STRATEGIC TRADE POLICY, INTELLECTUAL PROPERTY RIGHTS PROTECTION, AND NORTH–SOUTH TRADE

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Abstract

In this paper we analyze the issue of optimal tariffs when the Northern and Southern firms compete in quantities in an imperfectly competitive Northern market and there are potentially varying degrees of intellectual property rights (IPR) violation by the South. IPR violation is reflected through the leakage of technological knowledge ("spillovers") from the Northern to the Southern firm creating unit cost reduction. It is shown that optimal tariffs in this framework are always higher than in the simple duopoly model since they serve here not only as profit shifting devices but also as instruments that influence domestic innovative activity, generate scale economies and countervail the IPR violation of the South. The other notable difference from the standard duopoly model is that positive tariffs may be desirable from the world welfare point of view.

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1. INTRODUCTION

The appearance of strategic trade theory 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).

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

[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.

relationship has already made its way into economic encyclopedias.[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 paper aims to show that the distinctive role of strategic trade policy in the specific case when IPR violation prevails is not as a profit shifting or facilitating device but rather as a specific policy instrument that may help overcome appropriability problems. More 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 paper 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.

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[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.

(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 modeled 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.

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[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 – U.S. case when the U.S. threatened China with the sanctions due to the IPR infringement on CDs. The U.S. had the power to effectively prevent China redirecting sales of the CD's to, for instance, the European Union or Latin America.

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 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.

d) Due to its impact on innovative activity, a positive tariff may be optimal even from the

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

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[7]. Second, the innovating firm (firms 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 paper 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 paper and is referred to as the "South."

[7] I am grateful to a referee for pointing this out.

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.[8] 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 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."[9] 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.[10]

Much like in Žigić (1998b), the core model in this paper is a model of duopolistic

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[8]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.

[9]As Spence(1986) shows, the difference between the concept of process innovation vis-a-vis product innovation is semantic rather than fundamental.

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

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, $f(x) \leq \alpha$, $f(0) = 0$, $f'(x) > 0$ and $f''(x) < 0$. α is a parameter that 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 $Q = q_s+q_n$ 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 $S_n = (½)(q_s+q_n)^2$.

2.2. The Role of Tariff

The optimal policy mix when foreign and domestic firm 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[11] 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

[11]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.

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[12].

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 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 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.[13]

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 $A - 2q_n - q_s - C = 0$.

[12] As referee pointed out, 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 1984).

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

The optimization problem for the foreign firm yields[14]:

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

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:

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

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

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

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

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 action is given by X where $x \in X = [0, x^{\circledast}]$ and $x^{\circledast}$ is the solution of the equation $\alpha - f(x) = 0$.[15] 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 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.

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

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

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

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

f'(x*) is positive by definition 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 better exploit the scale economies of the firm[16]. 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.

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

[16] It can be shown that average costs of the Northern firm are monotonically declining as tariff increase from zero on. The discussion on the scale economies generated by the imposition of tariff within analysed model can be obtained from the author upon request.

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) behavior 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[17].

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":

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

Tariff t_p just suffices to eliminate the competitor from the market and we refer to it as a "predatory tariff"[18].

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.

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

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

[18]Note that t_m = [A -α- (1 - 2 β) 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).

The question is, however, what caused such a reverse reaction of the domestic firm here in comparison with its behavior 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" behavior. 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 increased tariff has the same effect. In fact, the government, by increasing the tariff (assumed to be initially in the predation interval $t \epsilon [t_p, t_m]$), 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. 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 innovativness 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 $t \epsilon [t_p, t_m]$ induces domestic firm to undertake the strategic predation strategy.

The policy conclusions are exactly reversed in the situation characterized by high spillovers ($\beta > 1/2$).

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 the R&D investment, x^*_p, in such a way as to exclude the foreign firm. Given x^*_p, the last stage payoff is given by

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

The first–order condition for a maximum yields,

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

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

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

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 (β > 1/2) whereas the opposite holds for small spillovers (β < 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 $\beta > 1/2$. 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[19], we obtain

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

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

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[20] (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 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, deriving 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 β) t f'(x)]/3. Interestingly enough, dR(x)/dx > 0 for β > 1/2 but dR(x)/dx < 0 for β < 1/2. Thus, the only thing we have to prove is that "net sum" is positive when spillovers

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

are small (that is, dS(x)/dx + dR(x)/dx > 0 for β < 1/2). The "net sum" is given by

$$\frac{dR(x)}{dx} + \frac{dS(x)}{dx} = \frac{5\beta t - 4t + (1+\beta)[2(A-\alpha) + (1+\beta)f(x)]f^{/}(x)}{9} \qquad (16)$$

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 β < 1/2 (and, therefore, for all β∈[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[21] 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 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".[22]

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[21] 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).

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

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 maxW*(t) s.t. $q_s^* \geq 0$. 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 solving the equation dW(t)/dt = 0 for t. Denote this solution as t* where

$$t^* = \frac{3\beta f(x^*) + (1+\beta)^2 f(x^*) x^{*\prime} f^{\prime}(x^*) + (A-\alpha)(3+2(1+\beta)x^{*\prime} f^{\prime}(x^*))}{9+(4-5\beta)x^{*\prime} f^{\prime}(x^*)} \qquad (18)$$

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

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

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 the welfare net of tariff revenue requires optimal tariff 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.

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 above proposition as stated 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).

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

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

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

g_{cc} is relevant only if β > 1/2 since it is easy to demonstrate that monopoly welfare is never higher than welfare in duopoly if β < 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 (see Fig 1.).

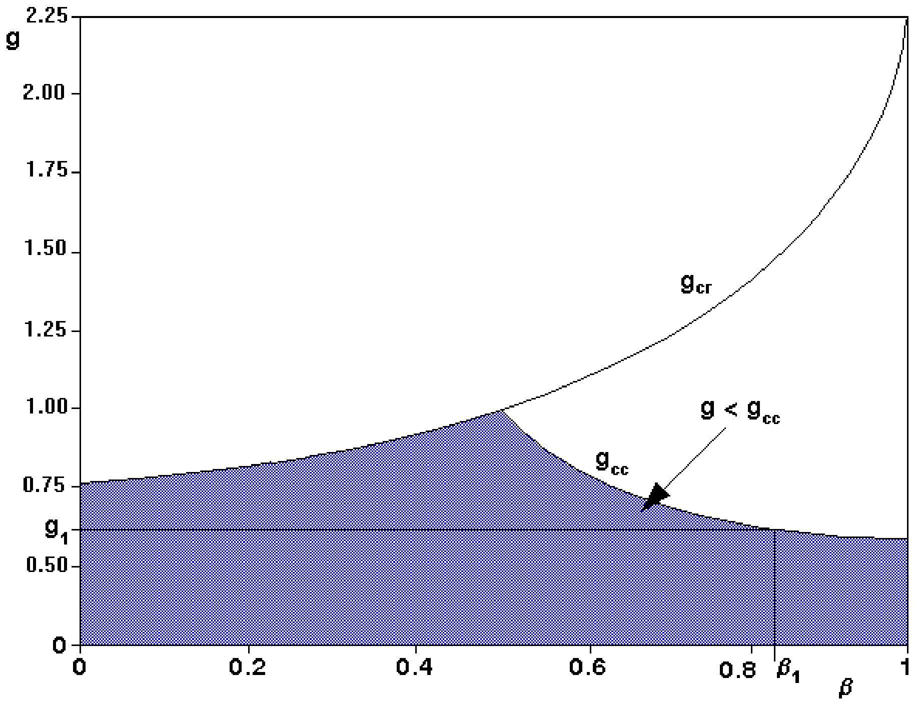

Fig.1. The region of parameters ($g < g_{cr}$ and $g < g_{cc}$) consistent with the duopolistic competition in both regimes.

Interpreting the Proposition 1 in the light of the above discussion 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 β >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 β > 1/2 so that the unconstrained 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.

4.3. The three roles of the optimal tariff [26]

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.[27]

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[28] is , $t^* = (A- c)/3$. This can be easily seen by evaluating t* at β = 0 and f(x) =0 (or t** at β = 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

24 Note that the constrained monopoly cannot be the optimal market form here because when β > 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.

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

26 I am grateful to the referee for encouraging me to write this subsection.

27 It can easily be shown that dt*/dβ > 0 in relevant region.

28 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.

the Southern firm. The optimal tariff in this case is the special case of t* with β = 0. In order to get graphical representation of the problem, we use here t** when β = 0. Thus,

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

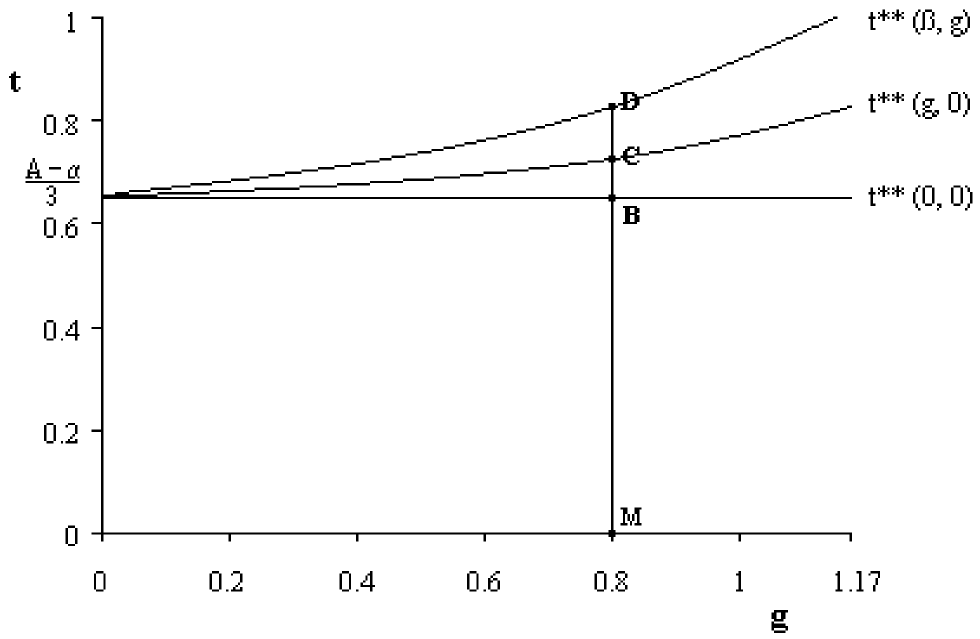

Fig. 2 The decomposition of the optimal tariff on its three roles; A = 10, α = 8

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).

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.[29] 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 form zero to 1.[30]

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 behavior 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 $\beta \leq 1$ 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:

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[29] 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.

[30] 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.

$$\frac{d\Pi_s^*}{d\beta} = \frac{\partial\Pi_s^*}{\partial x}\frac{dx_c^*}{d\beta} + \frac{\partial\Pi_s^*}{\partial\beta} = \frac{2(A-\alpha-2t-(1-2\beta)f(x_c^*)(2f(x)-(1-2\beta)(x_c^*)'f'(x_c^*))}{9}$$

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 $t^* \in [0,t_p)$.[31]

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 be slightly less than β_1 since $W^*(t^*) > W^*_m$ has to hold).[32]

5.2. The Stackelberg–Nash game between the governments

Our full-fledged, four-stage game requires, however, that the Southern government takes

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[31] 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 $dq^*_s/d\beta > 0$.

[32] 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 $\beta^{**} \in (1/2,1)$.

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*(β) 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

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

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*/dβ > 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, 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:

$$\underset{\text{w.r. }\beta}{Max}[\Pi_s^*(\beta)]$$

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

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

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

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 $d\Pi_s^{*}(\beta)/d\beta > 0$ [33] 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 33).

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 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 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).

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[33] Similarly to footnote 31, we can again write $\Pi^*_s(\beta, t^*(\beta)) = q^{*2}_s$ but now, $d\Pi^*_s/d\beta = 2q^*_s(dq^*_s/dt \; dt^*_s/d\beta + dq^*_s/d\beta)$ 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 permissable 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.

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.[34] To illustrate this point, let us assume that North and South together represent the relevant world market of the good under considerations. Let again 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, $\partial\Pi_s^*(t)/\partial x \, dx^*/dt + \partial\Pi_s^*(t)/\partial t$, that captures the total effect of the tariff on the Southern firm's profit. Since this total effect, $d\Pi^*(t)/dt$, 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

[34] I am grateful to both referees for pointing to this important issue.

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:

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

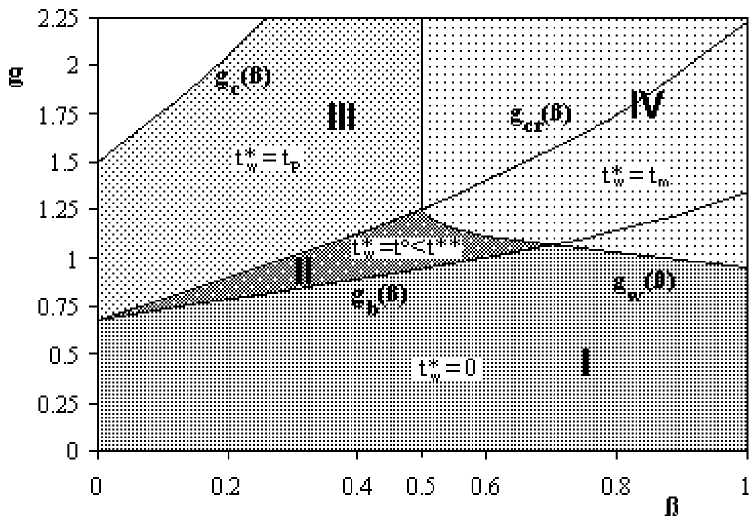

Fig 3. The optimal tariff from the world welfare point of view as a function of g and IPR violation

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

Another interesting question 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[35]. In other words, the

[35] Recall from Lemma 4 that for β < 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,(β > 1/2), an increase in tariff beyond t_p boosts the R&D spending, hence, the optimal tariff will be t_m. The formal

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).

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. [36]

7. CONCLUDING REMARKS

In this paper, we have examined the functions of tariffs in the situation when there are IPR violations. Besides their traditional role as a device to shift foreign profit to the domestic treasury and domestic profit, tariffs in these circumstances have an additional role as an instrument that reduces 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.[37]

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proof can be found in Žigić 1996b or obtained upon request form the author.

[36] 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.

[37] 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

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.

As is well known, the optimal design of strategic trade policy is sensitive to the type of market competition (see Spencer, 1986). Bertrand competition will not be so useful here since we concentrated on duopoly as the core model. A moment of reflection tells us that in our setup the domestic market will be completely covered by a domestic producer who charges a price equal to the unit cost of the foreign firm, that is, $p^* = \alpha - \beta(gx) + t$, provided that $p_m \geq p^*$ where p_m stands for the monopoly price. Thus, the resulting market form will be a constrained monopoly (or the unconstrained one if $p_m \leq p^*$). As was shown in Žigić 1998b, the crucial comparative static result—the impact of tariff on the R&D expenditures—is qualitatively the same under either quantity or price competition in the case of a constrained monopoly. The optimal tariff is however, lower in the Bertrand case since the competition is tougher and there are, in general, fewer distortions to correct.

An interesting extension of our model would allow for the announcement of a strategic trade policy to precede the actual intervention. This would imply changes in the moves in the game and as a consequence the government would leave itself open to strategic manipulation by its own firm (see, for instance, Grossman and Maggi, 1998). The domestic firm may want to engage in costly and possibly welfare reducing signalling in order to seek rents from the government. For instance, it may be profitable for the domestic firm with low R&D efficiency to pretend that it is of the high R&D efficiency type. The welfare implications of these issues, in particular whether free trade may reemerge as the optimal solution for a certain range of parameters in this setup, seem to be an interesting topic for future research.

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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.

APPENDICES

Appendix A

Monopoly profit is given by (A.1.1)

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

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

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

with

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

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 = α - β f(x) + t holds. Taking this into account, the predatory profit can be written as

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

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:

$$\partial\Pi/\partial x|_{t=t_s} = \frac{(A-\alpha+f(x_p))f^{/}(x_p)}{4} + \frac{(1-\beta)(A-\alpha+f(x_p))f^{/}(x_p)}{2} - 1 \qquad \text{(A.1.5)}$$

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 B

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 C

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 1,000 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
West Germany	203	260	294	283	128.16	462	50
Japan	184	275	328	254	531.61	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.

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