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Tariffs, Spillovers and North-South Trade

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Abstract: In this paper, author examine the issue of the optimal tariff in circumstances in which trade between the 'North' (a developed country) and the 'South' (a developing country) takes place. Firms compete in quantities ('Cournot competition') in an imperfectly competitive Northern market. In addition, there are leakages of technological knowledge ('spillovers') from the North to the South. The interaction between tariffs and spillovers, together with its consequences for the social welfare of the North, is the focus of the paper. Another closely related motivation of this paper stems from the observation that the so called punitive tariffs are being used as device to punish violators of intellectual property rights.

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Introduction

The economics of tariffs has been well established and studied within the field of international trade and, in particular, in its subfield, known as strategic trade theory and policy. One of the main lessons of this literature is that tariffs may act as a strategic weapon to shift the profit from the foreign to the domestic firm in a situation in which imperfect competition prevails (e.g., see Brander and Spencer, 1981 and 1984, McMillan, 1982, Krugman, 1984, Spencer, 1986, Helpman and Krugman, 1989, Bhattacharjea, 1995, etc.). The government, therefore, has an incentive to

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impose a tariff to secure a higher profit or higher market share for a domestic firm. The announced tariff changes the nature of the 'game' among foreign and domestic firms by altering the strategic interactions among them. What is crucial for this result is that the government has the credibility to commit to its policy choice (e.g. its tariff) before the firms make their choices. This requirement is usually met in practice. Therefore, one can assume that the government 'moves first' in the game. Another important feature of the tariffs is that they are a device by means of which the government can influence the market structure. Confining our analysis to the simplest case of two firms and the quantity competition between them, there are three possible market patterns which could arise in equilibrium as a consequence of the erected tariff: duopoly, constrained monopoly, and unconstrained monopoly.

Technological spillovers, defined as the leakage of important pieces of technical information which can be used by the recipient at zero or small marginal costs[1], are a pervasive phenomenon in the era of the third scientific revolution and the ever more integrated world economy (see Coe and Helpman, 1993, for a thorough empirical examination of international spillovers in 22 industrial countries). Evidence suggests that Northern innovative activity boosts the productivity of developing countries: in the period 1985–1990, a one percent rise in US research and development stock increased the total factor productivity of the 77 developing countries by an average of 0.04 per cent. Some countries (e.g. Singapore) displayed increases in their total factor productivity of 0.22 per cent (see Hoffmaister, 1995, for more details). One of the media through which spillovers spread around the world economy is international trade.

In terms of modelling, spillovers can be viewed as both parameter and endogenous strategic policy variable. Thus, in the first part of the paper, spillovers are considered to be exogenously given to both the firms and the governments. Later, we interpret the spillovers as the variable (or proxy) which reflects the degree of intellectual property rights (IPR) protection (or violation) by the South. Thus, spillovers are viewed there as a strategic policy variable under the control of the Southern government.

Here, we examine the issue of the *optimal tariff* when the 'North' (a developed country) and the 'South' (a developing country) engage in international trade. Firms compete in quantities ('Cournot competition') in an imperfectly competitive Northern market. In addition, there are leakages of technological knowledge from the North to the South. The interaction between tariffs and spillovers, together with its consequences for the social welfare of the North, is the focus of the paper. Another closely related motivation of this paper stems from the observation that tariffs are being used as device to punish (or a threaten) violators of IPR, as, for instance, the recent China vs. US IPR dispute clearly indicates. Such tariffs are called *punitive tariffs*. Imposing a punitive tariff bears in itself strategic considerations-that is, there is an intention to influence the other party's behavior. However, the primary role of that tariff is not 'profit shifting.' Instead, a punitive tariff is used to force the violator, through appropriate punishment, to change his behavior.

The positive analysis, as well as the welfare implications of the tariff for the North, relies on the duopoly model developed by Chin and Grossman (1990). This model can be roughly classified as the 'R&D with spillovers' model[2] stemming from related industrial organisation literature.

The main new insights the analysis provides can be summarised as follows:

a) In a situation where there is leakage of technological information and, as a consequence, the disincentive to invest in R&D, the tariff may serve not only as a 'profit shifting' tool but also as a technological policy tool to restore the incentive for investing in the, socially desirable, research, and development (R&D) activity.

b) The optimal tariff, and, consequently, the welfare-maximising market structure of the Northern country, hinges crucially on the level of spillovers, as well as on the efficiency of the innovative activity ('R&D efficiency'). Given the efficiency of innovative activity, all three market forms could appear in equilibrium. More specifically, the market structure preferred by the Northern government essentially depends on whether spillovers are small or large.

c) If the level of spillovers is under the control of the Southern government, then the optimal market structure will always be duopoly with the highest possible level of spillovers (provided that the duopoly is achievable for the given level of R&D efficiency).

d) If tariff is used only as an *ex post* mechanism to punish the violator (i.e. a punitive tariff) then the preferred market structure will always be duopoly and the infringement of IPR will never be observed in equilibrium if the threat of introduction of punitive tariff is credible.

The Model

Assumptions

There are only two countries, 'North' and 'South.' 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. Thus, the consumption of the entire world takes place in the North. 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 optimisation problem for the Southern market is independent of its optimisation decision for the Northern market). In other words, the arbitrage is not important (because it may be too costly) and it is not allowed for in the analysis (see Brander and Spencer, 1981, and 1984). In addition, we assume that export to the Northern market is essential for the Southern firm[3]. This assumption is needed to circumvent the non-interesting and trivial outcome in which IPR violation is complete and the Southern firm produces only for its domestic market.

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).

The Southern firm does not perform R&D but benefits through spillovers from the R&D activity of the Northern firm. As Helpman (1993) pointed out, most technological imitation takes place in newly industrialised countries, while the majority of less developed countries engage in this activity only marginally. The former group is relevant in the model developed and is referred to as the 'South' in this paper.

A '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[4]. Thus, we deal with so called 'process innovations' here.

The character of the North-South relationship is modelled by relying on the concept of strategic interaction. We consider three sequential (three- stage) games here. In the first game, we assume that the level of spillovers is exogenously given and we concentrate on the optimal tariff and corresponding welfare maximising market structure. In the first stage of that game, the Northern government selects the optimal tariff anticipating the R&D choice of its firm (second stage) and subsequent competition between two firms (third stage).

In the second game, the assumption is that the Southern government has the power to manipulate the level of spillovers (the strength of IPR protection) to maximise domestic welfare. Thus, in the second game there are four players: the Northern and Southern governments and their firms. In the first stage of that game the Northern and Southern governments set the optimal tariff and the optimal level of IPR respectively. This subgame precedes the competition between firms. The second game can be viewed as a natural prelude to the third game in which the Northern government reacts only conditionally and *ex post* by setting a punitive tariff. That is, it commits to zero tariff unless there is an IPR violation.

The Core Model

The starting (core) model here is a model of duopolistic competition between the Northern and the Southern firms. The Northern firm has unit costs of production (C):

$$C = \alpha - (gx)^{1/2}, \quad x \leq \alpha^2/g$$

where parameter g describes the efficiency of the R&D process and x denotes the R&D expenditures of the Northern firm. The expression $(gx)^{1\ 2}$ is an 'R&D production function,' and it is assumed to have the same functional form as in Chin and Grossman (1990). The parameter α can be thought of as pre-innovative unit costs.

The Southern firm benefits through spillovers from the R&D activity carried out by the Northern firm but it also pays specific tariff t per unit of production. Its unit cost function is $c=\alpha - \beta\ (gx)^{1\ 2} + t$ (t stands for the specific tariff imposed by the Northern government). β denotes the level of spillovers. The value of β is perceived as a parameter by the firms and is assumed to be common knowledge for both parties.

The inverse demand function of 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 $Q = q_s + q_n$, $A > \alpha$. Parameter A captures the size of the market, whereas q_s and q_n denote the choice variables - the corresponding quantities - of the South and the North.

Social welfare (W) is defined as the sum of consumer surplus (S) and the firm's profit (π). Consumer surplus is defined as

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

In case of a linear demand function for the North, where good Z is supposed to be consumed exclusively, the above expression becomes: $S_n = (q_s + q_n)^2/2$.

We start to solve the game backwards assuming there is a duopoly competition in the last (third) stage of the game. In the last stage, the firms choose the equilibrium quantities. The Northern firm maximises

$$\underset{q_n}{Max}\left[\pi_n\right] = (A - Q)q_n - Cq_n - x \qquad (1.a)$$

given q_s. The first-order condition for a maximum is $\partial\pi_n/\partial q_n = 0$ and it yields $A\text{-}2q_n\text{-}q_s\text{-}C = 0.$

The optimisation problem for the Southern firm means:

$$\underset{q_s}{Max}\left[\pi_s\right] = (A - Q)q_s - cq_s - tq_s \qquad (1.b)$$

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 and price 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 Northern 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 second stage of the game, the Northern firm selects x in order to maximise its profit. Note that the set of R&D action is given by $X = [0, \alpha^2/g]$[5]. Substituting expressions for C and c into (3) and maximizing with respect to R&D investment, we obtain:

$$x_t^* = \frac{(A - \alpha + t)^2 (2 - \beta)^2 g}{(9 - (2 - \beta)^2 g)^2}. \tag{4}$$

The second-order condition is satisfied for all permissible values of parameters, and the optimal R&D expenditure, x_t^*, is always positive.

The appropriate substitution of (4) into the expressions for equilibrium quantities, profits, and consumer surplus yields the corresponding equilibrium values expressed in terms of parameters and tariff t.

Duopoly and Constrained Monopoly

The Existence of Duopoly

The preceding describes the last two stages of the game assuming that duopoly is a viable market form. However, in the situation in which there is unit cost asymmetry, there is a critical difference between unit costs beyond which duopoly ceases to exist. In fact, there are three cases to be distinguished:

1) The difference in unit costs between the firms is not so high, and there is (asymmetric) duopoly competition in equilibrium.

2) The difference in unit costs exceeds the critical level, but the low unit costs firm is not capable of exercising full monopoly power because the monopoly price would invite competition by another firm. The optimal strategy for this firm is to choose an

R&D investment and a quantity of production that will lead to the limiting price. This strategy is labelled as 'strategic predation' and the corresponding market structure is described as a constrained monopoly.

3) The differences in costs are so sizeable that they enable the lower unit costs firm to exercise unconstrained monopoly power.

Suppose, for the moment, that there is no tariff. The size of unit cost differences, then, depends on the degree of spillovers, β, and the R&D efficiency, g. As for the impact of g and β on unit cost asymmetry, it is clear that for a given g, the higher β causes the lower cost difference, whereas for a given β, the higher g results in the higher cost difference. Roughly speaking, for both firms to produce in equilibrium, g should not be 'too high' and/or β should not be 'too low.'

There exists a critical value of the cost reducing parameter, g_c, beyond which the duopoly is no longer sustainable. In the model with no spillovers (like the one in Chin and Grossman, 1990), for an asymmetric duopoly to be sustained, that is, $g_c=3/2$ must be true. In the model adopted in this paper, the critical level for the duopoly market structure to emerge also depends on the value of spillovers. As spillovers increase, g_c also increases. This is intuitive because in the presence of positive spillovers the critical R&D efficiency should rise with β: as β increases, the rival captures more of the cost reducing innovation and this prevents the Northern firm from gaining a larger cost advantage. Thus, for duopoly to exist, the South must have a positive production in equilibrium. That is, $q_s^* > 0$.[6] Expressing this inequality in terms of the structural parameters of the model yields, after appropriate rearranging, the following expression,

$$g < \frac{3}{(1-\beta)(2-\beta)} \tag{5}$$

to which we refer to as 'the sustainability condition' for duopoly. Further, the value of g is confined to the interval $[0,4)$.[7]

Now let us introduce a tariff. In light of the above analysis, a tariff could be interpreted as a device to control the difference between the Northern firm and Southern firm unit costs. In other words, a government can, by selecting the appropriate tariff, always raise the tariff so high that the difference in unit costs forces the foreign firm to exit and, depending on the height of tariff, enables the domestic firm to charge either the limit price or the monopoly price. The Northern government can also decide to keep the Southern firm in the market by charging a low tariff or, if the domestic firm initially holds an unconstrained monopoly position, the desirable tariff could even be negative (as is the case of subsidised imports). We will neglect the possibility of negative tariff[8] by assuming that the pre-tariff competition is of the duopolistic type, that is, (5) is assumed to hold. Since the demand function is linear, the optimal tariff is always nonnegative. Technically, duopoly will be the viable market form unless the tariff reaches a certain critical value, t_p, at and beyond which the best response of the Southern firm will be to exit the market because the Northern firm has adopted the strategic predation strategy as optimal, that is, it has committed to a level of R&D for which the rival firm's optimal production (as well as profit) is zero. By increasing tariff further beyond t_p, the difference in marginal costs becomes so large that at (and beyond) the value of tariff t_m, the Northern firm gains an unconstrained monopoly position. The profit of the Northern firm, as a function of the value of tariff could be written as

$$\pi_d(t),\ if\ 0 < t \le t_p$$

$$\pi_n(t) = \pi_p(t),\ if\ t_p \le t \le t_m$$

$$\pi_{m,}\quad if\ t \ge t_m$$

(at the point t_p, $\pi_d(t_p) = \pi_p(t_p)$ and at the point t_m, $\pi_m = \pi_p(t_m)$).

The Constrained Monopoly and Strategic Predation

Strategic predation (or limit pricing) behaviour turns out to be the optimal strategy for the Northern 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 stage the Northern firm commits to the R&D level which will force the Southern firms to choose zero output in the last stage of the game. This is the best the Southern firm could do in this situation. In the last (third) stage, the Northern firm, which remains alone 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 Northern firm to select unconstrained monopoly R&D expenditures.

In terms of mathematics, given t the Northern firm solves the equation $q_s{}^*(x) = 0$ for x. Denote this solution as x_p where subscript 'p' stands for 'predatory.' Solving the actual equation yields

$$x_p = \frac{(A - \alpha - 2t)^2}{(1 - 2\beta)^2 g} \tag{6}$$

where t is now from the interval $t \in [t_p, t_m]$.

Given x_p, the last stage payoff is given by

$$Max\left[\pi_p\right]=(A-q)q-Cq-x_p. \quad (7)$$

The first-order condition for a maximum yields,

$$A-2q-C(x_p)=0 \Rightarrow q_p=(A-C(x_p))/2. \quad (8)$$

Substituting (8) into (7), gives the predatory profit function π_p as a function of predatory R&D expenditures:

$$\pi_p(x_p)=\frac{(A-\alpha+\sqrt{g x_p})^2}{4}-x_p$$

Similarly, equating q_s* (expression A.2 in Appendix 1) to zero and solving for t yields the value of the 'threshold' predatory tariff t_p:

$$t_p=\frac{(A-\alpha)(3-g(1-\beta)(2-\beta))}{6-g(2-\beta)} \quad (9)$$

t_p is the lowest tariff at which predation starts to become an optimal strategy. (Recall that at t_p, the necessary condition for duopoly is also fulfilled, with the optimal duopoly output for the Southern firm, $q^*_s = 0$.) A further increase in tariff will at some point result in the monopoly outcome as an optimal strategy. The lowest tariff at which an unconstrained monopoly arises is denoted by t_m. To figure out this value analytically we have first to recall that tariff t_m is reached if, for a given level of spillovers, the optimal strategy for the Northern firm is to choose the (unconstrained) monopoly level of output and monopoly level of R&D. On the other hand, the Southern firm could not make any positive profit at the resulting monopoly price. (At t_m, the Southern firm's profit is exactly zero, that is, the Southern firm just breaks even.) Formally, it means that at t_m,

$$p_m=\alpha-\beta\sqrt{g x_m}+t_m \quad (10)$$

holds, where 'p_m' denotes the monopoly price whereas 'x_m' is the level of R&D chosen by an unconstrained monopoly. Substituting the value x_m[9] expressed in terms of parameters into the equation (10) and solving explicitly for t one obtains

$$t_m=\frac{(A-\alpha)(2-g+\beta g)}{4-g} \quad (11)$$

It is also important to note that t_m is, at the same time, the highest level of predatory tariff, that is, the condition for the predation is also fulfilled at this point.

The Impact of Tariff

The Effect of Tariff on R&D investment in Duopoly

As already mentioned, in the scope of our interest (that is, in the region of parameters g and β in which a duopoly is a viable market form), erecting a tariff could induce profit shifting while preserving the duopoly competition. It could, alternatively, induce the exit of the Southern firm leaving it aside as a potential competitor which re–enters the market if the domestic firm charges monopoly price. Finally, it could secure the unlimited monopoly position for its own national. Note, however, that the above considerations refer to pure possibilities of the Northern government; that is, they specify its strategy sets and are, at the moment, devoid of issues such as what will be the optimal strategy for the (Northern) government.

Lemma 1:

$dx_t^*/dt > 0$ if (5) holds and $t \in [0,t_p]$ (see Figure 1) (see editorial note).

Thus, the erection of tariffs is not only a strategic tool to limit the share of the Southern firm, but also helps increase the R&D level towards the socially optimal R&D expenditures.[10] The intuition for this result lies in a specific 'feedback' mechanism: an increase in tariff increases the unit costs of the competitor and leads to the 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 cost advantage, thus higher output will follow and so on.

The Effect of Tariff on R&D investment in Constrained Monopoly

The economic implication of the change in tariff differs dramatically when duopoly ceases to be the market form. As we will see, the level of spillovers plays a crucial role in determining the direction of the tariff's influence on R&D, and in turn on quantities, profits and welfare when the constrained monopoly is the actual market form.

Lemma 2:

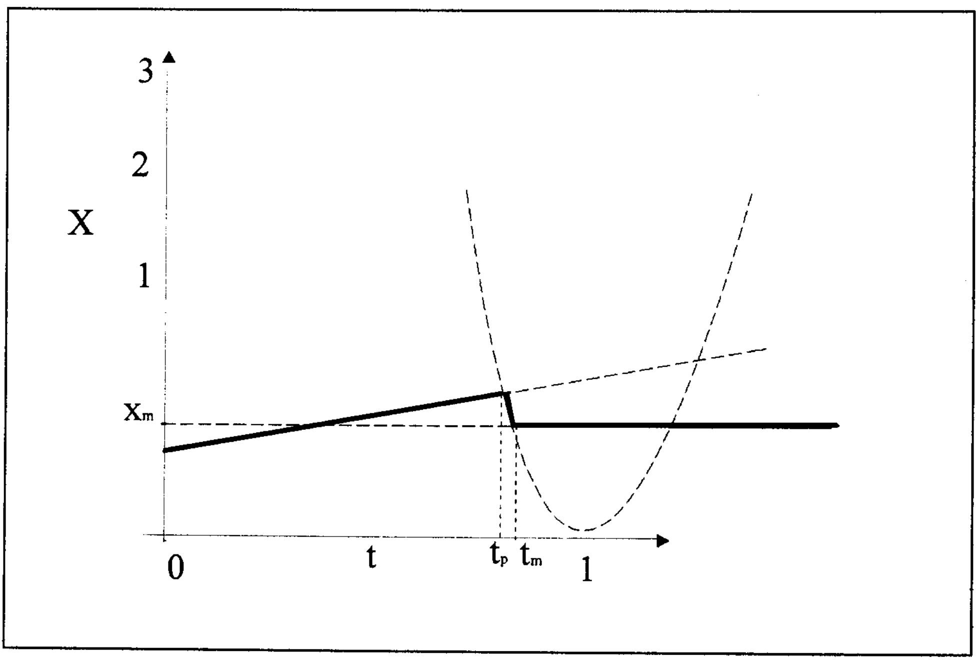
$dx^*_p/dt \leq 0$ *if* $< 1/2$

provided that predation is the optimal strategy for a given $t \in [t_p, t_m]$, i.e., that constrained monopoly is the equilibrium market form (see editorial note).

Note, that x^*_p moves monotonically (and declines if $\beta<1/2$) in the defined interval $t \in [t_p, t_m]$. Beyond the upper boundary, t_m, the domestic firm exhibits an unconstrained monopoly and the level of tariff has no further influence on the R&D expenditures, and the optimal R&D becomes x^*_m, the R&D level which the unconstrained monopoly chooses (see Figure 1).

The question is, however, what caused such a reverse reaction of the Northern firm here in comparison with its behaviour in the duopoly case. (Recall that in duopoly optimal R&D increases as a response to an increase in the tariff. See Fig 1.) The answer is not difficult once we understand the logic of 'predatory' behavior. When the Northern firm preys, it spends more resources on innovative activity than it would if it followed myopic profit maximisation. In other words, it commits to higher R&D to induce the exit (or prevent the entry) of the rival. The increased tariff yields the same effect instead. In fact, the government, by increasing the tariff (which is, 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 maximising 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, thus, it will have a counter productive implication for social welfare.

Figure 1. The impact of tariff on R&D when spillovers are small ($\beta<1/2$)



The policy conclusions are exactly reversed in the situation characterised by the high spillovers (β>1/2).

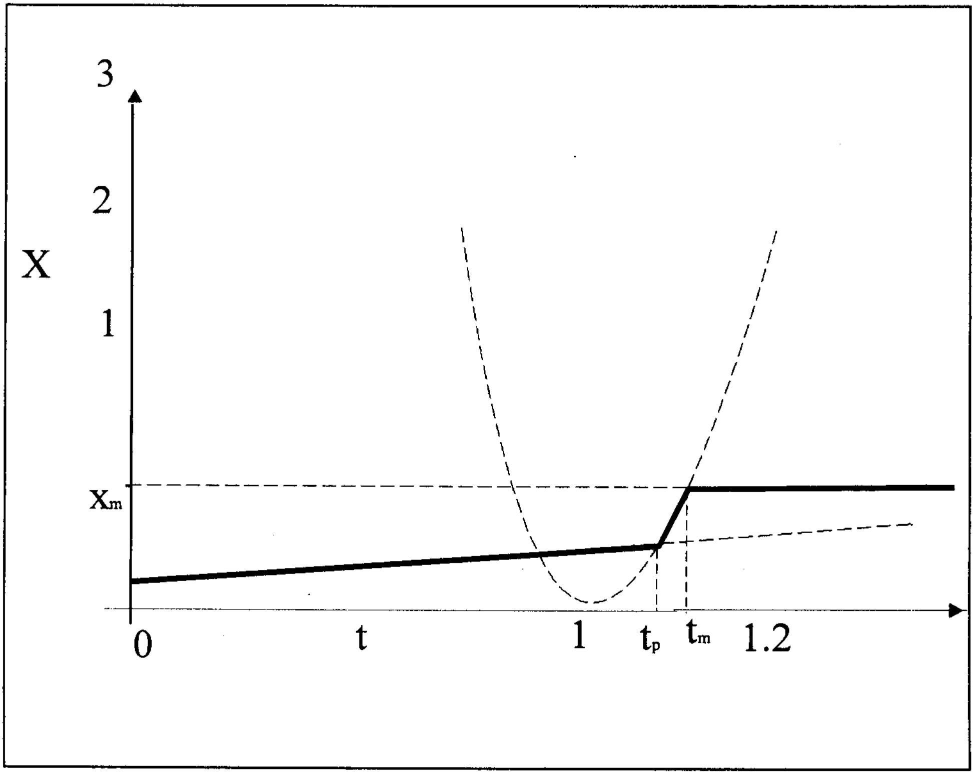
Lemma 3:

$dx^*_p/dt>0$

if β>1/2 if predation is an optimal strategy (see editorial note).

Note that here, the actual level of R&D is smaller than the corresponding monopoly R&D due to the high disincentive of spillovers (see Figure 2). An increase in tariff cushions the potential competition from the South and reduces disincentives to invest in R&D, and the optimal response of the profit-seeking firm is to increase the R&D level and thus move again towards the monopoly (or myopic) profit maximising point. The policy concern now is not to put tariff too low. Note that the increased tariff in this case also helps to move the R&D closer towards the social optimum andthus, as in duopoly, serves as a technological policy tool for restoring

Figure 2. The impact of tariff on R&D when spillovers are big (β>*1/2*)



the incentive for R&D investment. Furthermore, observe that at the level of $\beta = 1/2$, the optimal level of R&D coincides with the 'decision theoretical' solution. That is, the selected level of R&D to induce the exit of the Southern firm is the same as if the Northern firm were an unconstrained monopoly, ($t_p = t_m$ *at* $\beta = 1/2$).

Lemma 4:

$d\pi_p/dt>0$ (see editorial note)

The increase in the level of predatory tariff always increases the Northern firm's profit. As we already discussed, the change in tariff influences the adjustment in the optimal R&D expenditures plan towards the monopolistic profit that is, the highest achievable profit and, as a result, the corresponding profit is closer to the monopoly profit after the adjustment takes place.

The Optimal Tariff and the Intensity of Spillovers - Social Welfare Considerations

The First Game

So far, the tariff has been considered as given or arbitrarily set. At this point, we explicitly introduce the third player - the Northern government, which determines the level of tariff.

Now there are three actors in the game: the Northern government and two firms. In the first stage of the game, the Northern government acts as the Stackelberg leader and selects the optimal tariff by anticipating the reactions of the firms. In the second stage, the Northern firm selects the level of R&D, taking into account the subsequent market competition. In the third stage, the firms compete in quantities in the case of a duopoly or the Northern firm alone sets its optimal (constrained or unconstrained) monopoly output.

We assume, further, that the Northern government is maximising welfare, leaving aside the issue of the political economy of the tariff[11]. The optimal tariff t_{opt} will result then from the welfare maximisation described by the social welfare function (W), $W_n{*} = p_n^{*}\ Sn{*} + \mathrm{P}_n^{*}$, *where* $R_n^{*} = tq_s{*}$ is revenue raised by tariffs.

As in the case with the Northern firm's profit, the social welfare function is defined depending upon the level of the tariff. As we already saw, '*d*' stands for duopoly, '*p*' stands for predation, and '*m*' stands for monopoly, and the subscript '*n*' refers as before to 'North' and is often omitted if W^{*} unambiguously refers to the North.

$$W_n^*(t) = \begin{cases} W_d(t), & if\ 0 < t \le t_p \\ W_p(t), & if\ t_p \le t \le t_m \\ W_m, & if\ t \ge t_m \end{cases}$$

The welfare maximisation problem is a constrained one: the optimal level of Southern production should be nonnegative. Thus, the problem is written as $max[W_n^*(t)]\ s.t.\ q_s^* \ge 0$.

Let us concentrate, for the moment, on the function $W_d(t)$ and assume that there is an interior solution so that we can act as if we have an unconstrained optimisation problem. The optimal level of tariff in this case is simply obtained by solving the equation $dW_d(t)/dt = 0$ for t.[12] Denote this solution as t^*. The actual expression for t^* from the first order condition yields:

$$t^* = \frac{(a-\alpha)(27+(-2+\beta)g(10-2g-\beta(11-5g+4\beta g+\beta^2 g))}{81+(-2+\beta)g(32-6g-\beta(10-7g+2\beta g))} \tag{12}$$

Having this in hand, and relying on the analysis performed in the previous sections, we can characterise the optimal tariff levels, even without formally setting the Kuhn-Tucker conditions for the maximum.

As one could suspect, the crucial thing in finding the socially optimal tariff, is whether the level of spillovers is high or low. Another decisive factor, as we will soon see, is whether in given circumstances, duopoly could be viable or not. In other words, we must determine whether the constraint $q^*_s \ge 0$ is binding or not. We start with the case of small spillovers.

The Optimal Tariff when Spillovers are Small ($\beta<1/2$)

Imagine that our benevolent government, occupied with finding the welfare-maximising tariff, examines first whether duopoly is the socially desirable market structure. To make this investigation, it is necessary to check whether the welfare function $W_d^*(t)$ has an interior solution in the interval $t^* \in (0,t_p)$. Assume, for the moment that it has. In this case, the constraint $q^*_s \ge 0$ is *not binding*, implying that duopoly is a good candidate for the equilibrium market form[13]. Indeed, for small spillovers, this local optimum turns out always to be a global optimum as well, and we have $t_{opt} = t^*$ *for* $\beta<1/2$ (see editorial note).

The advantage of duopoly is its higher consumer surplus over monopoly and in addition, tariff revenue. These two items altogether outweighs the higher monopoly profit when spillovers are low. Thus, monopoly cannot be a socially optimal market structure, and t_m is never observed as an optimal tariff when spillovers are small.

If, on the other hand, the constraint is *binding*, it means that a further increase in tariff would add to the social welfare if it were possible. In other words, the marginal social welfare $(dW_d^*(t)/dt)$ would be positive at t, at which $q^*_s = 0$, if there were no constraint. This special value of t is, as we know, t_p - the lower bound of the interval $[t_p, t_m]$ in which strategic predation is a feasible strategy. A further increase in the tariff will decrease the consumer surplus due to the decrease in R&D expenditures in this situation (recall Lemma 3, that is, $dx_p/dt<0$ is the optimal response by the Northern firm to the increase in tariff when spillovers are small.) This will have overall negative welfare consequences despite the rise in the Northern firm's profit (see editorial note). Technically speaking, there is a 'kink' in social welfare function at point t_p, thus, the right–hand derivative, $dW_n^{*+}(t_p)/dt$, at point t_p, is positive whereas the left-hand derivative, $dW_n^{*-}(t_p)/dt$, is negative. The optimal tariff t_{opt} will be t_p in this case.

Thus, when spillovers are small, the only two candidates for the optimal tariff are t^* and t_p. Which of them appears optimal hinges on whether or not the constraint is binding, and that, in turn, depends on the level of R&D efficiency. If g is not very 'high', a low level of spillovers could be sufficient to warrant the duopolistic competition even if the tariff is added to the Southern firm's unit costs (see Figure 3). Thus, duopoly could be a viable market form and $t_{opt} = t^*$. (The critical level of R&D efficiency up to which duopoly is the equilibrium market form we denote by $g_{cr}(\beta)$. (See editorial note). If, on the other hand, the actual g is too big, then the strategic predation will be the optimal market form and $t_{opt} = t_p$. Proposition 1 summarizes the above discussion.

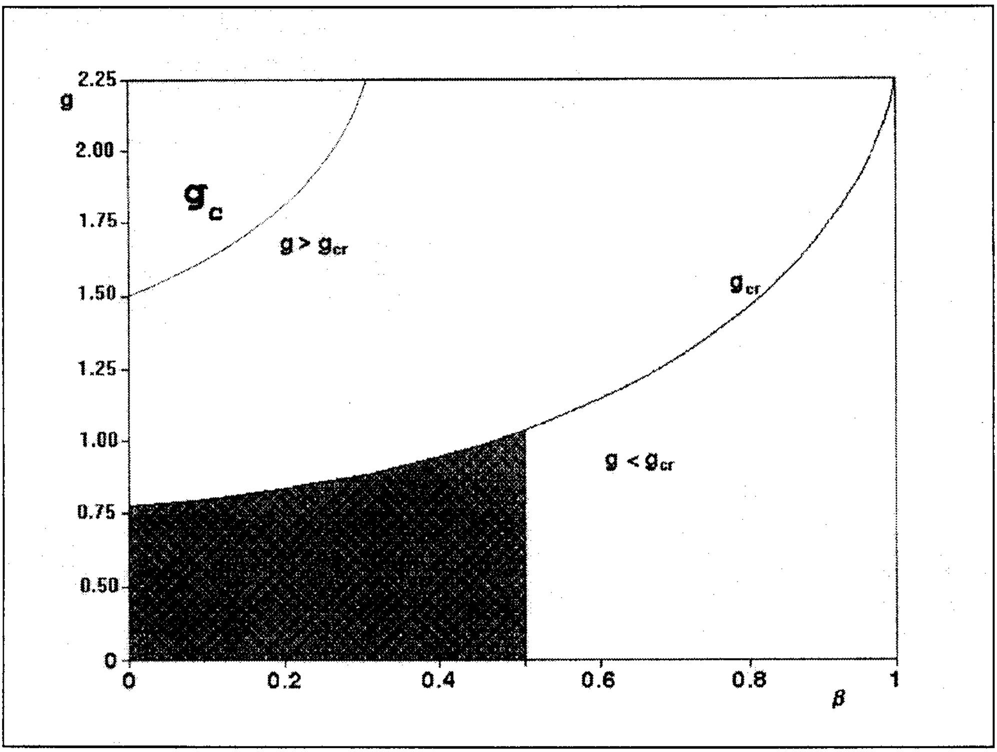
Proposition 1

If spillovers are small $(\beta<1/2)$ and R&D efficiency is such that $g<g_{cr}$, then the optimal tariff is t^* and the equilibrium market form is duopoly. If, for a given β, the R&D efficiency is higher than g_{cr} , the optimal tariff will be t_p and the prevailing market form will be constrained monopoly (see editorial note).

The Optimal Tariff when Spillovers are Large (β>1/2)

Let us start again with the situation in which an interior solution exists (i. e., the constraint is not binding and duopoly is again a candidate for the equilibrium market form and t^* is a candidate for the welfare-maximising tariff). However, this time, the local maximum, if it exists, should not necessarily be the global one. As we discussed earlier, in the situation characterised by high spillovers, the optimal level of R&D is lower than in monopoly (see Fig 3.), implying that the actual level of R&D is much below the socially desirable one and the total loss of welfare could be even bigger than in monopoly (see editorial note). In this situation, generated welfare in duopoly turns out to be lower than welfare generated in an unconstrained monopoly due to the high disincentive for R&D activity. On the other hand, the 'predatory tariff,' that is a tariff such that $t \in [t_p, t_m]$, could never appear as an optimal response unless it reaches the level t_m (see Lemmas 3 and 4). The increase in tariff beyond t_p simultaneously increases both the Northern firm's (predatory) profit and consumer's surplus and, thus, social welfare, until point t_m is reached at which further increases in tariff have no influence on social welfare[14] - ($dW^*(t_m)/dt = 0$). Thus, in these

Figure 3.: The region of parameters ($g<g_{cr}$ and $\beta<1/2$) in which duopoly is the optimal market form.



circumstances, the monopoly tariff (t_m) becomes an eligible candidate for the socially optimal level of tariff. The higher welfare in monopoly could result for two reasons. First, the monopoly profit is so big that it more than compensates for its lower consumer surplus and the absence of tariff revenue in comparison with duopoly. (Also notice that, in the case of duopoly, only a part of the generated duopoly profit, notably the Northern one, counts as the social welfare of the Northern country.) Second, if spillovers are very high, it is also possible that not only profit but even consumer surplus is higher in monopoly than in duopoly.

However, if R&D efficiency is rather 'low,' then the 'leakage' of knowledge ($\beta(gx)^{1/2}$) is not so dramatic, and the duopolistic outcome could still produce more social welfare. In addition, there is also positive revenue from tariff not present in a monopoly.

Thus, this time, the only two candidates for a socially desirable tariff are t^* and t_m. As is the case of small spillovers, the actual choice between these two tariff levels depends on the degree of R&D efficiency. If R&D efficiency is 'small,' that is, $g<g_{cc}(\beta)$ (see editorial note) then the disincentive of high spillovers is less intense, the duopolistic competition is socially desirable, and the welfare it creates more than compensates for the low level of R&D spending (even lower than in the case of unconstrained monopoly - see Figure4). If, conversely, the actual g is 'big,' then monopoly will be the optimal market form. However, the policy conclusion 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. Proposition 2 presents the above discussion more succinctly:

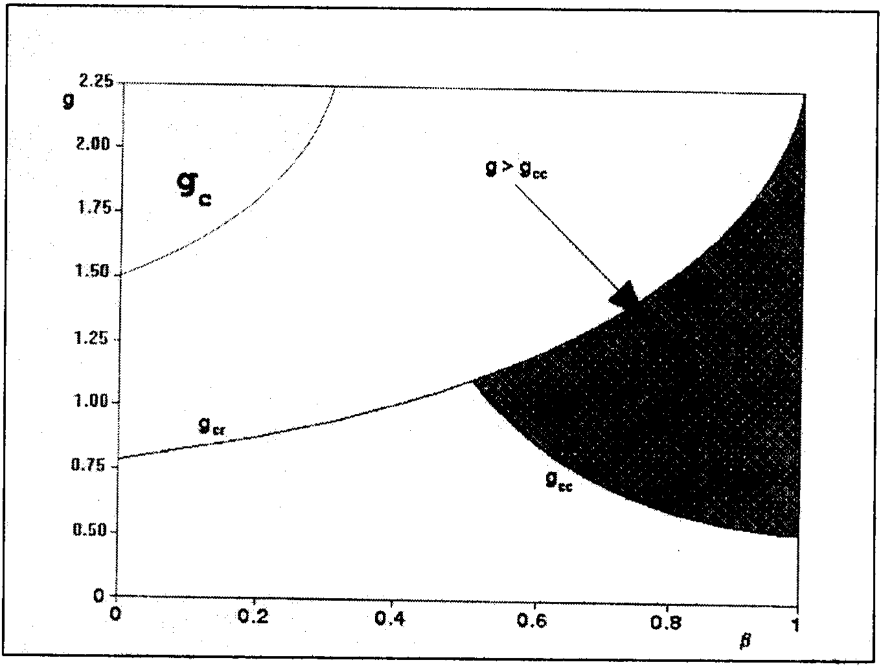
Proposition 2

If spillovers are large ($\beta > 1/2$) and R&D efficiency is such that $g<g_{cc}$, then the optimal tariff is t^* and the equilibrium market (welfare-maximising) form is duopoly. If the R&D efficiency is higher than g_{cc}, then the optimal tariff will be t_m and the welfare-maximising market form will be unconstrained monopoly (see editorial note).

The Second Game

The nature of technological spillovers is mixed. In some sense, they could be regarded as a parameter, as is the case in the industrial organisation literature and in the first part of this paper. In another sense, they could be considered a strategic variable of the government which is able to manipulate the level of spillovers not only through the lax enforcement of intellectual property rights, but also, as happens in some developing countries (see Braga, 1990), by the direct procurement of important pieces of technological information for its nationals. (The government usually acquires these important pieces of information through patent disclosure.)

Figure 4. The region of parameters ($g>g_{cc}$ and $\beta>1/2$) in which monopoly is the optimal market form



Furthermore, the government could by its policy influence the absorption capacity for adopting innovations and, thus, ultimately, the level of spillovers. Considering spillovers as a parameter could be more convenient at the micro level. At the macro level, however, spillovers could be viewed as variable. The degree of the strength of the IPR regime as a variable under the control of the government could be a useful simplification for that purpose. Though spillovers at the macro level possess characteristics of both a parameter and a variable, for the sake of simplicity we will assume that in our context β is a variable under the full control of the Southern government and we will think of β as the measure of the degree of IPR protection.

In the second game, the Southern government selects the IPR regime through its interactions with the Northern government, which in turn selects the level of the optimal tariff. This game precedes the game between the firms. More specifically, in the first stage of the game, the Northern and Southern governments choose simultaneously the level of the tariff and the level of IPR protection, taking into account the subsequent game between the firms. In the second stage of the game, the Northern firm selects R&D expenditures, anticipating subsequent competition in the product market, given the level of tariff and spillovers. Finally, in the third stage, the firms compete in quantities in the Northern market.

The last two stages of this game are the same as in the previous game, so we turn immediately to the first stage of the game. As was already mentioned, in the first stage of the game the two governments simultaneously select their strategic variables anticipating the subsequent game between the firms - the Northern government selects the value of tariff and the Southern firm chooses the level of IPR protection. The corresponding payoff functions are given below:

$$W_n^*(t,\beta) = \pi_n^* + S_n + tq_s^* \quad (13.a)$$

$$W_s^*(t\beta) = \pi_s^* \quad (13.b)$$

The welfare functions can be expressed in terms of parameters and the strategic variables β and t respectively. To work out an equilibrium pair of strategies (t^{**}, β^{**}), if it exists, we should derive the corresponding 'reaction functions' of the Northern and Southern governments.

The Northern government's best response, for a given β, implies the optimisation problem: $Max[W^*_n]$ with respect to t for the given β. The analysis from previous section gives a clear clue to the solution of that problem. If $\beta < 1/2$ and duopoly is viable ($g < g_{cr}$), then the best response ('reaction function') $t^r(\beta)$ is obtained in the conventional manner, that is, by solving the $dW^*_n/dt = 0$ that gives us $t^r(\beta) = t^*(\beta)$. If the duopoly is not viable (the constraint, $q^*_s \geq 0$, is binding), then $t^r(\beta) = t_p(\beta)$. (The functions $t^*(\beta)$ and $t_p(\beta)$ are, in fact, the expressions (12) and (9), respectively, but are now expressed explicitly as a function of β.) Similarly, if for a given β, such that $\beta > 1/2$, duopoly is viable ($g < g_{cc}$), the reaction function will again be $t^r(\beta) = t^*(\beta)$, whereas, if $g \geq g_{cc}$, the reaction function will be $t^r(\beta) = t_m(\beta)$.

The optimisation problem of the Southern government is written as $Max[W_s^*(\beta, t)] \equiv Max[\pi_s^*(\beta, t)]$ with respect to, subject that $\beta \leq 1$ for the given t. However, this optimisation makes sense only if duopoly is a viable market form, i.e., if the actual reaction function of the Northern government turns out to be $t^r(\beta)$. In this case, whenever possible, the Southern government should select the highest possible value of β such that $g < g_{cc}$. (Note that $dW_s^*/d\beta > 0$ for all β in the permissible interval $\beta \in [0,1]$.) That is, by choosing β, it should not induce the Northern government to have $t_p(\beta)$ or $t_m(\beta)$ as its best response, because it will lead to $W_s^*(\beta,t) \equiv \pi_s^*(\beta,t) = 0$, which is definitely not desirable for the South.

In other words, the Southern government's dominant strategy is to play at the highest level of β, consistent with duopolistic competition, regardless of the erected tariff by the North[15]. (See Figure 5 for the regions of g and β consistent with duopoly competition.)

Note that the Southern government, by knowing the value of actual g, behaves like the Stackelberg leader, and the ordinary Nash equilibrium coincides with the Stackelberg equilibrium. Proposition 3 summarises the above discussion:

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 in competition with the Northern firm whenever possible. Because the Southern government's dominant strategy is to select the highest achievable level of spillovers for any level of tariff, the Cournot-Nash equilibrium coincides with the Stackelberg equilibrium.

Optimal versus Punitive Tariff

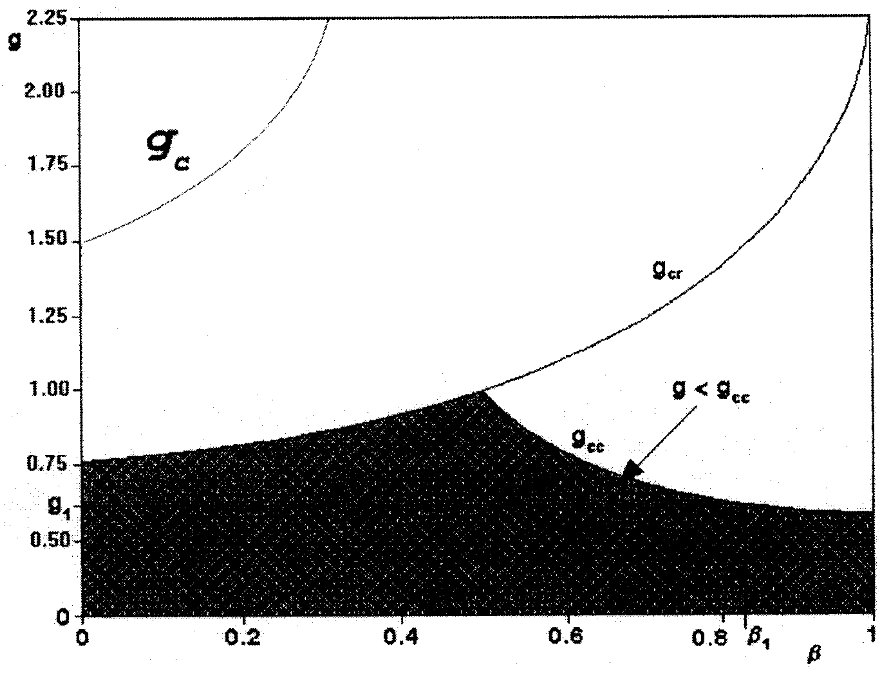
The GATT (until recently) and the World Trade organisation (today) have acted as mechanisms to enact the 'co-operative' solution, which would be beneficial for all parties in the game. (The co-operative solution in our context is the situation in which the Northern government 'plays' $t = 0$, whereas the Southern government sets $\beta = 0$.)

In other words, by means of bilateral and multilateral agreements and negotiation rounds, tariffs have been abandoned or kept rather low. Thus, for the imposition of tariff in a real-life situation, there should be a 'strong reason,' different from the reasons stemming from 'strategic incentives' to shift the profit from the foreign competitor to its national firm. The violation of IPR surely belongs to such cases. It is enough to recall the recent China vs. US IPR trade dispute when the violation of intellectual property rights by China was a definite reason for the US government to threaten China with punitive, 100 per cent tariffs on the majority of its exports to the US. Trade law of US (cf: the Omnibus Trade and Competitiveness Act of 1988) envisages punishment for countries identified as 'egregious intellectual property rights transgressors that do not undertake or make progress in negotiations' with the US (see Braga, 1990). Similar legislation exists in the European Union.

Trade sanctions due to violations of IPR have been imposed in some cases: in 1987, the EC suspended its GSP benefits for Korean products in response to Korean prohibitive practices in the field of IPR; a year later, the US imposed 100 percent punitive tariffs against some Brazilian goods (see Braga, 1990).

The character of a punitive tariff is somewhat different than the 'ordinary' optimal tariff because it is basically an *ex post* instrument. It represents a trigger mechanism,

Figure 5. The region of parameters ($g<g_{cr}$ and $g<g_{cc}$) consistent with the duopolistic competition.



which is the sole reaction of the country authorities, conditional on an observed violation of IPR.

The above considerations suggest that the structure of our game should be modified if we want to account for these realistic features. Thus, the Northern government does not impose any tariff *ex ante*; that is, we assume that 'strategic incentives' to impose a tariff remain only incentives due to, say, multilateral tariff negotiations. The rules of the game are very simple now: the Northern government commits to the zero tariff level unless there are IPR violations. If the Northern government observes a violation of IPR (that is, it observes positive β), its executives immediately look for the file in which there is a solution for the optimal tariff and they implement this tariff as a punitive tariff. Thus, the punitive tariff is, in fact, the optimal tariff, but only applied conditionally and *ex post*.

The Southern government, on the other hand, has the easy task of comparing the value of its welfare function W_s^* $[\beta^{**},t^{**}]$ with the value of the same welfare function at $W_s^*(0,0)$. Clearly, if $W_s^*(\beta^{**},t^{**})>W_s^*(0,0)$, the Southern government will prefer to violate IPR despite the retaliation. (Note that the incentive constraint of the Northern government, that is, $W_n^*(\beta^{**},t^{**})>W_n^*(0,0)$ is not effective here due to the *ex ante* commitment to zero tariff.) Within the framework of our model, the Southern government will always select $\beta = 0$, because $W_s^*(\beta^{**},t^{**})<W_s^*(0,0)$ (see editorial note) for all possible sets of values of the efficiency parameter consistent with the existence of duopoly.

Concluding Remarks

The government incentive to raise tariff when imperfect competition prevails largely arises from the possibility that changing the strategic relationship between foreign and domestic firms shifts profits towards domestic nationals[16] and the domestic treasury. In our specific context, moreover, a tariff may act as a technological policy tool to increase the investment in socially desirable innovation.[17] The actual height of the tariff determines the market structure that arises in the economy.

Ascertaining the level of spillovers (considered to be a parameter) is essential to finding the optimal, welfare-maximising tariffs and the most desirable market structure in turn. Thus, a low level of spillovers would favour duopoly as a market form if it is feasible (or constrained monopoly otherwise) whereas a high level of spillovers would generally require (unconstrained) monopoly unless R&D efficiency is rather low (in which case duopoly is again the preferred market outcome).

When the Southern government chooses the level of spillovers as its policy variable reflecting the strength of IPR protection, it does so in a such way as to maintain the duopolistic competition, if the R&D efficiency is not so large as to make duopoly non-existent. The optimal level of IPR infringement is as high as possible, provided that it still does not trigger the predatory or monopoly tariff.

The precommitment of the Northern government to zero tariff, unless there is a violation of IPR, changes the nature of the game and the optimal level of spillovers is zero in this case. Thus, free trade without IPR violations will be observed in equilibrium. This conclusion is obtained within the world of perfect information, yet it seems to be consistent with the observed reality. That is, even if there is observed infringement of IPR (as in the US versus China dispute), the very threat of a punitive tariff (or occasionally even its temporary implementation) restores the equilibrium characterised by the no tariff situation and rather strengthened enforcement of IPR protection.

The optimal design of strategic trade policy is very sensitive to the type of market competition (see Spencer, 1986, for an instructive discussion of this problem). The natural question to ask is how the Bertrand-Nash type of competition fares here. Before commenting on this issue, it is useful to recall that we are using (at least implicitly) the segmented-market hypothesis and homogeneous products. A moment of reflection tells us that in this framework 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, $p^* = \alpha - \beta(gx) + t$ (more precisely, the price will be slightly lower, $p^* = \alpha - \beta(gx) + t - \varepsilon$, where ε is an arbitrary small number). The resulting market form will be either constrained monopoly, if p^* is lower than p_m, or monopoly, if $p_m \leq p^*$. Which of these two outcomes is welfare maximising is again a matter of the value of parameters β and g. As Žigić (1998a) has shown, the optimal tariff in Bertrand competition is generally lower than in Cournot competition. This is not surprising since Bertrand competition is tougher than Cournot and less or no intervention is optimal. Thus, desirable tariffs are low (or even zero) in this case.

Another issue related to the design of strategic tools is which instrument serves the purpose best. As was shown by Dixit (1988) and Cheng (1988) the optimal policy package when firms compete as an oligopoly in the home market contains both a subsidy and a tariff simultaneously. This issue is out of the scope of the analysis in this paper. The subsidy as tool was rejected on the intuitive basis: in circumstances in which spillovers prevail, subsidising domestic R&D means subsidising its foreign competitor as well. (Of course, the subsidy could be so big that it forces the foreign firm to exit the market. For the insightful analysis of subsidising R&D in duopoly with spillovers, see Hinloopen, 1997.) Furthermore, Bhattacharjea (1995) discussed numerous reasons why the implementation of a subsidy might be troublesome, starting from the high information content required to implement optimal subsidy, to the distorting effects of taxes necessary to finance the subsidy. Yet the possibility of the optimal mix of tariff and R&D subsidy may deserve analytical attention.

The second game in which both governments select their strategic variables has a prisoner-dilemma property. Thus, turning this game into a supergame by using, for instance, the second-stage–profit function as a payoff function will bring the free trade as a (subgame-perfect) Nash equilibrium together with the equilibrium from the one-shot game. However, the predictive power of this game may be rather low due to the multiplicity of (subgame perfect) Nash equilibrium.

Last but not least, more subtle models should account for other features of reality missing in the approach of this paper. Thus, in practice, when spillovers are considered as policy variable, their real boundaries go from a given β_{min} (the spillovers which could not be prevented even with the most rigorous enforcement of

IPR) up to β_{max} (the highest achievable level of spillovers the government could reach with its engagement). These boundaries can themselves be variables in more complex models rather than sheer parameters.

Editorial Note: Mathematical proofs can be obtained from the author on request.

NOTES:

[1] There is a basic difference between R&D spillovers and imitation; unlike R&D spillovers imitation implies active and costly processes in order to disentangle the original innovation

[2] The 'R&D with spillovers' literature concentrates on the research and development (R&D) models whose distinguished characteristics are a) a focus on process innovation; b) a strategic variable is R&D expenditure, which, via a certain R&D production function, reduces not only the unit costs of the firm that undertakes R&D but also the unit costs of other firms via spillovers; c) the strength of spillovers being measured by a parameter β, whose value ranges betweenzero and one. The value of β reflects the scope of information leakage, as well as the absorptive capacity of the receiving units, and is assumed to be determined by technological and organisational characteristics (see De Bondt et al., 1992, p. 37). For 'R&D with spillovers' models (games), see, for example, Spence (1986), Katz (1986), D'Aspremont-Jasquemin (1988), Kamien et al. (1992), Suzumura (1992), De bondt et al. (1992), Žigić (1998a,b).

[3] The reason for this may be a too narrow Southern market, balance of payment considerations, the fact that the presence on the Northern market enhances spillovers, etc. Alternatively one can assume that the presence of the Southern firm on the Northern market is essential for positive spillovers.

[4] This specification reflects empirical observations and was listed as a 'stylised fact' in Dasgupta (1986), p. 532, for instance.

[5] We assume that α is big enough that the optimal R&D (x^*) is always in the interior of the set X.

[6] This requirement is identical to $\Pi^s>0$ equilibrium.

[7] For $g=4$, the monopoly profit is not defined. See Chin and Grossman (1990), p. 107, note 7.

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

[9] $x_m = g(A-\alpha)^2/(4-g)$

[10] It is easy to show that the R&D expenditures of the Northern firm are below the social optimum (see Žigić, 1996a,b). This is intuitive since spillovers create a disincentive for innovative activity.

[11] That is, we assume that the government puts equal weight on consumer surplus, profit, and revenue. However, in real life this is generally not the case because of lobbying activities and the power of interest groups. Thus, we could think of the government maximising the welfare $W = \omega_1\pi_n^* + \omega_2 S_n^* + \omega_3 R_n^*$ where the weights ω1, ω2, and ω3 are determined in the political economy type of game which is beyond our considerations. Instead, we exogenously assume that ω1=ω2=ω3.

[12] The function $W_d^*(t)$ is concave due to R(t) so that the sufficient condition for a maximum is satisfied, that is, $d^2W_d^*(t)/(dt)^2 < 0$.

[13] The reason for possible appearance of the interior solution is the revenue collected through the tariff. Otherwise, the Northern government would surely prefer to have only its firm in the market because of its 'natural monopoly position' (see Žigić, 1998). Technically speaking, the tariff revenue function, R(t), gives rise to the concavity of the function W(t).

[14] The level of tariff (t_m) represents such a high entry barrier (or cause for exit of the Southern firm) that even the potential competition by the Southern firm is eliminated and tariff has no influence on any economic decisions of the monopolist.

[15] If, for example, the actual R&D efficiency is $g=g_1$, then the optimal response is (slightly less than) $\beta=\beta_1$. If the actual g exceeds the value g>1.171, then duopoly is not sustainable, no matter how high the level of β us set. Thus, the highest permissible value of g, consistent with the duopoly competition, is g=1.171, with the corresponding optimal value β*=1/2. Note that the value 1/2 is the lowest possible equilibrium value of β. On the other hand, for a value of g smaller than 0.385, the optimal value will be β*=1. For all other values of the parameter g between these two values, the optimal β will be in the interval β∈(1/2, 1) (see Figure 5)

[16] The incentive of the government to raise tariff is not offset by the possibility that the other party could impose a tariff if the Northern firm also exports to the Southern market, provided that the markets are segmented (see Brander 1986). Allowing for this will not qualitatively change the above analysis.

[17] In the above context, the tariff also acts as the instrument which partly or fully offset the IPR violation by the South (see Žigić 1998 b).

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