Optimal Tariff, Spillovers and North-South Trade

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Abstract

This paper investigates the issue of the optimal tariff policy of the domestic country ("North") in an environment in which its trade with the foreign country ("South") is accompanied by a leakage of technological information (spillovers). Three duopoly games were considered. The first one views spillovers as a parameter. In this setting the Northern government sets the tariff anticipating the subsequent competition between the firms. The second game assumes that the spillovers are a strategic variable under the control of the Southern government. The tariff and the optimal level of spillovers (interpreted as the degree of the intellectual property right protection), are determined now through the interaction between the Northern and Southern governments whose decisions precede the decisions of the firms. In the third game, the Northern government erects a tariff only if it observes the violation of intellectual property rights by the Southern government. Such a tariff is called a punitive tariff.

Abstrakt

Tento článek zkoumá záležitosti optimální tarifní politiky domácí země ("Sever") v prostředí, ve kterém je její obchod s cizí zemí ("Jih") doprovázen únikem technologických informací (druhotné efekty, v angličtině "spillovers"). Článek zvažuje tři duopolní hry. V první se na druhotné efekty pohlíží jako na parametr. V tomto uspořádání vláda Severu určí tarif, očekávaje následující soutěžení firem. Druhá hra předpokládá, že druhotné efekty jsou strategickou proměnnou, která je pod kontrolou vlády Jihu. Tarify a optimální úroveň druhotných efektů (které se interpretují jako stupeň ochrany práv duševního vlastnictví) jsou určovány interakcí vlád Severu a Jihu. Jejich rozhodnutí se uskuteční před rozhodováním firem. Ve třetí hře vláda Severu zavádí tarif pouze když pozoruje, že vláda Jihu porušila práva duševního vlastnictví. Takový tarif se nazýva trestní tarif.

Keywords: tariff, intellectual property rights, spillovers, strategic trade, duopoly, constrained monopoly, strategic predation, market structure, social welfare.

JEL Classification: L11, L13; O31, O38

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Introduction

The economic impact of tariffs has been well established and studied, especially in the international trade literature. In particular, recent advances in strategic trade theory and policy have stressed the role of tariffs as a strategic weapon available in the government policy arsenal (see, for example, Brander and Spencer, 1982, 1983, and 1984, Krugman, 1984, etc.)

One lesson of the strategic trade policy literature is that the government has an incentive to impose a tariff to secure a higher profit or higher market share for a domestic firm in a situation in which imperfect competition prevails. The announced tariff changes the nature of the "game" among foreign and domestic firms by altering the strategic interactions among them. Crucial for this result is that the government has the credibility to commit to its policy choice (e.g. tariff) before the firms make their choices. This requirement is usually met in practice. Equivalently, one can assume that the government "shoots first" in the game.

Another important feature of the tariff is that it is a device by means of which the government can influence the market structure. Confining our analysis 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.

Leakage of technological knowledge (spillovers) is a pervasive phenomenon in the era of the third scientific revolution and ever more integrated world economy (see Coe and Helpman, 1993, for a thorough empirical examination of international spillovers in 22 industrial countries). Spillovers from North to South are quite common. Evidence suggests that Northern innovative activity boosts productivity of developing countries: in the period 1985–1990, a 1 percent rise in U.S. research and development stock increased the total factor productivity of the 77 developing countries by an average of 0.04%. Some countries (e.g. Singapore) displayed increases in their total factor productivity by 0.22% (see Hoffmaister, 1995, for more details). One of the media through which spillovers spread around the world economy is international trade.

This paper analyzes the issue of the *optimal tariff* in the circumstances in which international trade between the "North" (a developed country) and the "South" (a developing country) takes place. Firms are in an imperfectly competitive environment. In addition, there are leakages of technological knowledge ("spillovers") from the North to the South. In other words, the interaction between tariff and *spillovers*, together with its consequences for the social welfare of the

North, is the focus of the paper.

Spillovers possess characteristics of both exogenous parameter and endogenous variable. Thus, in the first part of the paper, spillovers are treated as a parameter. Later in the paper, they are viewed as a strategic variable under the control of the Southern government. The interpretation is that the intensity of spillovers reflects the degree of intellectual property rights (IPR) protection by South.

One of the motivations of this paper stems from the observation that tariffs are currently being used as devices (or threats) to punish violators of IPR, as the recent China vs. U.S. IPR dispute clearly indicates. Such tariffs are called *punitive tariffs*. A discussion of optimal tariffs will help us to set the economic foundations for punitive tariffs. The idea of punitive tariffs is introduced as a concept different from (but related to) the optimal tariff in a situation in which spillovers are treated as the measure of the IPR protection.

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 originates from the "R&D with spillovers" family of models[1] from related industrial organization literature.

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

a) In the situation in which there is leakage of technological information

[1] 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 in the industry; this phenomenon is known as "spillovers;" c) the strength of spillovers being measured by a parameter β, whose value ranges between zero 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 organizational 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-Jacquemin (1988), Kamien et al. (1992), Suzumura (1992), De Bondt et al. (1992).

and, as a consequence, the disincentive to invest in R&D, the tariff can serve not only as a "profit shifting" tool but also as an ordinary 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-maximizing 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) The standard result that an increase in tariff always decreases domestic consumer surplus does not necessarily carry over in the presence of spillovers.

d) 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).

e) 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 remainder of the paper proceeds as follows. Section 1 states and discusses the assumptions of the analyzed games between the Northern and the Southern firms and develops the core duopoly model. In Section 2, the issue of the existence of a duopoly is discussed together with the issue of the alternate market forms (constrained and unconstrained monopoly) which can arise due to the tariff manipulation. Section 3 examines the effect of tariff on R&D expenditures, and other relevant microeconomic variables in two (out of three) equilibrium market structures that may appear within our framework (given that there are two firms). Section 4 explicitly introduces the government as an actor in the game and discuses the choice of the optimal tariff and, consequently, the equilibrium market structure. The last section is devoted to some concluding remarks.

1. The Model

1.1. 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 whole world consumption takes place in the North. Alternatively, and more generally, one could introduce the "segmented market" hypothesis in which both the Southern and the Northern firms produce for both markets but they perceive each other's markets to be different ones (e.g. the Southern firm considers the Northern market to be different from the Southern market and, consequently, its optimization problem for the Southern market is independent of its optimization decision for the Northern market; the same is true for the Northern firm). 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, 1982, 1983, and 1984, and Helpman, 1982).

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, p. 76).

The Southern firm does not perform R&D but benefits through costless spillovers from the R&D activity of the Northern firm. 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. The former group is relevant in the model developed in this paper and is referred to as "South" in this paper.

The focus is on the so called "process innovations." 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 reduction in unit costs.[2]

The nature of the North-South relationship is modeled by relying on the concept of strategic interaction. We consider three sequential (three stages) games here.

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

In the first game, we assume that the level of spillovers is exogenously given and we concentrate on the welfare implication of optimal tariff and the change of spillovers. In the first stage 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 a power to manipulate the level of spillovers (the strength of IPR protection) to maximize domestic welfare. Thus, in the second game there are four players: the Northern and Southern governments and their firms. The Northern government sets the optimal tariff through the interaction with the Southern government. 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.

1.2. The Core Model

The starting (core) model in the paper 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). α is a parameter that 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 $c = \alpha - \beta (gx)^{1/2}$. 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). The consumer surplus is defined as

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

In the case of a linear demand function for the North, which is the only one supposed to consume the good z, the above expression becomes:

$$S_n = \frac{(A - P)(q_s + q_n)}{2}.$$

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 maximizes

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

given q_s .

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

The optimization problem for the Southern firm means:

$$\underset{q_s}{Max}\pi^s = (A - Q)q_s - cq_s - tq_s \qquad (1.b)$$

given q_n and t (t stands for the tariff imposed by the Northern government). 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:

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

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

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 maximize its profit. Note that the set of R&D action is given by $X = [0, \alpha^2/g]$.[3] 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:

$$q^*_n = \frac{3(A - \alpha + t)}{9 - (2 - \beta)^2 g} \tag{5}$$

$$q^*_s = \frac{(A - \alpha)(3 - 2g + 3\beta g - \beta^2 g) - (6 - 2g + \beta g)t}{9 - (2 - \beta)^2 g} \tag{6}$$

$$\pi_n^* = \frac{(A - \alpha + t)^2}{9 - (2 - \beta)^2 g} \tag{7}$$

$$\pi_s^* = \frac{[(A-\alpha)(3 - 2g + 3\beta g - \beta^2 g) - (6 + 2g - \beta g)t]^2}{[9 - (2 - \beta)^2 g]^2} \tag{8}$$

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

$$S_n^* = \frac{[(A - \alpha)(-6 + 2g - 3\beta g + \beta g) + (3 - 2g + \beta g)t]^2}{2[-9 + (2 - \beta)^2 g]^2} \qquad (9)$$

2. Duopoly and Constrained Monopoly

2.1. The Existence of Duopoly

The preceding subsection 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.

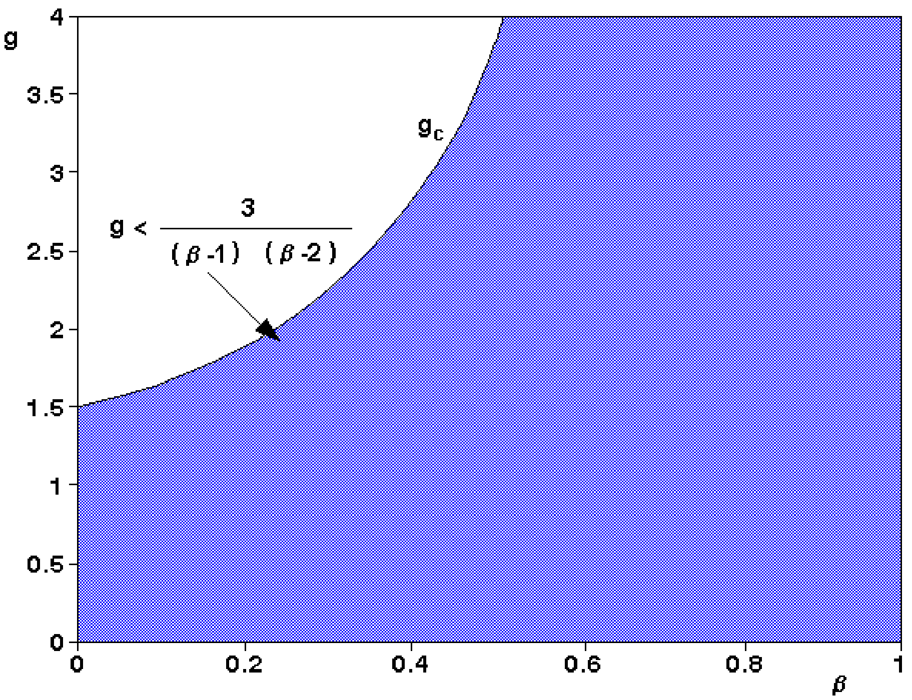
2) The difference in unit costs exceeds the critical level, but the low cost firm is not capable of exercising full monopoly power because the monopoly price would invite competition by another firm. The optimal strategy for the low cost firm is to choose an R&D investment and a quantity of production that will lead to the limiting price. This situation is described as a constrained monopoly and is analyzed in Section 3.

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

The unit cost differences in this model stem from three factors: the degree of spillovers (β), the intensity of R&D cost reduction (g), and the level of erected tariff. As far as the impact of g and β on unit cost asymmetry is concerned, for a given g, the higher β is, the lower the cost difference, and for a given β, the higher g is, the higher the cost difference. Roughly speaking, for both firms to produce, the cost reduction parameter (g) and the level of tariff (t) should not be "too high" and/or the spillovers parameter (β) should not be "too low."

Suppose, for the moment, that there is no tariff at all. Then 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 of Chin and Grossman, 1990), for an asymmetric duopoly to be sustained, $g < 3/2$ (that is, $g^c = 3/2$) must be true. In 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,

Figure 1
Region of Parameters g and β in Which Duopoly Exists and t = 0



g^c also increases. This is intuitive, because in the presence of positive spillovers the critical R&D efficiency (g^c) 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, $q_s^* > 0$.[4] Expressing this inequality in terms of the structural parameters of the model yields, after appropriate rearranging, the expression (10),

$$g < \frac{3}{(\beta - 1)(\beta - 2)} \tag{10}$$

to which we refer to as "the sustainability condition" for duopoly. Further, the value of g is confined to the interval [0,4).[5]

Now let us introduce a tariff. In the light of the above analysis, tariff could be

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[4] This requirement is identical to $\pi^s > 0$ in the equilibrium.

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

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 an appropriate tariff, always raise the tariff so high as to make the difference in unit costs enough to force the foreign firm to exit and, depending on the height of tariff, enable the domestic firm to charge either the limit price or monopoly price, respectively. The Northern government can instead decide to keep the Southern firm in the market by charging low tariff or, if the domestic firm initially holds an unconstrained monopoly position, the desirable tariff could even be negative (subsidizing imports). In further considerations, we will neglect the possibility of negative tariff by assuming that the pre-tariff competition is of the duopolistic type, that is, (10) is assumed to hold. Since the demand function is linear, the optimal tariff is always nonnegative.[6] Technically, duopoly will be the viable market form unless 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 the level of R&D for which the rival's firm's optimal production (as well as profit) is zero. By increasing tariff further beyond t_p, the difference in the marginal costs becomes so large that at (and beyond) the value of tariff (denote it as t_m), the Northern firm gains unconstrained monopoly position. The profit of the Northern firm, as a function of the value of tariff could be written as

$$\pi_n(t) = \begin{cases} \pi_d(t), & \text{if } 0 < t \le t_p \\ \pi_p(t), & \text{if } t_p \le t \le t_m \\ \pi_m, & \text{if } t \ge t_m \end{cases}$$

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

2.2. The Constrained Monopoly and Strategic Predation

Strategic predation (or limit pricing) behavior 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 to last stage the Northern firm commits to the R&D level which will force the Southern firms to pick up the zero output in the last stage of the game (it is the best the Southern firm could do in this situation). In the last

[6] A sufficient condition for this result to hold is to have 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).

stage, two firms are supposed to compete in quantities, but the best that the Southern rival could do in the given circumstances is to produce zero quantity and thus exit the market. The Northern firm, which remains in the market, then chooses the monopoly output. However, this output (and correspondingly, price) is generally different than the output which would result were the Northern firm to select the unconstrained monopoly R&D expenditures.

In terms of mathematics, 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

$$x_p = \frac{(A - \alpha - 2t)^2}{(-1 + 2\beta)^2 g} \tag{11}$$

Given x_p, the second stage payoff is given by

$$\mathrm{Max}[\pi_p] = (A - q_p)q_p - Cq_p - x_p\ . \tag{12}$$

First-order condition for a maximum,

$$d\pi_p/dq_p = 0\ ,\quad \text{yields } A - 2q_p - C(x_p) = 0 \ \Rightarrow\ q = (A - C(x_p))/2\ . \tag{13}$$

Substituting (13) into (12), gives the predatory profit function π_p as a function of predatory R&D expenditures:

$$\pi_p(x_p) = \frac{(A^2 - 4\,x_p - 2A(\alpha - [gx_p]^{1/2}) + (\alpha - [gx_p]^{1/2})^2}{4}\ .$$

Similarly, substituting x_p into the $q_s = 0$ equation and solving for t yields the value of predatory tariff t_p:

$$t_p = \frac{(\alpha - A)(-3 + 2g - 3\beta g + \beta^2 g)}{6 - 2g + \beta g}\ . \tag{14}$$

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 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 profit is exactly zero, that is, the Southern firm just breaks even.) Formally, it means that at t_m,

$$p_m = a - \beta(gx_m)^{1/2} + t \tag{15}$$

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 expressed in terms of parameters into the equation (15) and solving explicitly for t one obtains

$$t_m = \frac{(A - \alpha)(2 - g + \beta g)}{4 - g}. \tag{16}$$

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.

3. The Impact of Tariff

The impact of tariff on the price, quantities and profits (and thus on the welfare) crucially depends on the emerging market form in equilibrium. As is clear from the discussion in Subsection 2.1, the Northern government has decisive power to influence the market form by properly choosing the level of tariff.

As we 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 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 comes back in 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.

3.1. The Effect of Tariff in Duopoly

3.1.1. The Impact on the Equilibrium Quantities, Price and Profits

The effects of tariffs on the equilibrium values in duopoly have been very well established in the vast body of the literature concerning the optimal tariff argument (see, for instance, Krugman, 1984, McMillan, 1982, Brander and Spencer, 1981, Brander, 1986, Spencer, 1986, among many others). The main results are that the tariff shifts the reaction curve of the foreign firm downwards causing a decrease in its equilibrium output and shifting profit in favor of the domestic rival. On the other hand, the impact of the tariff on the domestic consumer surplus is negative because the reduction in foreign output is always higher than the corresponding increase in domestic production.

The first group of results (the effect of tariff on the domestic and foreign firm's quantities and profits) carries over in our framework and we will not discuss them here. However, the second conclusion that a tariff can have only a negative impact on the consumer surplus appears less general. The sentence: "Tariff reduces domestic consumption" (Brander and Spencer, 1984, p. 200) was put forth as the Proposition 3, in the similar Cournot-Nash duopoly model without spillovers. However, the presence of spillovers allows for the possibility that the increase in domestic output due to tariff can be higher than the decrease in foreign firm output. The reason is, as we will see later, that the imposition of tariff in duopoly may increase the incentive to invest in R&D.

Lemma 1:

$dQ^*/dt > 0$, if $g > 3/(2 - \beta)$

Proof: See Appendix 1.

The corollary of Lemma 1 is that the impact of tariff on price, dP^*/dt, hinges as well upon the level of spillovers and the R&D efficiency parameter.

3.1.2. The Incentive for R&D and Tariff

The issue of policy concern is the impact of a tariff on R&D. As we will see, the tariff induces an increase in domestic R&D expenditures and thus, acts as a policy tool which restores R&D incentives that are suboptimal, due not only to the public good nature of innovative activity but also to the fact that the Northern firm, when it chooses the R&D level, maximizes profit and not social welfare.

Before we prove this beneficial influence of a tariff on the firm's R&D expenditures, we should first show that the research and development activity of the Northern firm is indeed below the socially desirable level.

The social underinvestment in R&D implies that the derivative of the social welfare function (W(x)) with respect to R&D is positive at the profit maximizing point (x*). This lead us to our second lemma:

Lemma 2:
$dW(x)/dx|_{x=x^*} > 0$

Proof:

First, note that $d\pi/dx|_{x=x^*} = 0$ by the first order condition of profit maximizing. This requires that the impact of R&D on consumer surplus at point x* has to be positive, that is, $dS(x)/dx|_{x=x^*} > 0$ to have $dW(x)/dx|_{x=x^*} > 0$.

To prove this, we rely on the fact that Sign[dS(x)/dx] = -Sign[dP(x)/dx]. The equilibrium duopoly price expressed in terms of R&D and parameters describes the following expression:

$$P(x) = \frac{2\alpha + A + t - [gx]^{1/2} - \beta[gx]^{1/2}}{3}$$

whereas its derivative with respect to x is given below:

$$dP(x)/dx = \frac{-(1+\beta)g}{6\,[gx]^{1/2}} < 0 \text{ , for all } \beta < 1.$$

The Sign[dS(x)/dx] = -Sign[dP(x)/dx] implying that Sign[dS(x)/dx] = 1 (thus, dS(x)/dx > 0 always, not only at x = x*).

Q.E.D.

The increase in R&D expenditures always improves the consumer surplus, implying that $dW(x)/dx|_{x=x^*} > 0$ and indicating that there is too little R&D from the social welfare point of view. To make the argument simpler, we neglect the revenue collected through tariffs, which could also be a part of the welfare function. Its introduction will reinforce the above argument if spillovers are high

($\beta > 1/2$), but it weakens (but does not reverse it [see Lemma 3] if $\beta < 1/2$).[7]

Once more, too little R&D expenditure arises not only because of spillovers but also because the producer did not take into account the beneficial impact of R&D on the consumer's surplus. At the same time, note that tariff is an instrument preferred (from the Northern government point of view) to an R&D subsidy, because the foreign rival will benefit from the subsidy as well (via increased R&D expenditures).

Now we are ready to prove that an increase in tariff improves the R&D expenditures (and thus, welfare) if duopoly is a market form in equilibrium. (Duopoly is a sufficient but not necessary condition for this result to hold.)

Lemma 3:

$dx_t^*/dt > 0$, if (10) holds

Proof:

The derivative of (4) is

$$dx_t^*/dt = \frac{2(-2+\beta)^2 g(A - \alpha + t)}{[-9 + (-2+\beta)^2 g]^2} > 0$$

provided that $(A - \alpha + t) > 0$. Without loss of generality, we assume that it is always so.

Q.E.D.

Thus, tariff is not only a strategic tool to confine (or to reduce) the share of the Southern firm, but it also helps to increase the R&D level towards the socially optimal R&D expenditures. The increase in tariff has the same effect as the increase in unit costs of the competitor. By increasing tariff, the Northern

[7] In the case of tariff, the revenue collected through tariff is R(x), whereas $R(x) = tq_s(x)$ and $tq_s(x)$ is given below as

$$tq_s(x) = \frac{t(-\alpha + A - 2t - [gx]^{1/2} + 2\beta[gx]^{1/2})}{3} \quad \text{and} \quad dR(x)/dx = \frac{(-1+2\beta)gt}{6\,[gx]^{1/2}} > 0, \text{ for } \beta > 1/2,$$

and $dR(x)/dx < 0$, if $\beta < 1/2$.

government undermines the competitive strength of the Southern firm and, in turn, encourages the domestic firm to invest more in R&D.

3.2. The Effect of Tariff 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 4:

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

provided that predation is the optimal strategy for given t, i.e., that the constrained monopoly is the equilibrium market form.

Proof:

If for given t, the optimal strategy for the Northern firm is to predate, then $\pi_p^*(t) \geq \pi^*(t)$ has to hold. This in turn implies that the actual t will be from the range $t \in [t_p, t_m]$ and the sign of dx^*_p/dt should be evaluated only for t's from this interval. Let us start with the evaluation at the lower point of the interval. The derivative

$$dx^*_p/dt = \frac{4(\alpha - A + 2t)}{(-1 + 2\beta)^2 g}$$

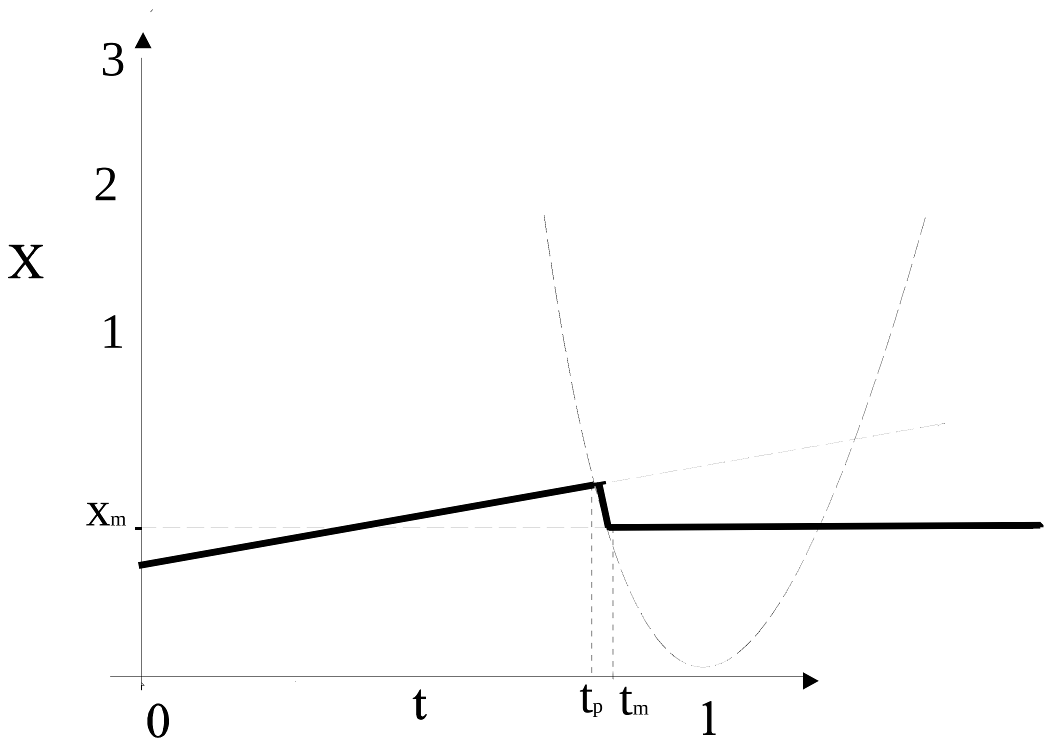
evaluated at t_p gives

$$dx^*_p/dt\big|_{t=tp} = \frac{4(\alpha - A)(-2 + \beta)}{(-1 + 2\beta)(6 - 2g + \beta g)} < 0$$

because the sign of the above expression is Sign$[-1+2\beta] = -1$ if $\beta < 1/2$. The x^*_p is monotonically declining in the interval $t \in [t_p, t_m]$ if $\beta < 1/2$. Thus, when the upper boundary of the interval is reached (that is, the tariff t_m) it enables the domestic firm to exhibit an unconstrained monopoly. The level of tariff has no more 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 2).

Q.E.D.

Figure 2
The Impact of Tariff on R&D When Spillovers Are Small ($\beta < 1/2$)



The question is, however, what caused such a reverse reaction of the Northern 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 Northern firm predates, it spends more resources on innovative activity than it would if it followed myopic profit maximization. In other words, it commits to higher R&D to induce the exit (or prevent the entry) of the rival but the increased tariff yields the same effect instead. In fact, the government, by increasing the tariff (which is, initially in the predation interval $t \in [t_p, t_m]$), predates 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 the R&D spending, decrease the output and, thus, it will have a counterproductive implication for the social welfare.

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

Lemma 5:

$dx^*_p/dt > 0$

if $\beta > 1/2$ if predation is an optimal strategy.

Proof: Analogous to Lemma 4.

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 3). 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 maximizing 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 and thus, as in duopoly, serves as an "ordinary" policy tool for restoring the incentive for R&D investment.

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. 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 $\beta = 1/2$).

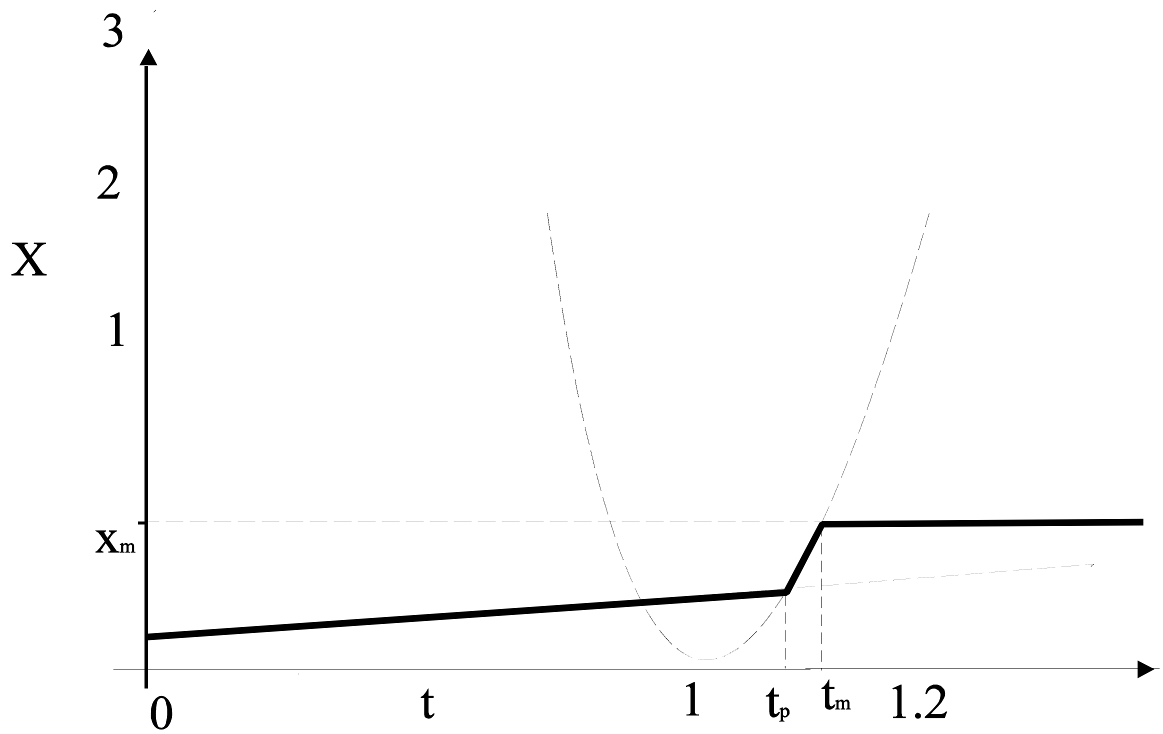
Lemma 6:

$d\pi_p/dt > 0$

Proof: See Appendix 2.

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 took place.

Figure 3
The Impact of Tariff on R&D When Spillovers Are Big (β >1/2)



4. The Optimal Tariff and the Intensity of Spillovers—Social Welfare Considerations

4.1. The First Game

So far, the tariff was 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 maximizing welfare, leaving aside the issue of the political economy of the tariff.[8] The optimal tariff t_{opt} will result then from the welfare maximization described by the social welfare function (W), $W_n^* = \pi_n^* + S_n^* + R_n^*$, where $R_n^* = tq_s^*$ is revenue raised by tariff and where.

Similarly, as in the Northern firm's profit, the social welfare function is defined depending upon the level of 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.

$$W^*_n(t) = \begin{cases} W_d(t), & \text{if } 0 < t \leq t_p \\ W_p(t), & \text{if } t_p \leq t \leq t_m \\ W_m, & \text{if } t \geq t_m \end{cases}$$

The welfare maximization problem is a constrained one: the optimal level of Southern production should be nonnegative. Thus, the problem is written as $\max[W_{in}^*(t)]$ s.t. $q_s^* \geq 0$.

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 optimization problem. The optimal level of tariff in this case is simply obtained by solving the equation $dW_d(t)/dt = 0$ for t.[9] Denote this solution as t*. The actual expression for t* from our first order condition yields:

$$t^* = \frac{(\alpha - A)(27 - 20g + 32\beta g - 11\beta^2 g + 4g^2 - 12\beta g^2 + 13\beta^2 g^2 - 6\beta^3 g^2 + \beta^4 g^2)}{(-81 + 64g - 52\beta g + 10\beta g - 12g + 20\beta g - 11\beta^2 g^2 + 2\beta^3 g^2)} \quad (17)$$

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

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[8] That is, we assume that the government puts equal weights on the consumer surplus, profit, and the revenue. However, in real life this is generally not the case because of lobbying activity and power of interest groups. Thus, we could think of the government maximizing 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.

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

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

4.1.1. The Optimal Tariff When Spillovers Are Small ($\beta < 1/2$)

Imagine that our benevolent government, occupied with finding the welfare-maximizing 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. Assume, for the moment, it has. In this case, the constraint $q^*_s \geq 0$ is *not binding*, and that implies that duopoly is a good candidate for the equilibrium market form,[10] and the optimal tariff (t_{opt}) could be such that $t_{opt} = t^*$, $t^* \in (0,t_p]$. 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 Appendix 3 for proof).

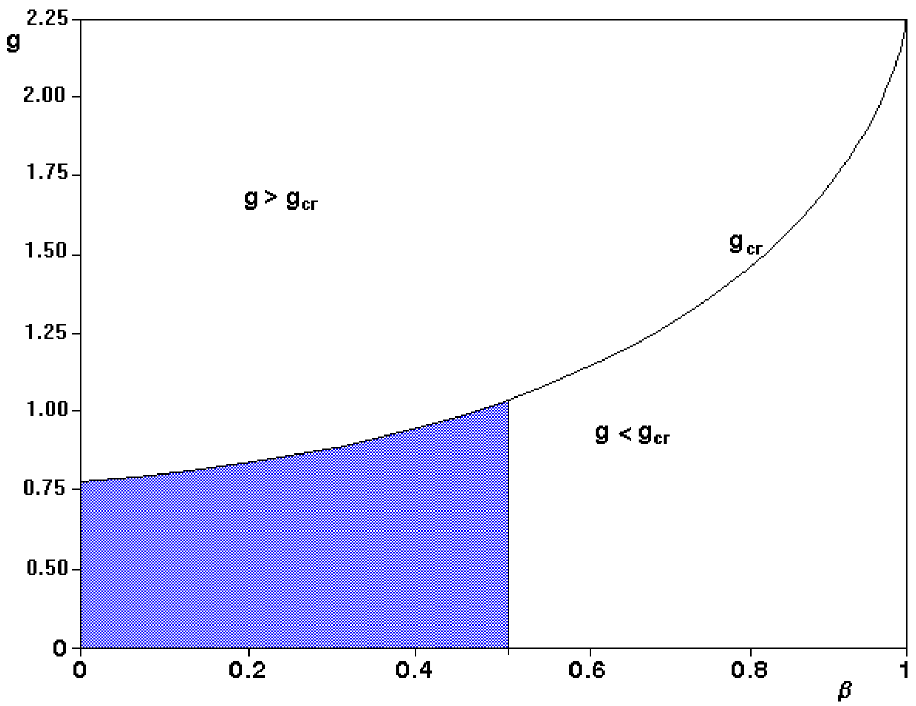
At first glance, the obvious reason for this intuitive conclusion may seem to be small spillovers; the quantities offered on the market are higher than those offered by an (unconstrained) monopoly and, correspondingly, the market price is lower than the monopoly price. However, this is only necessary but not sufficient condition. In fact, when spillovers are "high," it is quite possible that the quantities produced in duopoly exceed those in a monopoly, but the overall welfare is still higher in monopoly (see Appendix 6 for an example). All that matters is that for $\beta < 1/2$ the sum of consumer surplus and monopoly profit is always lower than the corresponding sum of consumer surplus, Northern firm profit and tariff revenue. Thus, monopoly could not 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. As we showed in Section 3.2, (Lemma 4), a further increase of the tariff will decrease

[10] The reason why the interior solution for t could appear is the revenue collected through tariff. Otherwise, the Northern government would surely like to have only its firm in the market because of its "natural monopoly position" (see Žigić, 1995, pp. 47–49). Technically speaking, the tariff revenue function, R(t), gives rise to the concavity of the function W(t).

the consumer surplus due to the decrease in R&D expenditure in this situation. (Recall that $dx_p/dt < 0$ is an 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 Appendix 4 for proof). Technically speaking, the right-hand derivative at point t_p, $dW_d{}^{*+}(t_p)/dt > 0$ but $dW_p{}^{*+}(t_p)/dt < 0$. On the other hand, a decrease of the tariff from the level t_p will decrease the welfare and the left-hand derivative ($dW_d{}^{*-}(t_p)/dt$) is clearly positive. The optimal tariff t_{opt} will be t_p in this case.

Figure 4
The Region of Parameters ($g < g_{cr}$ and $\beta < 1/2$)
in Which Duopoly is the Optimal Market Form



Thus, when spillovers are small, the only two candidates for the optimal tariff are t^* and t_p. Which of them will appear as the optimal one hinges on whether or not the constraint is binding, and that, in turn, depends on the level of R&D efficiency—g [and the actual level of β in the interval $\beta \in (0,1/2)$]. If g is not very "high," a small level of spillovers could be enough to warrant the duopolistic competition even if on top of the Southern firm unit costs is the optimal tariff t^* (see Figure 4). (The difference in the unit costs may not be so big as to prevent the Southern firm from competing.) 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 Appendix 3 for its derivation).

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 the spillovers are small* ($\beta < 1/2$) *and the R&D efficiency is such that* $g < g_{cr}$, *then the optimal tariff is* t^* *and the equilibrium market form is duopoly. If, for 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.*

Proof: See Appendix 3.

4.1.2. The Optimal Tariff When Spillovers Are Large ($\beta > 1/2$)

Let us start again with the situation in which an interior solution exists (that is, the constraint is not binding and duopoly is again a candidate for the equilibrium market form and t* is a candidate for the welfare-maximizing tariff). However, this time, the local maximum, if it exists, should not necessarily be the global one. As we discussed in Subsection 3.2.2, in the situation characterized by high spillovers, the optimal level of R&D is lower than in monopoly, implying that the actual level of R&D is much below the socially desirable one and the total loss of the welfare could be even bigger than in monopoly (see Appendix 5 for the proof). 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 Lemma 5). The increase in tariff beyond t_p increases simultaneously both the Northern firm's (predatory) profit and consumer's surplus and, thus, social welfare, until the point t_m is reached at which further increases in tariff has no influence on social welfare[11]—($dW^{+*}(t_m)/dt = 0$). Thus, in these circumstances, the monopoly tariff (t_m) turns out to be 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

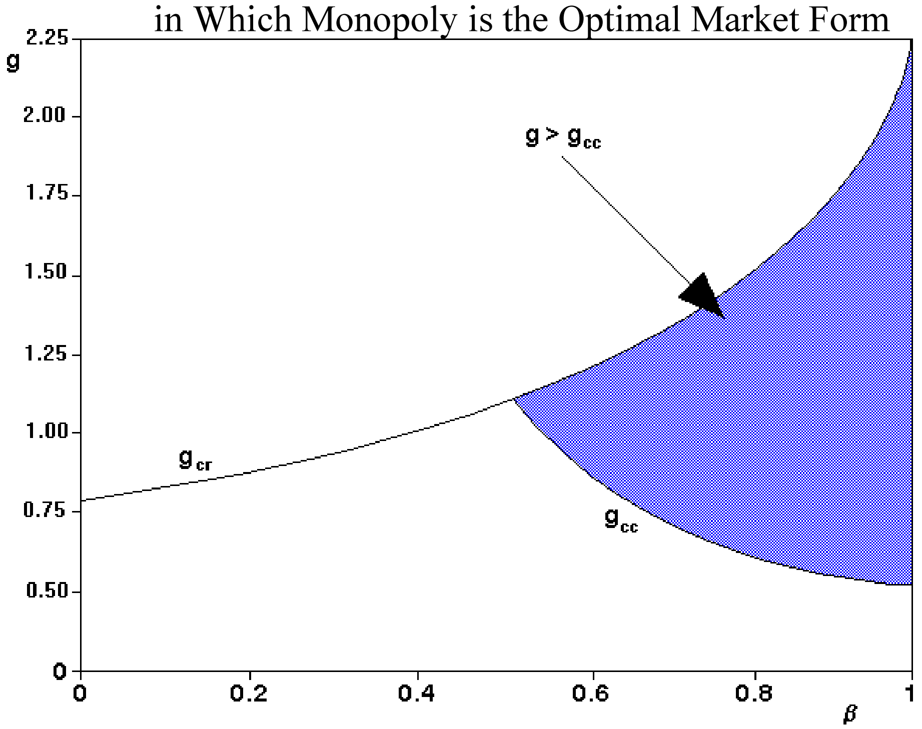
[11] That is, the level of tariff (t_m) represents such a high entry barrier (or cause for exit of the Southern firm) that even the potential competition by the Southern firm is eliminated and tariff has no influence on any economic decision of the monopolist.

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 a positive revenue from tariff not present in a monopoly.

Thus, this time, the only two candidates for a socially desirable tariff are t_d and t_m. Similarly, as in the case of small spillovers, the actual choice between these two tariffs' levels depends on the degree of R&D efficiency. If R&D efficiency is "small," that is, $g < g_{cc}(\beta)$ (see Appendix 5 for the more precise meaning of critical value "g_{cc}") then the disincentive of high spillovers is not so 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 Figure 5). If, conversely, the actual g is "big," then monopoly will be the optimal market form.

Figure 5
The Region of Parameters ($g > g_{cc}$ and $\beta > 1/2$)
in Which Monopoly is the Optimal Market Form



Proposition 2 presents the above discussion more compactly:

Proposition 2

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

Proof: See Appendix 4.

4.1.3. The Effect of Spillovers on the Optimal Tariff

Before we switch to the second game, we will focus for a while on the comparative static result of spillovers influence on all three potential tariffs—t_m, t_p, and t^* (which can appear in equilibrium).

Let us start with the simplest case—the monopoly tariff. Intuition says that t_m has to increase with any increase in spillovers to preserve the gap necessary to secure the undisturbed setting of the monopoly output by the Northern firm.

Lemma 7:

$dt_m/d\beta > 0$

Proof:

$$dt_m/d\beta = \frac{(A - \alpha)g}{(4 - g)} > 0$$

Q.E.D.

Similarly, the "predatory tariff" t_p, should also increase with an increase in spillovers to prevent the positive profit of the Southern firm.

Lemma 8:

$dt_p/d\beta > 0$

Proof:

$$dt_p/d\beta = \frac{(A - \alpha)g(12\beta + 4g - 4\beta^2 g + \beta g - 15)}{(6 - 2g + \beta g)^2}$$

Sign[$dt_p/d\beta$] = Sign[$(-15 + 12\beta + 4g - 4\beta^2 g + \beta g)$] = 1, for all values for which a duopoly is a viable market form (that is, $g < g_{cr}$).

Q.E.D.

The impact of spillovers on t* is not a priori clear: on the one hand, the increase in β leads to an increase in disincentives for innovative expenditures, and restoring this incentive would require an increase in tariff; on the other hand, the increase in tariff will decrease the revenue collected through tariff and, more importantly, it will decrease the consumer surplus due to the fact that dQ*/dt evaluated at t* is always negative. Thus, the outcome hinges on the actual parameter values and one can expect all three signs to be feasible in equilibrium.

Lemma 9:

$dt^*/d\beta > 0$
if $g < g_{dt}$

Proof:

Straightforward calculation shows that $dt^*/d\beta > 0$ implies an inequality.[12] Turning this inequality into an equation and solving explicitly for g gives us the value g_{dt}. The explicit expression for g_{dt} is quite long and therefore it will not be reproduced in this text.

Q.E.D.

4.2. Spillovers as a Strategic Weapon: the Second Game

The nature of technological spillovers is mixed. In some sense, they could be regarded as a parameter, as is done in the industrial organization 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 the intellectual property rights but also, as happens in some developing countries (see Braga, 1990, p. 78), by the direct procurement of the important 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

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[12] The inequality is written as

$$-594 + 621\beta + 720g - 1260\beta g + 774\beta^2 g - 162\beta^3 g - 272g^2 + 704\beta g^2 - 728\beta^2 g^2 + 376\beta^3 g^2 - 97\beta^4 g^2 + 10\beta^5 g^2 + 32g^3 - 112\beta g^3 + 160\beta^2 g^2 - 120\beta^3 g^3 + 50\beta^4 g^3 - 11\beta^5 g^3 + \beta^6 g^3 < 0.$$

The right hand side of that inequality is a part of the derivative of expression (17) with respect to β. The sign of that derivative depends only on the sign of this expression.

absorption capacity for adopting innovations and, thus, in ultima linea, the level of spillovers. Considering spillovers as a parameter could be more convenient on the micro level, on 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 (see Žigić, 1995). Though spillovers on the macro level possess both characteristics of the parameter and the variable, for the sake of simplicity we will assume that in our context the β is a variable under full control of the Southern government and we will think of β as the measure of the degree of the IPR protection.

In the second game, the Southern government selects the IPR regime through the interactions with the Northern government that in turn selects the level of 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 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 the 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 the game we discussed in the previous sections, so we turn immediately to the first stage of the game. As 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 payoffs' functions are given below:

$$W_{ni}^{*}(t,\beta) = \pi_{ni}^{*} + S_{ni}^{*} + tq_{s}^{*} \tag{18.a}$$

$$W_{s}^{*}(t,\beta) = \pi_{s}^{*} \tag{18.b}$$

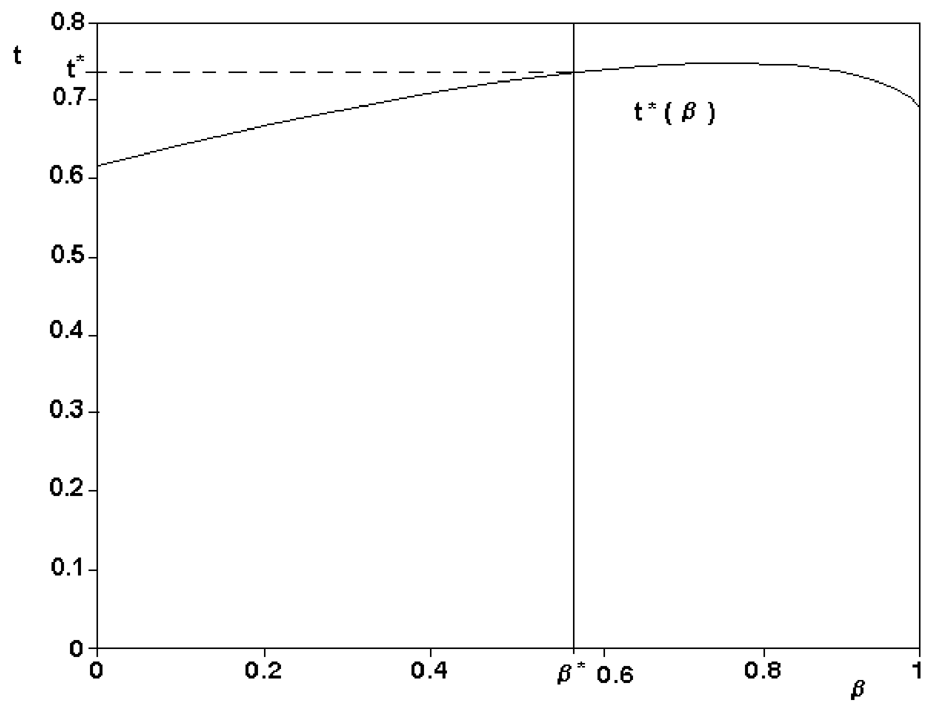
By means of expressions (5)–(9), the welfare functions can be expressed in terms of parameters and the strategic variables β and t respectively.

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 optimization 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") $t^{*}(\beta)$ is obtained in the pretty standard manner, that is, by solving the $dW^*_{nd}/dt = 0$ that gives us $t^*(\beta) = t^*(\beta)$. If the duopoly is not viable (the constraint, $q^*_s \geq 0$, is binding), then $t^*(\beta) = t_p(\beta)$. (The functions $t^*(\beta)$ and $t_p(\beta)$ are, in fact, the expressions (17) and (14), respectively, but are now expressed explicitly as a function of β.) Similarly, if for a given β, such that $\beta > 1/2$ and duopoly is viable ($g < g_{cc}$), the reaction function will again be $t^*(\beta) = t^*(\beta)$, whereas, if $g \geq g_{cc}$, the reaction function will be $t^*(\beta) = t_m(\beta)$.

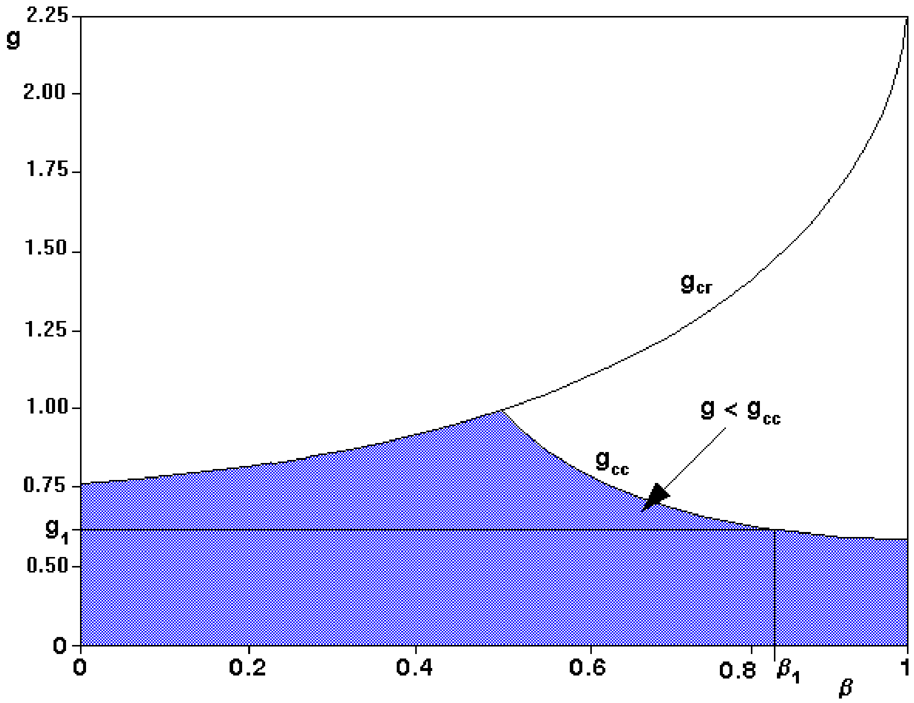
The optimization problem of the Southern government is written as $Max[W_s^*(\beta,t)] \equiv Max[\pi_s^*(\beta,t)]$ with respect to β, subject that $\beta \leq 1$ for the given t. However, this optimization makes sense only if duopoly is a viable market form, i.e., if the actual reaction function of the Northern government turns out to be $t^*(\beta)$. In this sense, the Southern government should always, if possible, pick up the highest possible value of β such that $g < g_{cc}$. ($dW_s^*/d\beta > 0$ for all β in the permissible interval $\beta \in [0,1]$.) That is, by picking 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 surely not desirable for the South (see the reaction functions in Figure 6).

Figure 6
The Reactions Functions of the Northern and Southern Governments



In other words, the Southern government has a dominant strategy to play the highest level of β, consistent with the duopolistic competition, no matter what the erected tariff by the North is. (See Figure 7 for the regions of g and β consistent with the duopoly competition.) If, say, the actual R&D efficiency is $g = g_1$, then the optimal response is $\beta = \beta_1$. If the actual g exceeds the value g > 1.171, then duopoly is not sustainable, no matter how high the level of β is set. Thus, the highest permissible value of g, consistent with the duopoly competition, is g = 1.171, with the corresponding optimal value $\beta^* = 1/2$. 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 7).

Figure 7
The Region of Parameters ($g < g_{cr}$ and $g < g_{cc}$)
Consistent with the Duopolistic 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 summarizes 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 always (if possible) in competition with the Northern firm. Because the Southern government has a dominant strategy to select the highest achievable level of spillovers for any level of tariff, the Cournot-Nash equilibrium coincides with the Stackelberg equilibrium.

4.3. Optimal Versus Punitive Tariff

GATT (until recently) and the World Trade Organization (today) have acted as mechanisms to enact the "cooperative" solution, which would be beneficial for all parties in the game. (The cooperative 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 last China vs. U.S. IPR trade dispute when the violation of intellectual property rights by China was a definite reason for the U.S. government to threaten China with punitive, 100% tariffs on the majority of its exports to the U.S. The U.S. trade law (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 U.S. (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 E.C. suspended its GSP benefits for Korean products in response to Korean prohibitive practices in the field of IPR; a year later, the U.S. 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, 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 last game should be modified if we want to account for these realistic features. Thus, in the third game, the Northern government does not impose any tariff ex ante; that is, we assume that "strategic incentives" to impose tariff remain only incentives due to, say, multilateral tariff negotiation. In this situation, the Southern government is explicitly (and not implicitly) in the position to exercise the Stackelberg leader position, concerning its strategic choice—the degree of IPR violation.

The rules of the game are very simple now: the Northern government commits to the zero tariff level unless there are IPR violations. In the case that the Northern government observes a violation of IPR, its executives immediately look for the file in which there is a solution for the optimal tariff in the second game and implement this tariff as a punitive tariff. Thus, the punitive tariff is, in fact, an 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 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 $W_n^*(\beta^*,t^*) < W_n^*(0,0)$ for all possible sets of values of the efficiency parameter consistent with the existence of duopoly.

Conclusion

The government incentive to raise tariff largely arises from the possibility that changing the strategic relationship between foreign and domestic firms shifts profits towards domestic nationals.[13] Moreover, the actual height of the tariff determines the market structure that can arise in the economy. Knowing the level of spillovers (considered to be a parameter), on the other hand, is essential to find out the optimal, welfare-maximizing tariffs and the most desirable market structure in turn. Thus, a low level of spillovers would favor duopoly as a market form if it is achievable (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).

[13] The incentive of the government to raise tariff is not offset by the possibility that the other party could impose tariff as well (in case that we use the segmented market argument).

When the Southern government picks the level of spillovers as its policy variable (considered as the strength of IPR protection this time), 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 nonexistent. The optimal level of IPR infringement is the biggest 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, the free trade without IPR violation 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 the IPR (as in the U.S. versus China dispute), the very threat of a punitive tariff (or occasionally even its temporary implementation) restores the equilibrium characterized by the no tariff situation and rather strengthened enforcement of IPR protection.

As is well known, the optimal design of strategic trade policy is very sensitive to the type of market competition. (See Spencer, 1986, for an instructive discussion of that problem.) In this respect, 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. Thus, firms are able to price discriminate between markets. A moment of reflection tells us that 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, $p^* = \alpha - \beta(gx) + t - \epsilon$, where ϵ is some 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 maximizing is again the matter of the value of parameters β and g.

Another related issue of the design of the strategic tools is which instrument serves the purpose best. This issue was 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, subsidizing domestic R&D means subsidizing its foreign competitor as well. (Of course, the subsidy could be so big that it forces the foreign firm to exit the market.)

Furthermore, the comparison of the welfare gains from subsidy versus tariffs is complicated due to the fact that subsides require taxes (not present in the case of tariff). The cost of taxation should be subtracted from the welfare gains created by subsidizing R&D. This makes the comparison between these tools rather complex. The possibility of the optimal mix of tariff and R&D subsidy may deserve analytical concern.

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 some 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.

Furthermore, 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, say, the second-stage–profit function as payoff functions 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 is rather low in comparison with the approach used in the paper.

APPENDICES

Appendix 1: The Effect of Tariff on Consumer Surplus

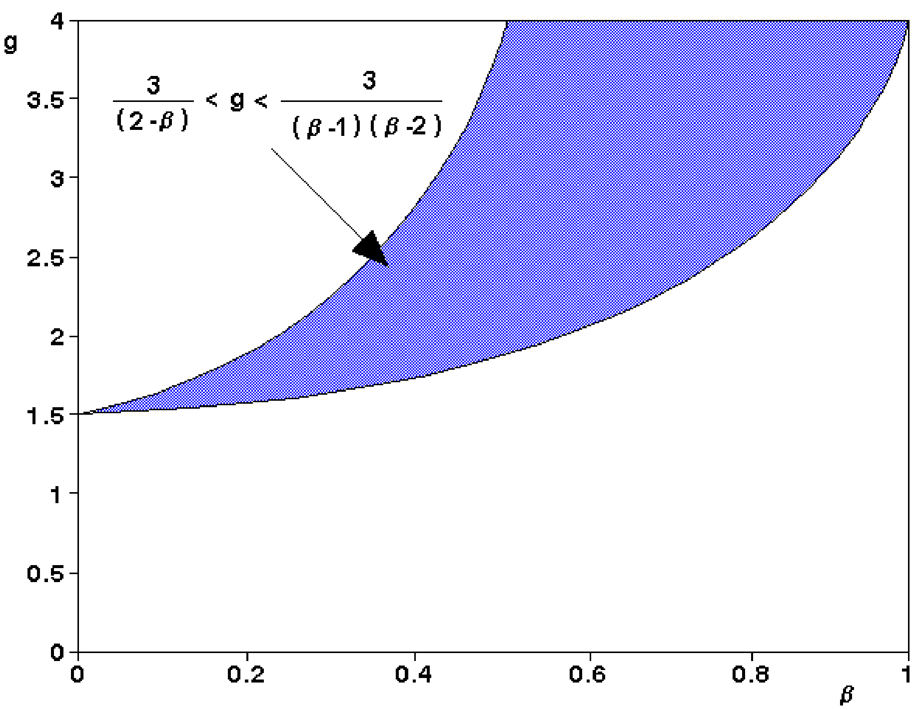
Using the expressions (5) and (6) from Section 1.2, we get $Q^* = q_s^* + q_n^*$. Taking the derivative of Q* with respect to t gives:

$$dQ^*/dt = \frac{3 - 2g + \beta g}{[(2 - \beta)^2 g - 9]}$$

Sign[dQ*/dt] = -Sign[3 − 2g + βg] since the denominator is negative for all permissible values of parameters. Thus, dQ*/dt is positive if (3 − 2g + βg) < 0. Solving the above inequality yields g > 3/(2 − β) for dQ*/dt > 0.

The intersection of the region of parameters defined by g > 3/(2 − β) with the region of parameters for which duopoly is a viable market form in the absence of tariff (see Figure A1.1) is not an empty set. (Note, however, that the above discussion takes tariff as a parameter so that discussion of the optimal tariff is not present here.)

Figure A1.1
The Region of Parameters in Which the Rise in Tariff Increases Domestic Consumer Surplus



Appendix 2: The Effect of Tariff on Predatory Profit

The predatory profit expressed as a function of tariff is written as:

$$\pi_p(t) = \frac{-2\alpha A(-1+2\beta)^2 g + A^2(-1+2\beta)^2 g - 4(A-\alpha-2t)^2}{4(-1+2\beta)^2 g} +$$

$$+ \frac{g[A-\alpha+\alpha(-1+2\beta)-2t]^2 + 2A(-1+2\beta)g(\alpha-A+2t)}{4(-1+2\beta)^2 g}$$

whereas its derivative is

$$d\pi_p(t)/dt = \frac{2(-2\alpha+2A+\alpha g-Ag-\alpha\beta g+A\beta g-4t+gt)}{(-1+2\beta)^2 g}.$$

Solving the inequality $d\pi_p(t)/dt \geq 0$ for t, we find that this implies

$$t \leq \frac{(A-\alpha)(2-g+\beta g)}{4-g}.$$

Note that the right hand side of the above inequality is, in fact, t_m, the level of tariff at and after the unconstrained monopoly arises. The tariff, t_m, is at the same time the upper limit for which the predatory profit is defined (recall that the predatory profit is defined only for $t\in[t_p,t_m]$).

In addition to the above analysis, we could evaluate the derivative, $d\pi_p(t)/dt$, at the lower and upper bound of the interval. This evaluation yields :

$$d\pi_p/dt|_{t=tp} = \frac{2(A-\alpha)}{(6-2g+\beta g)} > 0\ , \text{ for all values of } \beta < 1.$$

$d\pi_p/dt|_{t=tm} = 0$ for all values of $\beta < 1$.

Appendix 3: The Region of Parameters g and β for Which Duopoly is the Welfare-Maximizing Market Structure—The Case of Small Spillovers

When spillovers are low, $\beta < 1/2$, then the necessary and sufficient condition for duopoly to be the social welfare-maximizing market form is that the constraint $q^*_s \geq 0$ is not binding. In other words, the outcome of the maximization problem is, in this situation, the same as if the problem were the unconstrained one. This welfare is obviously higher than the welfare if the constraint were binding by the simple fact that unconstrained maximum is never smaller than the constrained one. (If the constraint is binding [$q^*_s = 0$], strategic predation and t_p are the optimal setup.) Thus, as soon as the Southern firm has positive output in equilibrium, the tariff $t^* = \text{Arg}[\text{Max}W^*_{nd}]$ represents the socially optimal tariff. To find the region of β and g consistent with the positive Southern output, it requires solving the inequality $q^*_s|_{t=t^*} \geq 0$ for g. Alternatively, by turning this inequality into an equation and solving for g, it gives us the value of $g_{cr}(\beta)$—the critical value of g beyond which duopoly ceases to exist:

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

If $g < g_{cr}$, then duopoly is viable at the tariff t*, and the social welfare is maximized.

Another related issue is to show that the "duopoly" welfare is higher than the (unconstrained) "monopoly" welfare in situations where $\beta < 1/2$. To show this let us first evaluate the "duopoly" welfare at the optimal tariff level ($W^*_{nd}|_{t=t^*}$ is denoted as $W^{**}_{nd}(\beta)$):

$$W^{**}_{nd}(\beta) = \frac{(A-\alpha)^2(63-32g+44\beta g-14\beta^2 g+4g^2-12\beta g^2+13\beta^2 g^2-6\beta^3 g^2+\beta^4 g^2)}{(162-128g+104\beta g-20\beta^2 g+24g^2-40\beta g^2+22\beta^2 g^2-4\beta^3 g^2)}.$$

Second, note that $W^{**}_{nd}(\beta)$ is (locally) monotonically declining "in the left-hand neighborhood" of $\beta = 1/2$, i.e, it approaches its minimal value in the interval $\beta\epsilon[0,\beta)$ as β approaches one-half. (In fact, it is possible to show that the derivative $dW^{**}_{nd}/d\beta < 0$ on the whole interval $\beta\epsilon[0,1/2]$ unless the R&D efficiency, g, is rather small, in which case it becomes negative soon after a certain small value of β is reached. That value is always much smaller than 1/2.)

To prove that the $W^*_m \leq W^{**}_{nd}(\beta)$ for $\beta < 1/2$, the easiest way seems to be to find a limit of $W^{**}_{nd}(\beta)$ when it goes to 1/2 and compare this value with the value of "monopoly" welfare W^{*}_{m} which is given in the expression below:

$$W^{*}_{m} = \frac{(A - \alpha)^2(6 - g)}{(4 - g)^2}.$$

Taking the limit gives us:

$$\lim_{\beta \to 1/2}[W^{**}_{nd}(\beta)] = \frac{(A - \alpha)^2(112 - 24g + g)^2}{16\,(18 - 9g + g)^2}.$$

It is straightforward to check that $\lim[W^{**}_{nd}(1/2)] > W^{*}_{m}$ for all g such that duopoly is sustainable.

Appendix 4: The Welfare Impact of Tariff in Predatory Regime

The social welfare function in predatory regime, $W_p(t)$, defined at the interval $t \in [t_p, t_m]$ is written as:

$$W_p = \frac{-2\alpha A(-1 + 2\beta)^2 g + A^2(-1 + 2\beta)^2 g + g(-2\alpha + A + 2\beta\alpha - 2t)^2}{4(-1 + 2\beta)^2 g} +$$

$$+ \frac{2g(\alpha - A - \alpha\beta + A\beta + t)^2 + 2A(-1 + 2\beta)g(\alpha - A + 2t)4(\alpha - A + 2t)^2}{4(-1 + 2\beta)^2 g}.$$

The derivative of W_p with respect to tariff yields:

$$dW_p/dt = \frac{4A(-1 + 2\beta)g - 4g(-2\alpha + A + 2\alpha\beta - 2t) + 4g(\alpha - A - \alpha\beta + A\beta + t) - 16(\alpha - A + 2t)}{4\,(-1 + 2\beta)^2 g}.$$

Evaluating this derivative at the boundaries of the domain, (i.e., t_p and t_m) yields:

$$dW_p/dt\big|_{t=tp} = \frac{(A - \alpha)(1 + 4\beta)}{(-1 + 2\beta)(6 - 2g + \beta g)}$$

$\text{Sign}[dW_p/dt|_{t=tp}] = \text{Sign}[(-1 + 2\beta)]$. Obviously, the sign of the derivative depends on whether β is higher or lower than one half. Thus, $\text{Sign}[dW_p/dt|_{t=tp}] = -1$, if $\beta < 1/2$. Similarly, evaluating dW_p/dt at t_m gives:

$$dW_p/dt|_{t=tm} = \frac{2(a - A)}{(4 - 8\beta - g + 2\beta g)}$$

$\text{Sign}[dW_p/dt|_{t=tm}] = -\text{Sign}[4 - 8\beta - g + 2\beta g]$ and again the derivative depends whether β is higher or lower than one half. Thus, $\text{Sign}[dW_p/dt|_{t=tm}] = -1$, if $\beta < 1/2$.

Appendix 5: The Region of Parameters g and β for Which Duopoly is the Welfare-Maximizing Market Structure—The Case of Large Spillovers

In situations characterized by $\beta > 1/2$, the $g < g_{cr}$ is only necessary, but by no means, the sufficient conditions for duopoly to be the social welfare-maximizing market structure.

The social welfare when duopoly is the market structure is defined as

$$W^*_{nd}|t=t^* \equiv W^{**}_{nd}(\beta).$$

The social welfare in the situation when the Northern firm is an unconstrained monopolist is given by W^*_m where

$$W^*_m = \frac{(A - \alpha)^2(6 - g)}{(4 - g)^2}.$$

The values of β and g for which the $W^*_m \geq W^{**}_{nd}(\beta)$ lead us, after some simple algebraic manipulation of the above inequality, to the following inequality:

$$-36 + 86g - 80\beta g + 104\beta^2 g - 111g^2 + 200\beta g^2 - 168\beta^2 g^2 + 72\beta^3 g^2 - 16\beta^4 g^2 + 40g^3 -$$
$$- 100\beta g^3 + 96\beta^2 g^3 - 44\beta^3 g^3 + 8\beta^4 g^3 - 4g^4 + 12\beta g^4 - 13\beta^2 g^4 + 6\beta^3 g^4 - \beta^4 g^4 \geq 0$$

Turning this inequality into an equation and solving explicitly for g gives us the value $g_{cc}(\beta)$. The explicit expression for $g_{cc}(\beta)$ is extremely messy and therefore will not be reproduced in the text. Thus, if $g > g_{cc}(\beta)$ the monopoly welfare exceeds the welfare from duopoly.

Appendix 6: Comparison Between Monopoly and Duopoly Welfare When Spillovers Are Large—An Example

By means of expressions (5) and (6) from Section 1.2, we get the total output produced and consumed in the equilibrium:

$$Q^* = q_n^* + q_s^* = \frac{(A - \alpha)(-45 + 28g - 28\beta g + 7\beta g^2 - 4g^2 + 8\beta g^2 - 5\beta^2 g^2 + \beta^3 g^2)}{(-81 + 64g - 52\beta g + 10\beta^2 g - 12g^2 + 20\beta g^2 - 11\beta^2 g^2 + 2\beta^3 g^2)}.$$

The monopoly output is given by the expression below:

$$Q_m = \frac{2(A - \alpha)}{(4 - g)}.$$

As a next step, we evaluate Q^* and Q_m at the following values of parameters: $A = 10$, $a = 8$, $g = 0.8$, $\beta = 0.7$.

The calculated values are: $Q_m = 1.25$ and $Q^* = 1.26424$

Finally, the calculation of the corresponding welfare values W^*_m and W^{**}_{nd}, where

$$W^*_m = \frac{(A - \alpha)^2(6 - g)}{(4 - g)^2} \quad \text{and}$$

$$W^{**}_{nd} = \frac{(A - \alpha)^2(63 - 32g + 44\beta g - 14\beta^2 g + 4g^2 - 12\beta g^2 + 13\beta^2 g^2 - 6\beta^3 g^2 + \beta^4 g^2)}{(162 - 128g + 104\beta g - 20\beta^2 g + 24g^2 - 40\beta g^2 + 22\beta^2 g^2 - 4\beta^3 g^2)}.$$

gives $W^*_m = 2.03125$ and $W^{**}_{nd} = 1.99714$.

Thus, despite the fact that the quantities produced and consumed are higher in the case of duopoly, the corresponding monopoly welfare in this case still exceeds the corresponding welfare in duopoly. This situation is not possible if spillovers are small, that is, $\beta < 1/2$.

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