditions under which the change in quality leadership from developed to transition country firm occurs.

The last relevant paper is Herguera et al. (2002), where the authors also set the stage for the action to be in the domestic, internal market and assume that the quality is chosen endogenously. More importantly, unlike the above-mentioned papers, Herguera et al. (2002) allow for the reverse sequencing of the strategic moves between the firms and the government. However, their analysis relies on the *ex ante* symmetry between the firms and is not carried out in the context of Northern versus Southern firms.

We put forward a simple strategic trade duopoly model with vertical product differentiation and we concentrate on the set-up where the action takes place in the domestic market of the South. The strategic choice considered is the firms' selection of product qualities, and duopoly as a market structure emerges endogenously from the nature of the competition and the size of the market. The trade policy in question is an import tariff and finally, the government sets the tariff only after the firms' quality choice has taken place[3].

All of the literature reviewed above focuses on the exogenously imposed "uncovered" market, i.e., on the situation where the distribution of the consumers with respect to their taste for quality is such that the lowest tail is not served in equilibrium. We, on the other hand, consider both "uncovered" and "covered" market cases and analyse the conditions under which these structures occur in equilibrium. The issue of whether the market is covered or not is endogenous and depends on the size of the market that seems natural to be taken as exogenous. Thus, for instance, the authors from the field of business strategy (Porter, 1990; Linder, 1961), consider market size to be the starting point (parameter) and investigate how it impacts other relevant variables like qualities, international competitive advantage, and the like. Our main focus is when there is a "covered" market in equilibrium. Following Shaked and Sutton (1982), we label such a market a "natural duopoly."

Natural duopoly is an appropriate setup if, roughly speaking, the taste for quality is predominant in the market in the sense that even the consumer with the lowest valuation for quality prefers to buy a quality good than to buy nothing. Thus, natural duopoly as a market structure would be endogenously determined. That is, the number of firms is not arbitrarily set to two but is the outcome of the given size of the market (determined in turn by the distribution of the consumers' taste for quality) and the nature of the competition that enables only two firms to survive in equilibrium. Lastly, the issue of long-run equilibrium seems to be best addressed in the natural duopoly set-up since a "non-natural duopoly" where the market is not fully covered may not be sustainable in

[3]Obviously we again focus on the government "non-commitment" regime. Following Neary's (1991) terminology, we, like Herguera et al. (2002) label this set-up as an "ex post tariff game".

the long run due to the possibility of entry of other firms (to serve this uncovered segment of the market).

Much like Zhou et al. (2000) and Moraga-González and Viaene (2005), we assume that firms differ in quality cost efficiency. This is motivated by different abilities of the firms from the South (compared with their Northern counterparts) to elevate the quality level of their products. Namely, the generation of high quality varieties is tightly connected with R&D investment, learning by doing and the level of human capital and, therefore, it seems natural that at the margin an increase in quality would require a higher effort and higher costs on the part of the Southern firm than on the part of the Northern firm.

As for our major results, we show that for the optimal trade policy and for given market size, natural duopoly is the only equilibrium market structure. Furthermore, we clarify and quantify the phenomenon of so called "quality reversal"[4] (see Herguera et al., 2002, and Moraga-González and Viaene, 2005, for the different definitions of quality reversal).

We show that the key proposition of Herguera et al. (2002), which states that under the ex post optimal tariff the foreign firm always produces the low quality good, hinges on their assumption that both firms have identical quality costs. However, the difference in the quality costs is a key distinction between the firms in developed and less developed countries. Thus, we show that the incidence of quality reversals depends on the relative cost efficiency in producing quality and if the difference in these efficiencies is "large enough", we do not observe a switch in the quality ladder. This result resembles the findings of Moraga-González and Viaene (2005), who obtain a similar result in a somewhat different set-up and using a different notion of quality reversal than Herguera

[4]The term "quality reversal" refers to the situation where, say, in free trade the foreign firm from a developed country was initially a high quality provider but due to the implemented trade policy the domestic, developing country firm switches from the low to the high quality producer in the new equilibrium.

et al. (2002). However, unlike Moraga-González and Viaene (2005), we quantify the occurrence of quality reversal and show that duopoly equilibrium in which a domestic, low-quality firm continues to produce the low-quality good (no quality reversal) holds for the majority of the parameter space.

The rest of the chapter is organised in the following way: in Section 2, we describe our model, which is solved in Sections 3 to 5. Section 6 concludes. Proofs and figures can be found in the appendices.

2 THE MODEL

There are two countries, one domestic and one foreign. In each country there is a group of firms potentially producing vertically differentiated products. The key difference between the two countries is the cost efficiency in generating quality with the firms from the North being more efficient.

Like Ghosh and Das (2001), Herguera et al. (2002), and Moraga-González and Viaene (2005), we also concentrate on the domestic market. For now, we assume that there are only two firms serving the domestic market and later we investigate under which conditions this constellation happens to be the equilibrium outcome. In particular, we are interested in the situation when there is one domestic and one foreign firm serving the domestic market in equilibrium.

In order to protect the domestic firm, the domestic government uses trade policy in the form of a tariff on imports.

The "*ex post* tariff game" has three stages. In the first stage, the firms choose their qualities. We denote by $s_1 > 0$ the higher quality and by $s_2 > 0$ the lower quality in the market. In the second stage, the domestic government decides on the tariff so as to maximise domestic welfare that consists of domestic consumer surplus, the domestic firm's profit, and tariff revenues. We denote $t_i \in \mathbb{R}$ the tariff imposed on firm i. In the last stage of the game, the firms compete in prices.

The consumers in the domestic market differ in their taste parameter θ, which is distributed with unit density over the interval $\left[\underline{\theta}, \bar{\theta}\right]$, where $0 \leq \underline{\theta} < \bar{\theta}$. Each consumer may either buy exactly one unit of the good from one of the firms, or buy nothing (which is equivalent to the assumption that a third modification of the good, with quality zero, is available for free), and the utility of a consumer with quality parameter θ is given by

$$U = \begin{cases} \theta s_i - p_i, & \text{if a unit of the good of quality } s_i \text{ is bought at price } p_i; \\ 0, & \text{otherwise.} \end{cases} \tag{1}$$

In the last stage, the firms produce at zero costs. In the first stage, however, the firms incur fixed costs of quality choice, $C(s_i) = a_i s_i^2/2$, where $a_i > 0$. The firm with the lower a_i is more cost-efficient, and in the setting of the Northern firm competing with the Southern firm the former one is likely to have the lower a_i.

For the sake of exposition, we write $\Theta = \underline{\theta}/\bar{\theta}$ and $S = s_2/s_1$; note that both Θ and S lie within $[0, 1)$. The game is solved by backward induction.

3 THE THIRD STAGE: PRICE EQUILIBRIUM

At this stage, qualities s_1 and s_2 are fixed, and the tariffs t_1 and t_2 are given. Note that the tariff imposed on the domestic firm equals zero, i.e., $t_1 = 0$ if the domestic firm is the high-quality one, and $t_2 = 0$ if the domestic firm is the low-quality one[5].

[5]Following Herguera et al. (2002), we constrain our trade policy to the choice of a single instrument, a tariff, noting that $t_1 = 0$ or $t_2 = 0$ is not necessarily the optimal policy. Namely, besides imposing a tariff on the foreign firm, it may be welfare improving to subsidise or tax the domestic firm as is shown in Ghosh and Das (2001). However, we assume that this is not a feasible option.

Given the prices p_1 and p_2, according to the utility function the consumer indifferent between the firms is characterised by the taste parameter value

$$\theta = \theta_{12} = \frac{p_1 - p_2}{s_1 - s_2},$$

and the consumer indifferent between firm i and not buying at all is characterised by

$$\theta = \theta_{i0} = p_i / s_i.$$

Firm i's demand function D_i is the measure of consumers who buy from firm i. The demand functions depend on where the indifferent consumers θ_{12}, θ_{10}, and θ_{20} are located with respect to each other and with respect to the consumers with the highest and the lowest quality sensitivities in the market, $\bar{\theta}$ and $\underline{\theta}$.

3.1 Market structures

The complete list of market structures and the correspondning conditions on prices (p_1, p_2) is presented in Appendix A. The most relevant market structures[6] are:

- *Duopoly*, when each firm has a positive market share, i.e. $\underline{\theta} < \theta_{12} < \bar{\theta}$. Then the high-quality firm serves the high quality sensitivity segment of the consumers, whereas the low-quality firm serves those whose sensitivity is neither too high to buy from the high-quality firm nor too low to buy nothing. More precisely, $D_1 = \bar{\theta} - \theta_{12}$ and $D_2 = \theta_{12} - \max\{\underline{\theta}, \theta_{20}\}$. Three subcases are distinguished according to the behaviour of the consumer with the lowest quality sensitivity.

  1. If the consumer with the lowest quality sensitivity strictly prefers buying from the low-quality firm to not buying, i.e., if $\theta_{20} < \underline{\theta}$, then $D_2 = \theta_{12} - \underline{\theta}$ and the

[6] No other market structure can occur after welfare maximisation in the second stage and, therefore, as an equilibrium of the entire game.

situation will be referred to henceforth as *over-covered market*, for even the consumer with the lowest quality sensitivity obtains a positive utility.

2. If the consumer with the lowest quality sensitivity is indifferent between buying from the low-quality firm and not buying, i.e., if $\theta_{20} = \underline{\theta}$, then $D_2 = \theta_{12} - \underline{\theta} = \theta_{12} - \theta_{20}$ and we will henceforth call this situation *exactly covered market*.

3. If the consumer with the lowest quality sensitivity strictly prefers not buying to buying from the low-quality firm, i.e., if $\theta_{20} > \underline{\theta}$, then $D_2 = \theta_{12} - \theta_{20}$ and the situation will be referred to as *non-covered market*, for there are consumers who are not served by either firm.

Further on, *covered market* will refer to either over-covered market or exactly covered market.

– *Monopoly of the high-quality firm with a covered market*, when all consumers buy from firm 1 so that $D_1 = \bar{\theta} - \underline{\theta}$ and $D_2 = 0$.

3.2 Price equilibria

The third stage profit of firm i $(i = 1, 2)$ equals

$$\Pi_i = (p_i - t_i)D_i.$$

Prices are chosen non-cooperatively, and each firm maximises its profit taking the rival's price as given.

A complete mathematical treatment of this price competition game for arbitrary tariffs and qualities is provided by Kúnin (2003). A complete analysis of the equilibirum market structures that can occur when one of the tariffs, which is the tariff on the domestic firm, is set to zero, along with the corresponding conditions on the other tariff and qualities, is presented in Kúnin and Žigić (2004). In particular, equilibrium prices, third stage profits and conditions on the tariff on the foreign firm for the outcome to be duopoly (regardless of market coverage) or high-quality firm monopoly (with a covered market) can be found in Appendix B.

4 The second stage: tariff choice

At this stage, the domestic government chooses the import tariff taking qualities s_1 and s_2 as given. The government's objective function is the domestic welfare W_i, which generally includes three components, namely, the domestic consumer surplus CS, the profit of the domestic firm Π_i, and the tariff revenue $t_j D_j$. The application of the optimal tariff does not necessary lead to duopoly, so that either the profit of the domestic firm or the tariff revenue may equal zero.

In general, the consumer surplus is defined as $CS = CS_1 + CS_2$, where CS_i is the surplus of the consumers who buy from firm i, $CS_i = \int_{Q_i} (\theta s_i - p_i) d\theta$. In the last integral, $Q_i \subseteq \left[\underline{\theta}, \bar{\theta}\right]$ denotes the set of quality parameters θ such that the consumers in Q_i buy from firm i. If firm i is out of the market, then Q_i is empty and, therefore, CS_i is zero. In particular, if there is a duopoly then the domestic consumer surplus equals

$$CS = \int_{\theta_{12}}^{\bar{\theta}} (\theta s_1 - p_1) d\theta + \int_{\max\{\underline{\theta}, \theta_{20}\}}^{\theta_{12}} (\theta s_2 - p_2) d\theta,$$

and if there is a monopoly of the high-quality firm and the market is either over-covered or exactly covered, then the domestic consumer surplus equals

$$CS = \int_{\underline{\theta}}^{\bar{\theta}} (\theta s_1 - p_1) d\theta.$$

If the social welfare is maximised at a tariff leading to monopoly with a covered market, then such a tariff is often not unique. The reason is that there is a range of tariffs that yield the same total welfare but different distributions of welfare.[7] In such cases, it is assumed that the government selects *the minimal non-negative* tariff among the set of optimal tariffs.

The complete derivation of the optimal tariffs can be found in Kúnin and Žigić (2004). The values of the optimal tariffs as well as the corresponding market structures and firms' profits can be found in Appendix C. The equilibrium market structure (after welfare maximisation) is determined by $\Theta = \underline{\theta}/\bar{\theta}$ and $S = s_2/s_1$.

A useful benchmark for analysing the outcomes under optimal trade policy is free trade, i.e. $t_1 = t_2 = 0$. In this case, the market structures occurring for given $\Theta, S \in [0, 1)$ are shown in Figure 1. Under free trade, the outcome is monopoly when the market is relatively homogeneous ($\Theta \geq 1/2$) and duopoly otherwise, for any qualities. If $\Theta \in [1/4, 1/2)$, i.e. when the market is sufficiently heterogeneous to sustain just two firms, then the outcome is duopoly with a covered market for any S, which is often referred to as *natural duopoly* following Shaked and Sutton (1982).

4.1 High-quality domestic firm

If the domestic firm produces the high-quality good, then the possible second stage equilibrium market structures are duopoly with a non-covered market, duopoly with an exactly covered market, and monopoly of the high-quality firm with a covered market (see

[7] This happens when for some optimal tariff the market structure is monopoly with an *over-covered* market. The monopolist sets its price at the highest level such that it is not profitable for the other firm to enter due to the tariff. Then a small increase in the tariff allows the monopolist to further increase its price while the market stays over-covered, which leads to a redistribution of welfare in favour of the monopolist. The reason for such a redistribution to occur is the special consumer utility structure $U = \theta s - p$. With this utility, the consumer surplus loss caused by a price increase (provided that the consumer does not switch to the other firm or to buying nothing) is *exactly* offset by the firm's gain.

Appendix C). These market structures are shown in Figure 2.

The outcome of the second stage is monopoly in two cases. First, if $\Theta \geq 1/2$ then there is monopoly under free trade so that no trade policy is needed to ensure that the high-quality domestic firm becomes a monopolist and $t_2 = 0$. Second, when $(1-S)/(2-S) \leq \Theta < 1/2$, then the low-quality foreign firm is driven out of the market by the optimal tariff of $t_2 = (\bar{\theta} - 2\underline{\theta})(s_1 - s_2)$, which is the minimal tariff leading to monopoly.

A comparison of Figures 1 and 2 shows that trade policy when the domestic firm produces the high-quality good shifts the market structure away from duopoly with a covered market. There are two equlibrium market structures under free trade which correspond to duopoly with a covered market; one of them, duopoly with an over-covered market, is not possible under trade policy, and the set of Θ and S for the other one, duopoly with an exactly covered market, is much smaller under trade policy than under free trade. In addition, trade policy shifts the market structure towards monopoly in the following sense: under free trade, the outcome is never monopoly when $\Theta < 1/2$, but the impact of optimal trade policy is such that for any positive Θ the outcome is monopoly if the qualities are sufficiently close, i.e. if S is sufficiently close to unity (see Figure 2).

4.2 Low-quality domestic firm

If the domestic firm produces the low-quality good, then the possible second stage equilibrium market structures are duopoly with a non-covered market, duopoly with an exactly covered market, duopoly with an over-covered market, and monopoly of the high-quality (in this case, foreign) firm with an over-covered market (see Appendix C).

In particular, if $2(1-S)/3 < \Theta < 2/3$ then the optimal tariff is $t_1 = (\bar{\theta} - \underline{\theta})(s_1 - s_2)$ and the outcome is duopoly with an over-covered market, and if $(2/3)(1-S)/(2-S) \leq \Theta \leq 2(1-S)/3$ then the optimal tariff is $t_1 = \bar{\theta}(s_1 - s_2)/3 + \underline{\theta} s_2$ and the outcome is duopoly with an exactly covered market. The market structures occurring under the optimal tariff when the domestic firm produces the low quality are shown in Figure 3.

A comparison of Figures 1 and 3 shows that trade policy when the domestic firm produces the low-quality good shifts the market structure towards duopoly since the range of Θ such that the outcome is monopoly is $[1/2, 1]$ under free trade and $[2/3, 1]$ under trade policy. The range of Θ such that the outcome is duopoly with a covered market for any S expands and shifts from $[1/4, 1/2)$ under free trade to $[1/3, 2/3)$ under trade policy.

5 The first stage: quality choice

At this stage, the firms simultaneously choose qualities s_1 and s_2 to maximise their profits net of quality costs $C_i(s_i) = a_i s_i^2/2$. Let $k_i = a_i/\bar{\theta}^2$, and let $K = k_2/k_1 = a_2/a_1$. The value of $K \geq 1$ can be interpreted as a measure of relative technological advance of firm 1 with respect to firm 2 for if quality s costs firm 1 $C_1(s)$ then the same quality s costs firm 2 $C_2(s) = KC_1(s)$.

It turns out that the outcome of the first stage and of the entire game is determined by Θ, which reflects consumer heterogeneity, and K.

The following approach is used to find quality equilibria. First, a pair of qualities (s_1, s_2) is found such that it would be an equilibrium *if the firms' positions on the quality ladder were* a priori *fixed*. Then this pair of qualities, called a *candidate equilibrium*, is checked for being an equilibrium, i.e. it is checked whether either firm is better off deviating in such a way that the high-quality firm becomes the low-quality one and vice versa.

More formally, a candidate equilibrium is a pair of qualities (s_1, s_2) such that (i) given s_2, the value s_1 maximises firm 1's profit subject to firm 1 being high-quality, $s_1 > s_2$;

(ii) given s_1, the value s_2 maximises firm 2's profit subject to firm 2 being low-quality, $s_1 > s_2$; (iii) both firms' profits are non-negative at (s_1, s_2). The last requirement is added since each firm can secure a non-negative profit in the entire game by entering as low-quality and choosing the quality of $s_i = 0$. Thus, in a candidate equilibrium, firm 1 is bound to produce higher quality.

A candidate equilibrium (s_1, s_2) is an equilibrium of the whole game when (i) and (ii) hold when the constraint $s_1 > s_2$ is *not* imposed. This means that firm 1 cannot strictly increase its profit by switching to be the low-quality firm, and firm 2 cannot strictly increase its profit by switching to be the high-quality firm. In more formal language, there does not exist $s_2' > s_1$ such that $\Pi_2^H(s_1, s_2') > \Pi_2^L(s_1, s_2)$, and nor does there exist $s_1' < s_2$ such that $\Pi_1^L(s_1', s_2) > \Pi_1^H(s_1, s_2)$, where Π_i^H and Π_i^L are firm i's profit functions when it produces high and low quality, respectively.

5.1 Quality reversals

It is a well-established fact that if there is no trade policy and the firms are identical, then the game has more than one equilibrium. Indeed, if (s_1, s_2) is an equilibrium of the whole game with $t_1 = t_2 = 0$ and $K = 1$ then so is (s_2, s_1). If the technologies possessed by the firms differ and/or trade policy is used, then often there are still two candidate equilibria, one with the domestic firm being high-quality and one with the domestic firm being low-quality.

However, unlike the case of free trade with identical firms, one of the candidate equilibria often turns out not to be an equilibrium of the entire game. A simple case, which does not have to involve trade policy, is the one when the technological margin between the firms is sufficiently wide so that the candidate equilibrium with the less advanced firm producing the high-quality good is not sustainable. A more interesting case arises when under free trade there is an equilibrium of the whole game wherein the domestic firm is high-quality or low-quality, but under the optimal trade policy the candidate equilibrium with the same position of the domestic firm is not an equilibrium of the whole game.

Herguera et al. (2002) refer to this last situation as a (policy-induced) *quality reversal*. They find that if $\Theta = 0$ and $K = 1$ (when there are two equilibria under free trade) then the candidate equilibrium under the optimal trade policy where the domestic firm produces the low-quality good is not an equilibrium of the whole game for the domestic firm's optimal response to the foreign firm's quality in the candidate equilibrium is to choose an even higher quality.

A slightly different (and, roughly speaking, complementary) definition of a quality reversal is employed by Moraga-González and Viaene (2005). In their model $\Theta = 0$ but the firms are allowed to differ in their quality cost efficiency, i.e. K can differ from 1. They show that even if there are two equilibria under free trade, then the one with the less efficient firm producing high quality is risk dominated (Motta et al., 1997). However, trade policy can reverse this result, i.e. the equilibrium with the less efficient domestic firm producing high quality becomes risk dominant. Thus, they define a quality reversal as the situation when, due to trade policy, the less efficient firm produces high quality in the risk dominant equilibrium.

5.2 Natural duopoly

A situation of particular interest is natural duopoly with a domestic low-quality firm. We assume that the model parameters are such that the market in question is a natural duopoly in the sense of Shaked and Sutton (1982), i.e., the consumer with the lowest quality sensitivity $\underline{\theta}$ prefers buying from one of the firms to not buying at all, and both firms are in the market in equilibrium. Thus, the distribution of tastes (or incomes) across consumers has to be heterogeneous enough in order to have more than one top-quality firm serving the whole market but, on the other hand, tastes should not be overly dispersed to enable more than two firms to survive in the market (Gabszewicz, 1985). In other words, there are exactly two firms that can survive in the market so that the number of firms is now endogenously determined.

As is shown in the previous section and in Appendix C, if the domestic firm is low-quality, then after the application of the optimal tariff the equilibrium structure is duopoly with covered market when $(2/3)(1-S)/(2-S) \leq \Theta < 2/3$. We restrict our attention to the case $\Theta \in [1/3, 2/3)$, for then the outcome of the entire game is duopoly with covered market regardless of quality choices $s_1 > s_2$. In particular, the market is exactly covered when $S \leq 1 - 3\Theta/2$ and over-covered otherwise[8].

[8]It is *a priori* not clear whether any other constellation of firms can form natural duopoly, given that only two firms are sustainable in equilibrium and given the size of the market. In Appendix C, we show that though the reverse constellation (labelled "DF") with the domestic firm producing high quality and the foreign firm producing low quality may form natural duopoly, this happens under quite restrictive conditions. In particular, for any $\Theta > 0$ if the qualities are sufficiently close then the market structure after the optimal tariff is imposed is monopoly of the high quality firm. This sharply contrasts with the case we focus on, where $\Theta \in [1/3, 2/3)$ is a sufficient condition for natural duopoly. Furthermore, the other two possible constellations with two domestic firms (labelled "DD") or two foreign firms (labelled "FF") serving the domestic less developed country market can form natural duopoly for some range of parameter Θ.

However, for some reasonable range of $K \in [K_-, K_+]$, the constellation that yields the highest social welfare is the one under our consideration, i.e. with the domestic LDC firm producing low quality and the foreign DC firm producing high quality variety in equilibrium (labelled "FD".) In other words, confining our analysis to the range of parameters $K \in [K_-, K_+]$ and relying on the Coase conjecture, the FD constellation turns to be the unique equilibrium outcome of the whole game. As for the intuition on the lower and upper bounds on the parameter K, the lower bound K_- ensures that the relative technological advance of the foreign firm is such that its presence in the market not only guarantees the existence of

The first-stage profit of the high-quality firm (divided by a positive constant $\bar{\theta}^2$) equals

$$\Pi_1 = (s_1 - s_2)/9 - k_1 s_1^2/2$$

in both "exactly covered" and "over-covered" cases. The first-stage profit of the low-quality firm (also divided by $\bar{\theta}^2$) equals

$$\Pi_2 = \Theta(2 - 3\Theta)s_2/3 - k_2 s_2^2/2$$

when the market is exactly covered and

$$\Pi_2^+ = (2 - 3\Theta)^2(s_1 - s_2)/9 - k_2 s_2^2/2$$

when the market is over-covered. It is immediately seen that firm 2's profit under an over-covered market strictly decreases in its own quality, $\partial\Pi_2^+/\partial s_2 < 0$, so that the market cannot be over-covered in equilibrium. This yields two options for firm 2's profit maximisation, given s_1. Namely, it can be maximised at a quality corresponding to the interior of the area when the outcome is an exactly covered market, which implies $S < 1 - 3\Theta/2$ (see Figure 3), or at a quality corresponding to the boundary of this area, which means $S = 1 - 3\Theta/2$. The former situation is further referred to an *interior equilibrium* and the latter one is referred to as a *boundary equilibrium* (though, strictly speaking, they are both *candidate* equilibria).

Proposition 1 *Let $\Theta \in [1/3, 2/3]$. Then for any k_1 and k_2 there exists a unique candidate equilibrium (s_1, s_2) such that the domestic firm produces low quality. In addition, the pair (s_1, s_2) corresponds to an interior equilibrium when $K > 6\Theta$ and to a boundary equilibrium when $K \leq 6\Theta$.*

the FD equilibrium but also makes sure that this FD constellation generates higher social welfare than the DD constellation due to higher average quality generated in equilibrium. Similarly, the upper bound K_+ ensures that the relative technological advantage of the foreign firm is not so high to make the social welfare in FF constellation even higher than the one in the FD constellation.

The proof of Proposition 1 can be found in Appendix D. If $K > 6\Theta$, then the candidate equilibrium in Proposition 1 is

$$s_1 = 1/(9k_1), \quad s_2 = \Theta(2 - 3\Theta)/(3k_2),$$

with the firms' first stage profits equal to[9]

$$\Pi_1 = (K - 6\Theta(2 - 3\Theta))/(162k_2), \quad \Pi_2 = \Theta^2(2 - 3\Theta)^2/(18k_2).$$

The corresponding values for $K \leq 6\Theta$ are[10]

$$s_1 = 1/(9k_1), \quad s_2 = (2 - 3\Theta)/(18k_1),$$

$$\Pi_1 = (3\Theta - 1)/(162k_1), \quad \Pi_2 = (12\Theta - K)(2 - 3\Theta)^2/(648k_1).$$

The intuition beyond the threshold $K = 6\Theta$ is that if K is low, then quality is (relatively) cheap for firm 2 so that its profit increases in its own quality until the market structure changes to duopoly with over-covered market, which results in a boundary equilibrium. If K is high, then quality is expensive for firm 2 so that its profit starts to decline before the market structure changes, so that there is an interior equilibrium.

5.3 Quality reversals in natural duopoly

In the set-up of natural duopoly with the domestic firm producing low quality, a quality reversal as defined by Herguera et al. (2002) occurs when the candidate equilibrium

[9]The low quality firm's candidate equilibrium profit does not depend on k_1 because the optimal s_2 does not depend on k_1 and the low quality firm's profit function before quality choice but after the optimal tariff is applied does not depend on s_1, which results from the model specification.

[10]Here the low quality firm's choice is determined by the boundary condition $S = 1 - 3\Theta/2$. As a result, both qualities and the high quality firm's profit do not depend on k_2. This seems to be a robust property of boundary equilibria for the threshold between interior and boundary equilibria does not depend on quality cost efficiencies.

derived in Proposition 1 is not an equilibrium of the entire game. A quality reversal as defined by Moraga-González and Viaene (2005) happens when the firm with the higher k_i produces high quality in equilibrium.

If the domestic firm in response to $s_1 = 1/(9k_1)$ chooses an even higher quality, it becomes the high-quality firm, and the outcome is described in Section 4.1 and depicted in Figure 2. Thus, the deviation underlying the quality reversal may result in either monopoly of the domestic firm (for smaller differences in qualities) or duopoly, which in turn can have either exactly covered or non-covered market.

Proposition 2 *If the degree of consumer heterogeneity* Θ *and the relative cost efficiency of the high-quality firm* K *are such that* $1/3 \leq \Theta \leq 2/3$ *and* $K \geq R(\Theta)$*, where* $1 \leq R(\Theta) < 2$ *for all applicable* Θ*, then in the candidate equilibrium in Proposition 1 there is no quality reversal by the domestic firm. In other words, the candidate equilibrium in Proposition 1 is an equilibrium of the entire game.*

The proof[11] of Proposition 2 and the explicit form of $R(\Theta)$ can be found in Appendix E. The graph of $R(\Theta)$ is depicted in Figure 4. For $\Theta < 1/2$, $R(\Theta)$ is strictly decreasing, and for $\Theta \geq 1/2$, $1 \leq R(\Theta) < 1.1$.

Note that if the firms possess the same level of technology, $K = 1$ (or if the domestic firm is more efficient, $K < 1$), then due to the trade policy there is always a quality reversal (as defined by Herguera et al., 2002). In other words, if the domestic firm is not less efficient in producing quality than the foreign firm, then the equilibrium wherein the

[11] It should be noted that Proposition 2 provides an answer to the question *when* there is a quality reversal but not *which market structure* arises after the quality reversal, nor does it characterise the other candidate equilibrium of the game, wherein the domestic firm produces high quality. However, if $1/2 \leq \Theta \leq 2/3$, then both the market structure after the quality reversal and the other candidate equilibrium surely feature monopoly of the domestic firm, see Section 4.1.

domestic firm supplies the low quality is ruled out by the trade policy. If $1 < K < R(\Theta)$, when the domestic firm is less efficient but the equilibrium with low-quality domestic firm is still ruled out, so that there is also a quality reversal as defided by Moraga-González and Viaene (2005). However, if the consumers are neither too homogeneous nor too heterogeneous ($1/3 \leq \Theta \leq 2/3$), then the minimal relative quality cost efficiency of the foreign firm guaranteeing no quality reversal, $K = R(\Theta)$, is not significantly greater than unity. Even for lower values of Θ (close to 1/3) there is no quality reversal when the foreign firm is at least twice as efficient as the domestic firm (the exact bound is $K \geq R(1/3) = 28/15$.) For higher values of Θ (above 1/2) even a ten percent difference in quality cost efficiency suffices for no quality reversal[12].

Again, put in the context where the action takes place in the Southern country market, the duopoly where the foreign firm (coming from the North) offers the high-quality good and the domestic, Southern country firm offers the low-quality good is sustainable provided that the relative quality cost efficiency in favour of the Northern country firm exceeds a certain threshold level and that the consumer heterogeneity is sufficiently "narrow." This relatively narrow range between the upper and lower bound of consumer tastes seems to picture very well some of the developing country markets where only a fraction of the people ("elite") may form the narrow market for, say, very expensive quality goods

[12] Another kind of a quality reversal that may happen is the reversal by the foreign firm to a lower quality than that of the domestic firm. It is possible to show that there is a quality reversal by the foreign firm in the following cases. For boundary equilibria, a reversal takes place when $\Theta < \Theta_r$, where $\Theta_r \approx 0.334335$. For interior equilibria, a reversal takes place when $K < 6\Theta(2 - 3\Theta)/(2 - 3\Theta_r)$.

Note that this kind of a quality reversal occurs for a very small range of parameters only. For instance, Lehmann-Grube (1997) shows that if $\Theta = 0$ then such quality reversals cannot occur. The intuition beyond the occurrence of this reversal in our case is that if Θ is relatively small ($\Theta \approx 1/3$) and so is K, then the market is large so that the products are less differentiated, which along with trade policy leads to lower profits for the foreign firm.

like cars.

5.4 Trade policy vis-à-vis free trade

Now we would like to summarise the implications of the optimal trade policy for equilibrium market structure and quality ranking when the range of consumer quality sensitivity is medium ($1/3 \leq \Theta \leq 2/3$) and the domestic firm is less efficient in quality production ($K > 1$). Recall that under free trade two cases are possible in this range of Θ (see Figure 1). Namely, there is monopoly if $1/2 \leq \Theta \leq 2/3$ and duopoly if $1/3 \leq \Theta < 1/2$.

If $1/2 \leq \Theta \leq 2/3$, then there is monopoly under free trade, and either firm may end up as the monopolist. Since quality is cheaper for the foreign firm, its monopoly quality is higher than that of the domestic firm so that the consumers are better off under foreign monopoly. As Bhattacharjea (1995) has noted, in the context of a developing countries "...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." So if the single foreign firm initially produces the high quality, then the simple optimal trade policy (tariff) results in duopoly as is shown in Section 4.2, provided that the foreign firm is sufficiently more efficient, i.e., $K > R(\Theta)$. In a sense, trade policy makes the market *artificially less homogeneous* "pushing" the foreign firm to serve the upper tail of the market and making the domestic firm viable in the lower tail. The gain in social welfare for the domestic country is the appearance of the domestic firm's profit and tariff revenue since both of them were zero under free trade. The cost of the trade policy is the decline in average quality and thus in consumer surplus. However, trade policy could have an even more powerful impact if the foreign firm is only slightly more efficient (that is, $1 < K < R(\Theta)$.) Then trade policy leads to quality reversal, and the new equilibrium market structure becomes domestic monopoly. If we explicitly add an entry stage to the very beginning of the game in our setup[13], the foreign firm would correctly anticipate that the trade policy would change the conditions of competition, so that it would either exit or not enter at all. The whole market is now captured by the less efficient domestic firm by virtue of trade policy and, as a consequence, the domestic firm produces a lower quality product in equilibrium compared to the product produced by the foreign monopolist under free trade, which causes losses in consumer surplus. However, these losses in consumer surplus are not so big due to the small difference in the firms' efficiencies (recall that in this region $R(\Theta) < 1.1$), so that the monopoly profit of the domestic firm more than compensates for these losses.

If $1/3 \leq \Theta < 1/2$, then under free trade there is duopoly with covered market. Here each firm can end up as the high quality producer (for there are two equilibria), though for *very* high values of K it may happen that the equilibrium with the less efficient domestic firm producing high quality is ruled out (see Moraga-González and Viaene, 2005). However, duopoly with the domestic firm producing low quality is both sustainable equilibrium and also the equilibrium selected by the risk dominance criterion. The optimal trade policy now seems to produce less dramatic effects since the equilibrium market structure is not changed when there is no quality reversal. As long as $K > R(\Theta)$, the duopoly equilibrium with the more efficient foreign firm generating the high quality remains sustainable, while the tariff changes the relative prices in favour of the domestic firm. The gain in social welfare for the domestic country is now the appearance of tariff revenue and the increase in the domestic firm's profit at the expense of the foreign competitor and the decrease in the consumer surplus. However, for the foreign firm to preserve its dominant position of the high quality producer, its relative efficiency in qual-

[13]Note that there is (at least implicitly) an entry stage in our setup since the number of firms is endogenously determined.

ity generation has to be increasing as the market becomes less homogeneous (that is, as Θ declines, see Figure 4.) In other words, the quality reversal is more likely in this range and, for given k_1, its likelihood increases, as Θ decreases. If $K < R(\Theta)$, then the optimal tariff results in quality reversal so that the more efficient firm in the best case produces the lower quality, which corresponds to quality reversal in the sense of Moraga-González and Viaene (2005). A much worse possible outcome of trade policy is that the foreign firm can be completely driven out of the market. In this case, the distortion caused by trade policy may result in a lower welfare than under free trade.

In the spirit of Sutton (1991), trade policy alters the *toughness* of post-entry price competition, and the direction of this change hinges on the parameters. If there is monopoly under free trade and there is no quality reversal under trade policy ($1/2 \leq \Theta \leq 2/3$, $K > R(\Theta)$), then price competition is *looser* under trade policy as there is space for both firms. If there is duopoly under free trade and there is quality reversal under trade policy ($1/3 \leq \Theta < 1/2$, $K < R(\Theta)$), then price competition might be *tougher* as the optimal tariff may lead to domestic monopoly.

6 Conclusion

The focus of our analysis is the interaction of strategic trade policy in the form of a tariff and competition in qualities and prices in the context of firms from North versus those from the South. The conspicuous effect of trade policy in this set-up is that it may affect the market structure as well as induce a firm to leap frog from low to high quality production and vice versa. The latter phenomenon is known as "quality reversal." Although a few particular cases of this phenomenon were previously addressed in the literature, our contribution is to place it in a more general analytical framework. In our set-up, the market structure is not exogenously set but instead emerges as a result of an interplay between the relevant structural parameters such as the size of the market and marginal efficiency in upgrading the quality on the one hand, and trade policy, on the other.

We concentrate on the situation when the domestic market is in the Southern country and possesses the characteristics of "natural duopoly" in the Shaked and Sutton (1982) sense. That is, the size of the market is such that given the optimal tariff only two firms can survive in it. We show that compared to free trade, the optimal trade policy in this set-up enables duopoly to be a viable and dominant market structure for the larger size of the market, where the size of the market is measured in relative terms as the ratio of the lowest to highest consumer's preference for quality.

As for the quality reversal, we demonstrate that trade policy has somewhat limited ability to induce it. Namely, the lag in quality cost efficiency of the Southern country firm vis-à-vis the Northern country firm should be relatively small for quality reversal to be the best response for the initially low-quality, domestic firm. We also discuss and compare our findings with other relevant results from trade literature that tackle the issue of quality reversal.

As for future research, the model developed and the results derived above enable us to extend our analysis to some other important issues like, for instance, the equilibrium of the whole game when the high-quality firm is the domestic one. Having this in hand, we can then study the social welfare implications of trade liberalisation in both South and North. Thus, for instance, one of the policy conclusions that our analysis seems to provide is that trade liberalisation in the Southern country might lead to major social welfare costs and undesired effects such as the establishment of foreign firms' monopolies. In the less drastic case, trade liberalisation may cause the policy induced domestic high-quality producers to re-switch to low quality production once the tariff barriers were removed. However, the exact outcome of trade liberalisation is an empirical issue that would depend upon the specific relative inefficiency in quality costs of a specific Southern country firm compared to its Northern country counterpart and upon the specific change in the key parameters that would determine the size of the market after the liberalisation.

APPENDIX

A Market structures and demand functions

In the model set up in Section 2, the demand facing firm i, D_i equals the measure of consumers that prefer firm i both to the other firm and to not buying at all. The consumer indifferent between the two firms is characterised by

$$\theta = \theta_{12} = (p_1 - p_2)/(s_1 - s_2),$$

whereas the consumer indifferent between firm i's good and the zero good is characterised by $\theta_{i0} = p_i/s_i$.

The demand functions depend on the mutual ordering of the values θ_{12}, θ_{10}, θ_{20} as well as $\underline{\theta}$ and $\bar{\theta}$. Kúnin and Žigić (2004) show that seven differens structures are possible. In three cases, the market is covered. These cases are (Mi), when firm i serves the whole market as a monopoly so that $D_i = \bar{\theta} - \underline{\theta}$ and $D_j = 0$, and (D), when the market is divided between the firms so that $D_1 = \bar{\theta} - \theta_{12}$ and $D_2 = \theta_{12} - \underline{\theta}$. In other three cases, the market is non-covered (it can be also said that the marked is *partially* covered.) These cases are (mi), when firm i serves all consumers who do not choose the zero good (so that it is a monopoly) so that $D_i = \bar{\theta} - \theta_{i0}$ and $D_j = 0$, and (d), when the market is divided between the firms and there are consumers who choose the zero good so that $D_1 = \bar{\theta} - \theta_{12}$ and $D_2 = \theta_{12} - \theta_{20}$. In the last case (z), all consumers in the market choose the zero good so that $D_1 = D_2 = 0$.

As is shown in Kúnin and Žigić (2004), These structures occur under the following conditions on prices p_1 and p_2.

Structure	Conditions
(M1)	$0 \leq p_1 < \underline{\theta} s_1$, $p_2 \geq 0$, $p_1 - p_2 < \underline{\theta}(s_1 - s_2)$
(M2)	$0 \leq p_2 < \underline{\theta} s_2$, $p_1 - p_2 > \bar{\theta}(s_1 - s_2)$
(D)	$0 \leq p_2 < \underline{\theta} s_2$, $\underline{\theta}(s_1 - s_2) < p_1 - p_2 < \bar{\theta}(s_1 - s_2)$
(m1)	$p_2/p_1 > s_2/s_1$, $\underline{\theta} s_1 < p_1 < \bar{\theta} s_1$
(m2)	$\underline{\theta} s_2 < p_2 < \bar{\theta} s_2$, $p_1 - p_2 > \bar{\theta}(s_1 - s_2)$
(d)	$p_2 > \underline{\theta} s_2$, $p_1 - p_2 < \bar{\theta}(s_1 - s_2)$, $p_2/p_1 < s_2/s_1$
(z)	$p_1 > \bar{\theta} s_1$, $p_2 > \bar{\theta} s_2$

It should be noted that a necessary condition for the low-quality firm to survive in the market is that the price-quality ratio (hedonic price) is lower for the low-quality firm, $p_2/s_2 < p_1/s_1$.

If there is an equality between some of the values θ_{ij}, $\underline{\theta}$, $\bar{\theta}$, then the resulting market structure is a boundary case of some structures listed above. An important case is *exactly covered market*, when the least quality-sensitive consumer is exactly indifferent between buying from the firm offering the better deal and not buying at all. The case of particular importance is duopoly with exactly covered market denoted (D/d), which is the borderline case between (D) and (d). It happens when $\theta_{20} = \underline{\theta}$ and $\underline{\theta} < \theta_{12} < \bar{\theta}$ (i.e., $p_2 = \underline{\theta} s_2$ and $\underline{\theta} s_1 < p_1 < \bar{\theta}(s_1 - s_2) + \underline{\theta} s_2$.)

Another special boundary structure is *constrained monopoly*, which takes place on one of the (Mi/D) and (mi/d) boundaries. If this case occurs in equilibrium, then there is monopoly, but the monopolist's price is less than the price it would charge were it a single firm initially. If the "constrained" monopolist increases its price, then the main reason for its profit to fall will be that then the other firm becomes sustainable.

B Price equilibria

Here we present last stage equilibrium prices and profits along with the conditions on tariffs when the resulting market structure is one of the following four.

- Duopoly with an over-covered market (D);
- duopoly with an exactly covered market (D/d);
- duopoly with a non-covered market (d);
- monopoly of the high-quality firm with a covered market (M1).

These four structures are the only ones that can occur after welfare maximisation. A complete mathematical treatment of welfare maximisation can be found in Kúnin and Žigić (2004).

High-quality domestic firm

Let the domestic firm produce high quality so that $t_1 = 0$.

The equilibrium market structure is duopoly with an over-covered market **(D)** when

$$(2\underline{\theta} - \bar{\theta})(s_1 - s_2)/2 < t_2 < \min\left\{\left((2\underline{\theta} - \bar{\theta})s_1 + (\bar{\theta} + \underline{\theta})s_2\right)/2, (\bar{\theta} - 2\underline{\theta})(s_1 - s_2)\right\}.$$

The equilibrium prices and profits are

$$p_1 = \frac{(2\bar{\theta} - \underline{\theta})(s_1 - s_2) + t_2}{3}, \quad p_2 = \frac{(\bar{\theta} - 2\underline{\theta})(s_1 - s_2) + 2t_2}{3},$$

$$\Pi_1 = \frac{\left((2\bar{\theta} - \underline{\theta})(s_1 - s_2) + t_2\right)^2}{9(s_1 - s_2)}, \quad \Pi_2 = \frac{\left((\bar{\theta} - 2\underline{\theta})(s_1 - s_2) - t_2\right)^2}{9(s_1 - s_2)}.$$

The equilibrium market structure is duopoly with an exactly covered market **(D/d)** when

$$\left((2\underline{\theta}-\bar{\theta})s_1+(\bar{\theta}+\underline{\theta})s_2\right)/2 \leq t_2 \leq \left((4\underline{\theta}-\bar{\theta})s_1+(\bar{\theta}-\underline{\theta})s_2\right)s_2/(2s_1).$$

The equilibrium prices and profits are[14]

$$p_1=\left(\bar{\theta}(s_1-s_2)+\underline{\theta}s_2\right)/2, \quad p_2=\underline{\theta}s_2,$$

$$\Pi_1=\frac{\left(\bar{\theta}(s_1-s_2)+\underline{\theta}s_2\right)^2}{4(s_1-s_2)}, \quad \Pi_2=\frac{(\underline{\theta}s_2-t_2)\left((\bar{\theta}-2\underline{\theta})s_1+(\underline{\theta}-\bar{\theta})s_2\right)}{2(s_1-s_2)}.$$

The equilibrium market structure is duopoly with a non-covered market **(d)** when

$$\left((4\underline{\theta}-\bar{\theta})s_1+(\bar{\theta}-\underline{\theta})s_2\right)s_2/(2s_1) \leq t_2 < \bar{\theta}s_2(s_1-s_2)/(2s_1-s_2).$$

The equilibrium prices and profits are

$$p_1=\frac{s_1\left(2\bar{\theta}(s_1-s_2)+t_2\right)}{4s_1-s_2}, \quad p_2=\frac{s_2\bar{\theta}(s_1-s_2)+2s_1t_2}{4s_1-s_2},$$

$$\Pi_1=\frac{s_1^2\left(2\bar{\theta}(s_1-s_2)+t_2\right)^2}{(s_1-s_2)(4s_1-s_2)^2}, \quad \Pi_2=\frac{s_1\left(\bar{\theta}s_2(s_1-s_2)-t_2(2s_1-s_2)\right)^2}{s_2(s_1-s_2)(4s_1-s_2)^2}.$$

Finally, the equilibrium market structure is high-quality firm monopoly with a covered market **(M1)** when

$$\max\left\{0,(\bar{\theta}-2\underline{\theta})(s_1-s_2)\right\} \leq t_2 < \underline{\theta}s_2.$$

The monopoly price is $p_1=\underline{\theta}(s_1-s_2)+t_2$, and the monopoly profit equals $\Pi_1=\left(\bar{\theta}-\underline{\theta}\right)(\underline{\theta}(s_1-s_2)+t_2)$.

[14]In this particular case, the equilibrium prices do not depend on the tariff t_2. This happens because an exactly covered market implies $p_2=\underline{\theta}s_2$. Then p_1 as the best reaction to p_2 does not depend on t_2 either because each firm's profit function (and, hence, its reaction function/correspondence) does not depend on the tariff imposed on the other firm.

Low-quality domestic firm

Let the domestic firm produce low quality so that $t_2 = 0$.

The equilibrium market structure is duopoly with an over-covered market **(D)** when

$$(2\underline{\theta} - \bar{\theta})(s_1 - s_2) < t_1 < \min\left\{(2\underline{\theta} - \bar{\theta})s_1 + (\bar{\theta} + \underline{\theta})s_2, (2\bar{\theta} - \underline{\theta})(s_1 - s_2)\right\}.$$

The equilibrium prices and profits are

$$p_1 = \frac{(2\bar{\theta} - \underline{\theta})(s_1 - s_2) + 2t_1}{3}, \quad p_2 = \frac{(\bar{\theta} - 2\underline{\theta})(s_1 - s_2) + t_1}{3},$$

$$\Pi_1 = \frac{\left((2\bar{\theta} - \underline{\theta})(s_1 - s_2) - t_1\right)^2}{9(s_1 - s_2)}, \quad \Pi_2 = \frac{\left((\bar{\theta} - 2\underline{\theta})(s_1 - s_2) + t_1\right)^2}{9(s_1 - s_2)}.$$

The equilibrium market structure is duopoly with an exactly covered market **(D/d)** when

$$(2\underline{\theta} - \bar{\theta})s_1 + (\bar{\theta} + \underline{\theta})s_2 < t_1 \leq \min\left\{(4\underline{\theta} - \bar{\theta})s_1 + (\bar{\theta} - \underline{\theta})s_2, \bar{\theta}(s_1 - s_2) + \underline{\theta}s_2\right\}.$$

The equilibrium prices and profits are

$$p_1 = \left(\bar{\theta}(s_1 - s_2) + \underline{\theta}s_2 + t_1\right)/2, \quad p_2 = \underline{\theta}s_2,$$

$$\Pi_1 = \frac{\left(\bar{\theta}(s_1 - s_2) + \underline{\theta}s_2 - t_1\right)^2}{4(s_1 - s_2)}, \quad \Pi_2 = \frac{\underline{\theta}s_2\left((\bar{\theta} - 2\underline{\theta})s_1 + (\underline{\theta} - \bar{\theta})s_2 + t_1\right)}{2(s_1 - s_2)}.$$

The equilibrium market structure is duopoly with a non-covered market **(d)** when

$$(4\underline{\theta} - \bar{\theta})s_1 + (\bar{\theta} - \underline{\theta})s_2 < t_1 < 2\bar{\theta}s_1(s_1 - s_2)/(2s_1 - s_2).$$

The equilibrium prices and profits are

$$p_1 = \frac{2s_1\left(\bar{\theta}(s_1 - s_2) + t_1\right)}{4s_1 - s_2}, \quad p_2 = \frac{s_2\left(\bar{\theta}(s_1 - s_2) + t_1\right)}{4s_1 - s_2},$$

$$\Pi_1 = \frac{\left(2\bar{\theta}s_1(s_1 - s_2) - t_1(2s_1 - s_2)\right)^2}{(s_1 - s_2)(4s_1 - s_2)^2}, \quad \Pi_2 = \frac{s_1 s_2\left(\bar{\theta}(s_1 - s_2) + t_1\right)^2}{(s_1 - s_2)(4s_1 - s_2)^2}.$$

Finally, the equilibrium market structure is high-quality firm monopoly with a covered market **(M1)** when

$$t_1 \leq (2\underline{\theta} - \bar{\theta})(s_1 - s_2).$$

Then the monopoly price is $p_1 = \underline{\theta}(s_1 - s_2)$, and the last stage monopoly profit of the foreign firm equals $\Pi_1 = (\bar{\theta} - \underline{\theta})\underline{\theta}(s_1 - s_2)$.

C Optimal tariffs

High-quality domestic firm

When the domestic firm produces the high quality, then three equilibrium market structures can realise after welfare maximisation according to Kúnin and Žigić (2004). These structures are duopoly with an exactly covered market (D/d), duopoly with a non-covered market (d), and monopoly of the high-quality domestic firm (M1). The tariff levels t_2 selected by the government along with the corresponding conditions on parameters and equilibrium market structures are given in the following table, where

$$\Theta_2 = \frac{(1-S)(5-2S)}{(4-S)(3-2S)}.$$

Range of values of Θ	Equilibrium	Optimal tariff t_2
$[0, \Theta_2)$	(d)	$\bar{\theta}s_2(s_1 - s_2)/(3s_1 - 2s_2)$
$[\Theta_2, (1-S)/(2-S))$	(D/d)	$\left((4\underline{\theta} - \bar{\theta})s_1 + (\bar{\theta} - \underline{\theta})s_2\right) s_2/(2s_1)$
$[(1-S)/(2-S), 1/2)$	(M1)	$(\bar{\theta} - 2\underline{\theta})(s_1 - s_2)$
$[1/2, 1]$	(M1)	0

Thus, the market structure after welfare maximistaion is determined by Θ and S as shown in Figure 2.

The firms' second stage profits at the optimal tariff levels are

$$\Pi_1 = \bar{\theta}^2 \frac{9s_1^2(s_1 - s_2)(2s_1 - s_2)^2}{(3s_1 - 2s_2)^2(4s_1 - s_2)^2}, \quad \Pi_2 = \bar{\theta}^2 \frac{s_1 s_2 (s_1 - s_2)^3}{(3s_1 - 2s_2)^2(4s_1 - s_2)^2}$$

when the outcome is duopoly with a non-covered market (d),

$$\Pi_1 = \bar{\theta}^2 \frac{(s_1 - s_2 + \Theta s_2)^2}{4(s_1 - s_2)}, \quad \Pi_2 = \bar{\theta}^2 \frac{s_2(s_1 - s_2 + \Theta(s_2 - 2s_1))^2}{4s_1(s_1 - s_2)}$$

when the outcome is duopoly with an exactly covered market (D/d),

$$\Pi_1 = \bar{\theta}^2 (1 - \Theta)^2 (s_1 - s_2)$$

(and $\Pi_2 = 0$) when the outcome is monopoly (M1) and $\Theta < 1/2$, and

$$\Pi_1 = \bar{\theta}^2 \Theta (1 - \Theta)(s_1 - s_2)$$

(and $\Pi_2 = 0$) when the outcome is monopoly (M1) and $\Theta \geq 1/2$.

Low-quality domestic firm

When the domestic firm produces the low quality, then four equilibrium market structures can realise after welfare maximisation according to Kúnin and Žigić (2004). These structures are duopoly with an over-covered market (D), duopoly with an exactly covered market (D/d), duopoly with a non-covered market (d), and monopoly of the high-quality foreign firm (M1). The tariff levels t_2 selected by the government along with the corresponding conditions on parameters and equilibrium market structures are given in the following table, where

$$\Theta_1^+ = \frac{2(1 - S)}{3(2 - S)}, \quad \Theta_1^- = \frac{(1 - S)(4 - 2S)}{(4 - S)(3 - 2S)},$$

and the label "(D/d)/(d)" stands for a mathematically special subcase of duopoly with an exactly covered market.

Range of values of Θ	Equilibrium	Optimal tariff t_1
$\left[0, \Theta_1^-\right)$	(d)	$\bar{\theta}s_1(s_1 - s_2)/(3s_1 - 2s_2)$
$\left[\Theta_1^-, \Theta_1^+\right)$	(D/d)/(d)	$(4\underline{\theta} - \bar{\theta})s_1 + (\bar{\theta} - \underline{\theta})s_2$
$\left[\Theta_1^+, 2(1-S)/3\right]$	(D/d)	$\bar{\theta}(s_1 - s_2)/3 + \underline{\theta}s_2$
$(2(1-S)/3, 2/3)$	(D)	$(\bar{\theta} - \underline{\theta})(s_1 - s_2)$
$[2/3, 1]$	(M1)	$(2\underline{\theta} - \bar{\theta})(s_1 - s_2)$

Thus, the market structure after welfare maximisation is determined by Θ and S as shown in Figure 3. In this figure, the area corresponding to case (D/d)/(d) is not shown as being out of scale since $\Theta_1^+ - \Theta_1^- \in [0, 0.008)$ for all S.

The firms' second stage profits at the optimal tariff levels are

$$\Pi_1 = \bar{\theta}^2 \frac{s_1^2(s_1 - s_2)(4s_1 - 3s_2)^2}{(3s_1 - 2s_2)^2(4s_1 - s_2)^2}, \quad \Pi_2 = \bar{\theta}^2 \frac{4s_1 s_2(s_1 - s_2)(2s_1 - s_2)^2}{(3s_1 - 2s_2)^2(4s_1 - s_2)^2}$$

when the outcome is duopoly with a non-covered market (d),

$$\Pi_1 = \bar{\theta}^2 \frac{(s_1 - s_2 + \Theta(s_2 - 2s_1))^2}{s_1 - s_2}, \quad \Pi_2 = \bar{\theta}^2 \frac{s_1 s_2 \Theta^2}{s_1 - s_2}$$

in case (D/d)/(d),

$$\Pi_1 = \bar{\theta}^2(s_1 - s_2)/9, \quad \Pi_2 = \bar{\theta}^2\Theta(2 - 3\Theta)s_2/3$$

when the outcome is "regular" duopoly with an exactly covered market (D/d),

$$\Pi_1 = \bar{\theta}^2(s_1 - s_2)/9, \quad \Pi_2 = \bar{\theta}^2(2 - 3\Theta)^2(s_1 - s_2)/9$$

when the outcome is duopoly with an over-covered market (D), and

$$\Pi_1 = \bar{\theta}^2(1 - \Theta)^2(s_1 - s_2)$$

(and $\Pi_2 = 0$) when the outcome is monopoly (M1).

D Proof of Proposition 1

Recall that if $\Theta \in [1/3, 2/3]$ and the domestic firm produces the low quality, then the profit of the high-quality firm (all profits are divided by $\bar{\theta}^2$) equals

$$\Pi_1 = (s_1 - s_2)/9 - k_1 s_1^2/2$$

under both exactly covered and over-covered market. The profit of the low-quality firm equals

$$\Pi_2 = \Theta(2 - 3\Theta)s_2/3 - k_2 s_2^2/2$$

when the market is exactly covered (i.e., $S < 1 - 3\Theta/2$) and

$$\Pi_2^+ = (2 - 3\Theta)^2(s_1 - s_2)/9 - k_2 s_2^2/2$$

when the market is over-covered ($S \geq 1 - 3\Theta/2$.)

The following conditions are necessary for a pair (s_1, s_2) to be an equilibrium. First, s_1 should deliver an interior (i.e., $S < 1$) maximum to Π_1 given s_2. Second, for an interior equilibrium s_2 should deliver an interior maximum to Π_2, whereas for a boundary equilibrium Π_2 should be increasing in S under exactly covered market and decreasing in S under over-covered market.

From the (unconstrained) first-order conditions it follows that

$$\partial\Pi_1/\partial s_1 = 0 \Rightarrow s_1 = 1/(9k_1)$$

and, for an interior equilibrium,

$$\partial\Pi_2/\partial s_2 = 0 \Rightarrow s_2 = \Theta(2 - 3\Theta)/(3k_2).$$

This implies $S = 3\Theta(2-3\Theta)/K$, which should satisfy $0 \leq S < 1-3\Theta/2$, whence $K > 6\Theta$.

For a boundary equilibrium, from $s_1 = 1/(9k_1)$ it follows that

$$s_2 = (1 - 3\Theta/2)s_1 = (2 - 3\Theta)/(18k_1).$$

By construction, $S = 1 - 3\Theta/2$. The condition on firm 2's profit is

$$\partial\Pi_2/\partial s_2 \geq 0 \Leftrightarrow K \leq 6\Theta.$$

(The other condition, $\partial\Pi_2^+/\partial s_2 \leq 0$, holds for any s_2.)

It remains to check whether the values obtained lead to non-negative profits. For an interior equilibrium, the profits are

$$\Pi_1 = \left(K - 6\Theta(2 - 3\Theta)\right)/(162k_2), \quad \Pi_2 = \Theta^2(2 - 3\Theta)^2/(18k_2),$$

i.e. Π_2 is never negative and Π_1 is non-negative when $K \geq 6\Theta(2-3\Theta)$, which is a weaker condition than $K > 6\Theta$ when $\Theta \geq 1/3$. For a boundary equilibrium, the profits are

$$\Pi_1 = (3\Theta - 1)/(162k_1), \quad \Pi_2 = (12\Theta - K)(2 - 3\Theta)^2/(648k_1),$$

which are both non-negative when $\Theta \in [1/3, 2/3]$ and $K \leq 6\Theta$.

Q.E.D.

E Proof of Proposition 2

Scaling

The following auxiliary result is used.

Lemma 1 *Let $\bar{\theta}$ and $\underline{\theta}$ be fixed, and let (s_1, s_2) be an equilibrium of the whole game when firms' cost functions are characterised by k_1 and k_2. Let $k_i' = \alpha k_i$, $\alpha > 0$. Then (s_1', s_2'), where $s_i' = s_i/\alpha$, is an equilibrium of the whole game when firms' cost functions are characterised by k_1' and k_2'.*

This result follows from the fact that the firms' second stage profits are homogeneous of degree one in qualities, whereas the cost functions are homogeneous of degree two in qualities and of degree one in k_i. Thus, if the first stage profit function of firm i is $\Pi_i(s_1, s_2; k_1, k_2)$, then

$$\Pi_i(s_1', s_2'; k_1', k_2') = \Pi_i(s_1, s_2; k_1, k_2)/\alpha,$$

whence the claim of the Lemma follows immediately.

According to this Lemma, it is possible to fix one of the k_i at some given k_i^0 and then the other k_j is determined from the relation $k_2 = Kk_1$.

Profits and deviations

Recall that the candidate equilibrium in question is the following. The high-quality firm always (for any K) chooses $s_1 = 1/(9k_1)$. The low-quality firm's choice is $s_2 = \Theta(2 - 3\Theta)/(3k_2)$ when $K > 6\Theta$ and $s_2 = (2 - 3\Theta)/(18k_1)$ when $K \leq 6\Theta$. Without losing generality (by Lemma 1), let $k_1 = 1/9$, which implies $k_2 = K/9$, $s_1 = 1$, $s_2 = 3\Theta(2 - 3\Theta)/K$ when $K > 6\Theta$ and $s_2 = 1 - 3\Theta/2$ when $K \leq 6\Theta$.

Then the profits equal

$$\Pi_1 = \left(K - 6\Theta(2 - 3\Theta)\right)/(18K), \quad \Pi_2 = \Theta^2(2 - 3\Theta)^2/(2K)$$

when $K > 6\Theta$ and

$$\Pi_1 = (3\Theta - 1)/18, \quad \Pi_2 = (12\Theta - K)(2 - 3\Theta)^2/72$$

when $K \leq 6\Theta$.

A quality reversal by the low-quality firm as defined by Herguera et al. (2002) takes place when in the candidate equilibrium above s_2 is not *the global* maximum of the low-quality firm's profit. In Proposition 1 it is shown that s_2 maximises Π_2 subject to the constraint $s_2 < s_1$, where s_1 is taken as given. Thus, a quality reversal occurs when there exists $s_2' > s_1$ such that the deviation profit exceeds the maximal profit provided above.

If the low-quality firm deviates to become the high-quality one, then according to Appendix C and taking into account that $k_2 = K/9$ and $s_1 = 1$ its deviation profits are the following (all profits are divided by $\bar{\theta}^2$; note that $S = s_1/s_2$ and $s_1 = 1$ is substituted for s_2 in the formulae of Appendix C.) If $\Theta \geq 1/2$, then the market structure after the deviation is always monopoly and

$$\Pi_2' = \Theta(1-\Theta)(s_2 - 1) - Ks_2^2/18.$$

If $\Theta < 1/2$ and the market structure after deviation is monopoly, which happens when $S \geq (1-2\Theta)/(1-\Theta)$, then

$$\Pi_2' = (1-\Theta)^2(s_2 - 1) - Ks_2^2/18.$$

If $\Theta < 1/2$ and the market structure after deviation is duopoly with an exactly covered market, which happens when $S < (1-2\Theta)/(1-\Theta)$ and either $\Theta \geq 5/12$ or $S \geq S_2(\Theta)$, where

$$S_2(\Theta) = \frac{7 - 11\Theta - \sqrt{9 - 18\Theta + 25\Theta^2}}{4(1-\Theta)},$$

then

$$\Pi_2' = \frac{(s_2 - 1 + \Theta)^2}{4(s_2 - 1)} - Ks_2^2/18.$$

Finally, if $\Theta < 5/12$ and the market structure after deviation is duopoly with a non-covered market, which happens when $S < S_2(\Theta)$, then

$$\Pi_2' = \frac{9s_2^2(s_2 - 1)(2s_2 - 1)^2}{(3s_2 - 2)^2(4s_2 - 1)^2} - Ks_2^2/18.$$

Reversal to monopoly

Two cases are distinguished, $\Theta \in [1/2, 2/3]$, when the only constraint is $S = s_1/s_2 \leq 1$, and $\Theta \in [1/3, 1/2)$, when there also is a lower bound on S. If the deviation profit is maximised at the upper bound on S, i.e. at $s_2 = s_1$, then there is no reversal because the profit of the low-quality firm in the candidate equilibrium is non-negative whereas any firm's profit is negative when $s_1 = s_2 \neq 0$.

If $\Theta \in [1/2, 2/3]$, then the deviation profit is unconditionally maximised at $s_2 = 9\Theta(1-\Theta)/K$, which is interior ($S < 1$) when $K < 9\Theta(1-\Theta)$. This upper bound on K is less than 6Θ for $\Theta \in [1/2, 2/3]$ so that there is no reversal to monopoly if the original equilibrium is interior. If the original equilibrium is boundary ($K < 6\Theta$), then the original profit is not less than the deviation profit when

$$K \geq \frac{54\Theta(1-\Theta)^2}{10 - 18\Theta + 9\Theta^2 + \sqrt{(4-3\Theta)(16-33\Theta+18\Theta^2)}}.$$

This threshold belongs to $(1, 1.1)$ for $\Theta \in [1/2, 2/3)$ and equals 1 when $\Theta = 2/3$.

If $\Theta \in [1/3, 1/2)$, then the deviation monopoly profit is unconditionally maximised at $s_2 = 9(1-\Theta)^2/K$, which is interior when $9(1-\Theta)(1-2\Theta) < K < 9(1-\Theta)^2$. If $K \leq 9(1-\Theta)(1-2\Theta)$, then the maximum occurs at the lower bound on S, $S = (1-2\Theta)/(1-\Theta)$. If $K \geq 9(1-\Theta)^2$, then the maximum occurs at $S = 1$ so that there is no reversal.

Since $9(1-\Theta)(1-2\Theta) \leq 6\Theta$ for $\Theta \in [1/3, 1/2)$, the deviation profit cannot be maximised at the lower bound on S when the original equilibrium is interior. If $K \geq 6\Theta$ and the deviation profit has an interior maximum, then the original profit is not less than the deviation profit when $K \geq (9 - 36\Theta + 50\Theta^2 - 24\Theta^3)/(2(1-\Theta)^2)$, which is strictly less than 6Θ for $\Theta \in [1/3, 1/2)$. Thus, there is no quality reversal from an interior equilibrium to monopoly for $\Theta \in [1/3, 1/2)$.

If the original equilibrium is boundary and the deviation profit has an interior maximum, then there is no deviation when

$$K \geq \frac{6 - 8\Theta - 6\Theta^2 + 9\Theta^3 + \sqrt{\Theta(13-30\Theta+18\Theta^2)(12-29\Theta+18\Theta^2)}}{(2-3\Theta)^2/6}.$$

This threshold belongs to $(1, 2)$ and is a decreasing function of Θ for $\Theta \in [1/3, 1/2)$. It equals the lower bound on K for interior maximisation of the deviation profit, $9(1-$

$\Theta)(1-2\Theta)$, at $\Theta = \Theta^b \approx 0.3478$, whence for $1/3 \le \Theta \le \Theta^b$ there is no reversal from a boundary equilibrium to monopoly at interior maximum.

If the original equilibrium is boundary and the deviation profit is maximised at the lower bound on S, then there is no deviation when

$$K \ge \frac{12(1-2\Theta)(2+8\Theta-27\Theta^2+18\Theta^3)}{20-69\Theta+84\Theta^2-36\Theta^3}.$$

This threshold lies above $9(1-\Theta)(1-2\Theta)$ for $\Theta \ge \Theta^b$, which means that for $\Theta^b < \Theta < 1/2$ there is a quality reversal when the deviation profit is maximised at the lower bound on S. At $\Theta = \Theta^b$, this threshold equals the previous one, and for $1/3 \le \Theta < \Theta^b$ it belongs to $(1.75, 2)$ and is a decreasing function of Θ for $\Theta \in [1/3, 1/2)$. Specifically, the value of this threshold at $\Theta = 1/3$, which is the maximal value of K such that there is a quality reversal by the low-quality domestic firm when $\Theta \in [1/3, 2/3]$, is $28/15$.

The lower bound on relative cost efficiency

From the above it can be concluded that there is no quality reversal by the low-quality domestic firm to monopoly when $K \ge R(\Theta)$, where $R(\Theta)$ is given by

$$R(\Theta) = \frac{12(1-2\Theta)(2+8\Theta-27\Theta^2+18\Theta^3)}{20-69\Theta+84\Theta^2-36\Theta^3}$$

for $1/3 \le \Theta \le \Theta^b \approx 0.3478$,

$$R(\Theta) = \frac{6-8\Theta-6\Theta^2+9\Theta^3+\sqrt{\Theta(13-30\Theta+18\Theta^2)(12-29\Theta+18\Theta^2)}}{(2-3\Theta)^2/6}$$

for $\Theta^b \le \Theta \le 1/2$, and

$$R(\Theta) = \frac{54\Theta(1-\Theta)^2}{10-18\Theta+9\Theta^2+\sqrt{(4-3\Theta)(16-33\Theta+18\Theta^2)}}$$

for $\Theta \in [1/2, 2/3]$. The function $R(\Theta)$, which is a continuous function with values in $[1, 2)$, is depicted in Figure 4.

Reversal to duopoly with an exactly covered market

This reversal is possible only for $\Theta \in [1/3, 1/2)$. The constraints on S are $S < (1 - 2\Theta)/(1-\Theta)$ and $S \geq S_2(\Theta)$. The first-order condition for an interior maximum is

$$\frac{\partial \Pi_2'}{\partial s_2} = \frac{1}{4} - \frac{K s_2}{9} - \frac{\Theta^2}{4(s_2-1)^2} = 0,$$

and the second-order condition is

$$\frac{\partial^2 \Pi_2'}{\partial s_2^2} = -\frac{K}{9} + \frac{\Theta^2}{2(s_2-1)^3} < 0.$$

If the constraints on S are taken into account, then it should be noted that if the first derivative is negative for all s_2, then the deviation profit is maximised at the lower bound on s_2, which corresponds to the upper bound on $S = s_1/s_2$. The first derivative $\partial\Pi_2'/\partial s_2$ is maximised at $s_2 = 1 + (9\Theta^2/(2K))^{1/3}$ (this solves $\partial^2\Pi_2'/\partial s_2^2 = 0$; the third derivative is easily shown to be positive.) Hence, the maximal value the first derivative can attain equals $\left(9 - 4K - 3(6K\Theta)^{2/3}\right)/36$. If $\Theta \geq 1/3$, then the last expression can be positive only for $K < 1.0333$ and $\Theta < 0.3587$, but at those values of K and Θ there is a quality reversal to monopoly as is shown above.

Thus, if K and Θ are such that there is no reversal to monopoly ($K \geq R(\Theta)$), then the deviation profit when the deviation leads to duopoly with an exactly covered market is maximised at the upper bound on S. However, at this bound duopoly turns into monopoly, and there is no reversal to monopoly. Therefore, neither is there a reversal to duopoly with an exactly covered market.

Reversal to duopoly with non-covered market

This reversal is possible only for $\Theta \in [1/3, 5/12)$, and the constraint on S is $S < S_2(\Theta)$. The first derivative of the deviation profit is

$$\frac{\partial \Pi_2'}{\partial s_2} = -\frac{K s_2}{9} + \frac{9 s_2(2s_2-1)(4 - 22s_2 + 51s_2^2 - 54s_2^3 + 24s_2^4)}{(3s_2-2)^3(4s_2-1)^3},$$

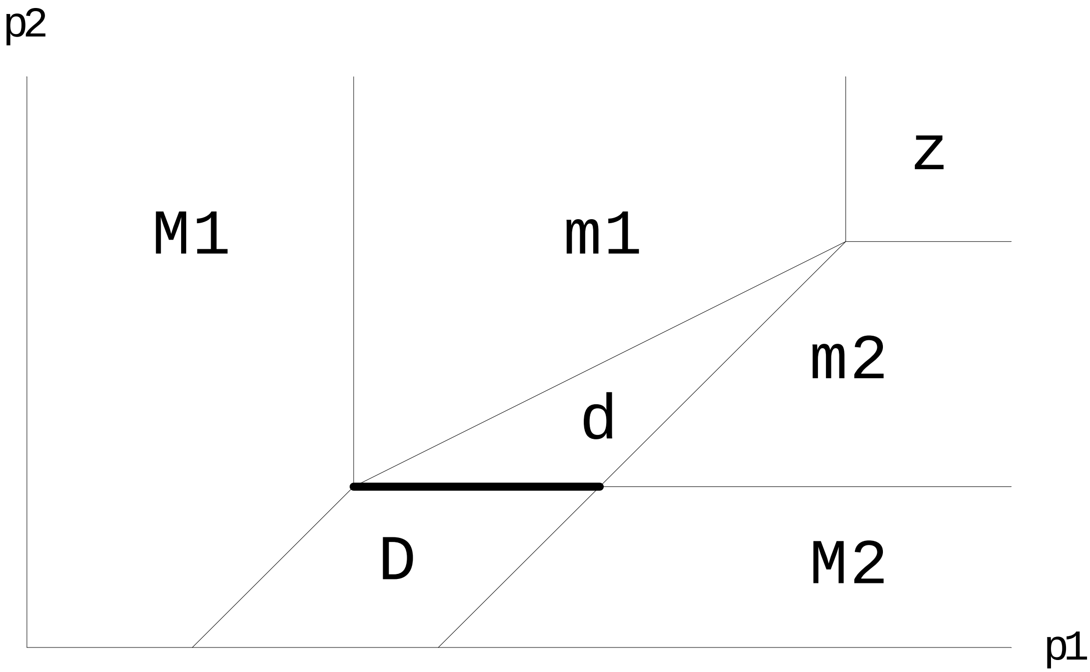
and the second derivative is

$$\frac{\partial^2 \Pi_2'}{\partial s_2^2} = -\frac{K(2 - 11s_2 + 12s_2^2)^4 + 648(1 - 4s_2 + 24s_2^3 - 48s_2^4 + 33s_2^5)}{9(3s_2 - 2)^4(4s_2 - 1)^4},$$

which is negative for $s_2 \geq 1$. Substituting the value of s_2 corresponding to $S = S_2(\Theta)$ into the first derivative yields that if there is no quality reversal to monopoly then the first derivative is negative for all applicable s_2. Thus, the deviation profit is maximised at the upper bound, where duopoly with a non-covered market turns into duopoly with an exactly covered market. As is shown above, absence of a quality reversal to monopoly implies absence of a quality reversal to duopoly with an exactly covered market. Hence, if there is no quality reversal to monopoly, then there is no quality reversal to duopoly with a non-covered market either.

Q.E.D.

Figure 1: Market structures and demand (the thick line corresponds to duopoly with exactly covered market)



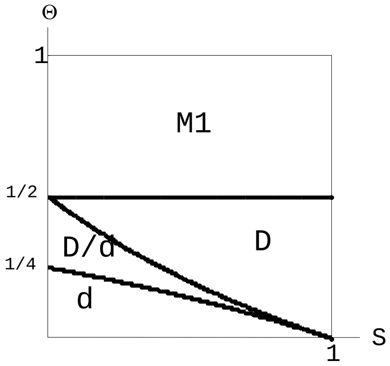


Figure 2: Free trade equilibria

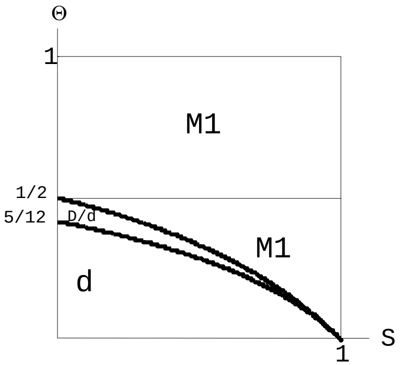


Figure 3: Equilibria under optimal tariff with h.q. domestic firm

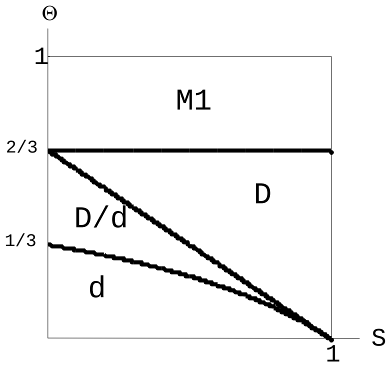


Figure 4: Equilibria under optimal tariff with l.q. domestic firm

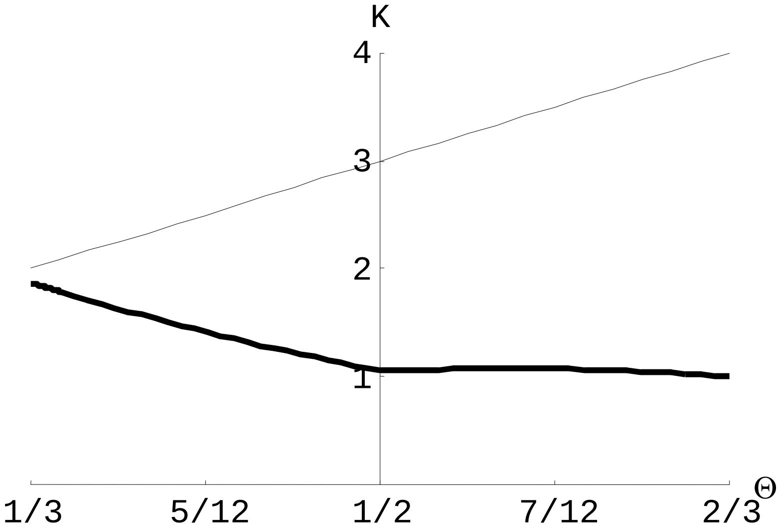


Figure 5: quality reversals in natural duopoly. The upper line is K=6Θ, the lower thick line is R(Θ), there is a reversal for K < R(Θ)

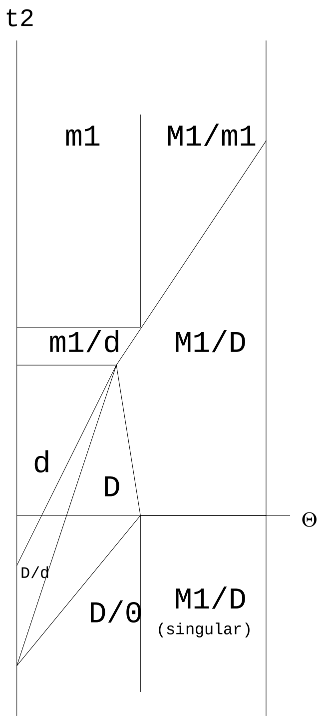


Figure 6: Equilibria with h.q. domestic firm

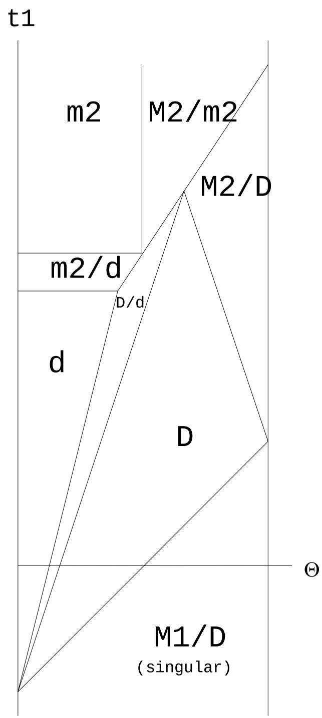


Figure 7: Equilibria with l.q. domestic firm

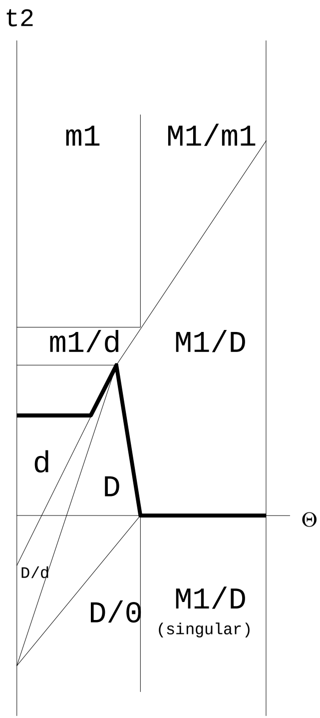


Figure 8: Optimal tariff with h.q. domestic firm

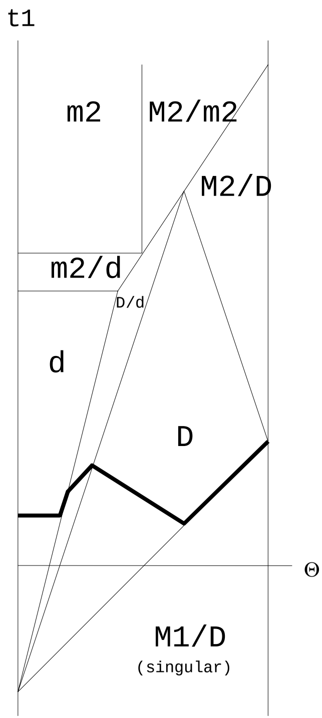


Figure 9: Optimal tariff with l.q. domestic firm

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Theory of Strategic Trade Policy in North–South Trade: Optimal Northern and Southern Tariffs in an Inherently Asymmetric Environment

Author: Krešimir Žigić

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Krešimir Žigić graduated from the Faculty of Economics, University of Zagreb, in 1982 and received his M. A. at the same university in 1988. Between 1982–1991, he was employed as a financial officer with the "Rade Končar" corporation in Zagreb and as a scientific assistant at the Faculty of Economics, University of Zagreb. He received his Ph.D. at CERGE-EI in 1996, where he has served as an assistant professor and researcher since graduating. He served as Deputy Director for Graduate Studies at CERGE-EI between 1997–1999. He is Research Affiliate at the Center for Economic Policy Research (CEPR) in London. He has published in journals such as the European Economic Review, the Journal of Development Economics, and International Economic Journal.

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