Strategic Trade Policy, the "Committed" versus "Non-Committed" Government, and R&D Spillovers

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Abstract: We compare the social welfare generated by a domestic government in the two types of policy setups: a "commitment" regime in which the government sets its policy instrument before the strategic choice is made by the domestic firm and a "non-commitment" regime where the policy variable is set after the strategic choice is made by the firm. The government conducts strategic trade policy in the form of optimal tariffs under which domestic and foreign firms compete in quantities in an imperfectly competitive domestic market where cost reducing R&D spillovers take place from the domestic to the foreign firm. We show that the "non-committed" government achieves generally a higher level of welfare and levies a lower optimal tariff than the "committed" government. Moreover, when the domestic government is allowed to use an R&D subsidy, that may or may not be accompanied by the optimal tariff, the resulting optimal subsidies are always positive.

Abstrakt: Článek se zabývá srovnáním společenského blaha domácí země za dvou různých obchodních politik domácí vlády: politiky „se závazkem“, kdy vláda volí nástroj regulace obchodu dříve, než firma svou strategickou veličinu, a politiky „bez závazku“, kdy je tomu naopak. Vláda reguluje obchod pomocí optimálních tarifů; firmy soutěží na neúplně konkurenčním domácím trhu v kvantitě zboží, přičemž dochází k transferu technologie redukující náklady na výzkum a vývoj od domácí k zahraniční firmě. Článek ukazuje, že politika „bez závazku“ vede obecně k vyššímu společenskému blahu a nižšímu optimálnímu tarifu, než politika „se závazkem“. Pokud má domácí vláda možnost dotovat výzkum a vývoj domácí firmy s tím, že taková dotace může, ale nemusí být doprovázena optimálním tarifem, optimální dotace je vždy pozitivní.

JEL: F13; L11; L13; O31

Keywords: government commitment, optimal tariffs and subsides, technological spillovers, first–best versus second–best strategic policy.

1. Introduction

As Maggi and Grossman (1998) noted, arguments for "strategic trade policy" have not convinced the majority of economists that the profession's traditional support for free trade should be abandoned, despite the theoretical attractiveness of strategic trade interventionism and its tempting prescriptions. Until recently, this stance mostly reflected either the *a priori* position of economists who argued against trade activism, (see, for instance, Baghwati, 1989; Krugman, 1987) or was based on results obtained in "calibration" models, which indicated that gains were at best modest when strategic trade policies are applied as profit shifting or facilitating devices (see, for instance, Venables, 1994; and Krugman and Smith, 1994).

Nowadays, there seems to be a third serious drawback to strategic trade theory policies. Recently, it was pointed out "... that governments and firms are likely to differ in their ability to commit to future action" (Neary and Leahy, 2000). Thus, the government may lack credibility with the firms whose behavior it tries to influence or there may be a time lag between the announcement and the implementation of strategic trade policies. As a consequence, the government may be forced to select its policy only *after* the strategic choice has been made by domestic firms.[1] This gives a strategic motive to the domestic firm to influence (or manipulate) the government's policy response. Under these circumstances, it was claimed, conducting strategic trade policy can cause inefficiencies and consequently can lead to a lower level of

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

social welfare compared to the corresponding social welfare under free trade (see for instance, Karp and Perloff, 1995; Neary and O'Sullivan,1997; Maggi and Grossman; 1998, Leahy and Neary, 2000; Ionascu and Žigić, 2001).

Žigić (2000),on the other hand, argued that in the particular case where free trade leads to unilateral violations of intellectual property rights (IPR) via, say, R&D spillovers, efficiency and welfare losses may be large due to the well known appropriability problem[2] as well as the somewhat less known failure of domestic firm to fully exploit economies of scale (see Žigić, 2000). This caused strategic trade to be strictly superior to free trade. More specifically, Žigić, (2000) showed that when domestic and foreign firm compete in quantities on the domestic market and there are IPR violations by the foreign firm, a strategic tariff reduces or completely eliminates illegally appropriated research output and thus thwarts IPR violations. However, this result was obtained under the recently challenged assumption that the government can commit to its policy instrument before the domestic firms' choice of strategy.

The goal of this paper is to show that in a world characterized by unilateral IPR violations and a "non-committed" government, the benefits of strategic trade policy measured in terms of social welfare are generally greater than the social welfare obtained under the corresponding commitment regime. In other words, we claim that the inability of the domestic government to commit to a tariff policy before the domestic firm's strategic decision does not weaken the case for strategic trade policy. On the contrary, it generally reinforces it.

Another contribution of the recent strategic trade literature, primarily due to Neary and Leahy (1996, 1997, 1999, 2000), stresses the distinction between "first–best" and "second–best" policy. The first–best versus second– best issue arises in the context of dynamic games where domestic firms have more than one choice variables (e.g., level of R&D and level of output). In this setup the first–best policy in principle includes more than one policy instrument in order to induce socially desirable levels of all choice variables. However, in many

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[2]See, for instance Mansfield et al. (1981) and Levine et al. (1987) for a comprehensive empirical analysis of the causes, forms and aspects of attenuated appropriability due to inability to capture the induced benefits of innovating activity and intellectual property. Vishwasrao (1993),for example, refers to USITC documents (1988), reporting aggregate losses for US firms amounting to 23.8 billion dollars due to inadequate IPR protection.

circumstances the government may be constrained to use only one instrument (for example, R&D subsidy). Such a constrained policy is coined "second-best." One interesting result from this literature is that in the case of Cournot competition, the R&D subsidy that is generally positive in the second–best policy turns out to be negative (R&D tax) if the first– best policy is implemented. We show that this is not the case in our model and that the R&D subsidy is always positive in both the first–best policy and second–best policy.

2. The model

2.1. Assumptions

Much like in Žigić (2000), the core model is assumed to be a Cournot– type duopolistic competition between a "domestic" and a "foreign" firm. The domestic firm has unit costs of production $C = \alpha - f(x)$, where x stands for R&D expenditures and f(x) can be viewed as an "R&D production function" with classical properties, $f(x) \leq \alpha$, $f(0) = 0$, $f'(x) > 0$ and $f''(x) < 0$. In addition, we assume that the corresponding monopoly profit (net of the R&D expenditure) is a strictly concave function for $x \geq 0$.[3] The parameter α can be thought of as pre-innovative unit costs describing old technology initially accessible to both the domestic and the foreign firm. The foreign firm benefits through spillovers from R&D activity carried out by the domestic firm. If it exports its products, the foreign firm also pays a specific tariff *t* per unit of production. Its unit (pre–tariff) cost function is $c = \alpha - \beta f(x)$ where $\beta \in [0,1]$ denotes the level of spillovers (or, equivalently, the level of the strength of IPR protection).

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

Social welfare (W) is defined as the sum of consumer surplus (S), the firm's profit (Π)

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[3] The monopoly profit as a function of R&D is given by $[A-\alpha+f(x)]^2/ 4 - x$. The concavity implies that its derivative and hence the function (A-a+f[x]) f'[x] decreases in x for $x \geq 0$ (see Kamien et al.)

and the revenue from tariffs (R). It is important to note that in order to focus on strategic interactions, most authors use a "third market" assumption, whereby domestic and foreign firms compete on a common export market. As a consequence, only the domestic firm's profit (net of subsidy) enters the social welfare function (see for instance, Karp and Perloff, 1995; Neary and O'Sullivan,1997; Leahy and Neary, 2000). Thus, our welfare function is more comprehensive and so the task of the domestic government is not constrained to deal only with strategic interactions[4] but also to take into account and to influence (if possible) the impact of the domestic firm's strategic choices on consumer surplus and tariff revenue.

As is already clear, the key assumption is that the government enacts the tariff only after it observes the domestic firm's choice of R&D. This government policy we coin the "non-commitment" regime and the associated variables have the attached subscript "nc". On the other hand, the "commitment regime" implies that the government is capable of committing inter–temporally to a tariff prior to the domestic firm's choices of R&D. This policy regime was discussed in Žigić,(2000) and the associated variables carry the subscript "c". Finally, note that both "nc" and "c" regimes are in fact the second-best policies since there is only one policy instrument and two choice variables (R&D and quantities).[5]

2.2. The game

We consider a sequential (threeSstage) game. In the first stage, the domestic firm chooses strategically its R&D investment taking into account its subsequent impact on both its foreign rival's behaviour and on the government's choice of tariff. That is, the non-committed government sets the tariff on imports only after it observes the firm's choice of R&D. The rational domestic firm anticipates this tariff since it is *ex post* optimal for the welfare maximizing government to intervene. This move represents the second stage of the game. Finally, in the

[4]There are potentially three types of strategic considerations that the domestic government faces: the standard "profit shifting" motive, the government's motive to counteract the domestic firm's strategic over or underinvestment and the government's motive to offset the domestic firm's manipulatory behavior (see Neary and Leahy, 2000).

[5] For the whole scope of possible commitment patterns between the firms and the government in a dynamic games setting, see Leahy and Neary, 1996.

last stage, the firms select quantities, and consequently, profits and welfare are realised. Alternatively, we can, following Neary and Leahy (2000), adopt a two–stage framework in which the government in the second stage of the game is able to commit only intra–temporally, setting its policy instrument, tariff, before the firms choose the quantities. Then, in the first stage the domestic firm selects its R&D investment.

We concentrate on the domestic market (alternatively, we may impose a segmented market hypothesis), with duopoly assumed to be a viable market form both before and after the tariff is set. We proceed by solving the game backwards. In the last (third) stage, the firms choose the equilibrium quantities. The domestic firm maximizes

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

given q_f .

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

The optimization problem for the foreign firm yields:

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

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

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

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

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

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

In the second stage of the game, the domestic government selects the optimal tariff given the R&D expenditure of the domestic firm. Its objective function is given by the expression

$$W^*(t) = \Pi^*(t) + S^*(t) + R^*(t) \qquad (4)$$

where S*(t) and R*(t) are respectively given by

$$S^*(t) = 1/2(q_d^* + q_f^*)^2 = \frac{(2(A-\alpha) - t + (1+\beta)f[x])^2}{18} \qquad (5)$$

and

$$R^*(t) = t\ q_f^* = \frac{t\ (A+\alpha - 2t - f(x) - 2(\alpha - \beta f(x))}{3}. \qquad (6)$$

It seems natural to assume that the function R(t) is concave in t, initially increasing as t goes above zero but eventually falling to zero as t reaches the prohibitive tariff, t_p (a tariff that causes the exit of the foreign firm). Thus, the whole tariff domain on which duopoly is defined is given by the interval $t \in [0,t_p]$.

Assuming an interior maximum, the optimal tariff, t_{nc}^* is obtained by solving dW/dt = 0, yielding:

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

Finally, in the first stage of the game, the domestic firm selects the optimal level of R&D by substituting t_{nc}^* into (3) to obtain

$$\Pi_d(x) = \frac{4(2(A-\alpha)+(3-\beta)f[x])^2}{81} - x. \qquad (8)$$

Maximizing (8) with respect to R&D investment gives the first order condition[6] and (implicitly) the optimal[7] x_{nc}* :

$$\frac{8(3-\beta)(2(A-\alpha)+(3-\beta)f[x_{nc}^*])f'[x_{nc}^*]}{81} = 1 \tag{9}$$

Note that the optimal R&D level could be obtained more elegantly and more intuitively by comparing the marginal cost and benefits of an increase in x. A small increase of x affects positively the subsequent government tariff by ∂t/∂x. This in turn, increases profit by ∂Π/∂t. In addition, a given increase in x also increases the domestic firm's profit directly by ∂Π/∂x. The associated cost of such an increase in x is one. Thus, the optimal x_{nc}* is found at the point where the marginal benefit of an increase in R&D is equal to its marginal costs, that is, where ∂Π/∂t ∂t/∂x + ∂Π/∂x = 1 holds. This expression describes the same first order condition (9).

3. Tariffs, R&D and Welfare in the Two Regimes

3.1. Optimal tariff

Before moving to a comparison of relevant variables in the two regimes, we first show that the optimal tariff is indeed positive. This can been checked by evaluating the impact of a tariff on social welfare. We begin with the optimal tariff in the commitment regime where marginal social welfare is given by (see Žigić, 2000) :

$$\frac{dW_c^*(t)}{dt} = \frac{\partial S^*(t)}{\partial x}\frac{dx_c^*}{dt} + \frac{\partial S^*(t)}{\partial t} + \frac{\partial \Pi^*(t)}{\partial t} + t\left(\frac{\partial q_f^*}{\partial x}\frac{dx_c^*}{dt} + \frac{\partial q_f^*}{\partial t}\right) + q_f^* \tag{10}$$

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[6] The second order condition requires

$$\frac{8(3-\beta)^2(f'[x])^2+8(3-\beta)(2(A-\alpha)+(3-\beta)f[x])f''[x]}{81} < 0$$

[7] The set of R&D actions is given by X where x ∈ X = [0,x®] and x® is the solution of the equation α - f(x) = 0. We assume that α is large enough that the optimal R&D is always in the interior of the set X.

Summing up the direct marginal impacts of the tariff on the domestic firm's profit and consumer surplus yields $\partial\Pi_{nc}*/\partial t + \partial S_{nc}*/\partial t = (f(x*)(1-\beta)+t)/3 > 0$. Since the indirect effect of the tariff (via R&D) on consumer surplus, $\partial S*/\partial x\ dx*_c/dt$, is always non–negative (see Žigić, 2000 for the proof), this unambiguously implies $dW_c*(t=0)/dt > 0$. This is in accord with the standard wisdom in strategic trade theory which claims that, given duopolistic Cournot competition between foreign and domestic firms, imposing a "low" tariff is beneficial in terms of social welfare under fairly general conditions (see Helpman and Krugman, 1989).[8]

The proof that $W_{nc}*(t=0)/dt > 0$ is even simpler because in the non-commitment regime the government sets the tariff only after the home firm sets its R&D, so the analogue to (10) is given by (11):

$$\frac{dW^*_{nc}(t)}{dt} = \frac{\partial S^*(t)}{\partial t} + \frac{\partial \Pi^*(t)}{\partial t} + t\,\frac{\partial q^*_s}{\partial t} + q^*_s\ . \qquad (11)$$

Of course, the fact that the optimal tariff in the non-commitment regime is positive can be seen by a visual inspection of expression (7).

In fact, the more relevant question in this setup is whether the optimal tariff is in the interior of set $t\epsilon[0,t_p]$ since it may easily be the case that the optimal tariff is exactly at t_p or even beyond it (see Žigić, 2000). The only force that may preserve the duopoly as the optimal market structure is tariff revenue, the benefits of which have to exceed the foregone gains stemming from the lower unit costs brought on by a tariff at or beyond t_p. This, in turn, requires certain restrictions upon the R&D production function, f(x). Namely, the efficiency of f(x), captured by its underlying parameters (and first and second derivatives) should not be "too large" (see Žigić, 2000).

3.2. Preliminary discussion

The domestic firm's profit is monotonically increasing in tariff on the whole domain

[8] A sufficient (but not necessary) condition for this result to hold is that there be a "positive terms of trade effect," which, in this context, means that the new equilibrium price rises by less than the increase in the tariff. This is surely the case with a linear demand function.

$t \in [0, t_p]$ ($\partial \Pi / \partial t > 0$ from (3)) since an increase in the tariff has the same effect as an increase in the competitor's unit cost. In the present context, the domestic firm can influence the magnitude of the tariff by means of R&D investment. Since the optimal tariff is positively affected by an increase in R&D ($\partial t / \partial x > 0$ from (7)), the domestic firm has an incentive (not present in the case of the committed government) to invest strategically in R&D in order to induce a higher tariff and so harm its competitor. Thus, we may expect that this new, additional strategic incentive leads to generally higher R&D by the domestic firm than in the case when there is a government commitment. Indeed it is easy to show that evaluating R&D in the commitment regime at tariff t_{nc}^*, results in $x_{nc}^* \geq x_c^* (t_{nc}^*)$. However, the tariffs are generally different in the two regimes since the non-committed government has an incentive to adopt a lower tariff than the committed government. The reason for this is that now the tariff does not have a "technological function" since R&D investments are already in place when the tariff is set. Contrary to this, the committed government that sets the tariff, t_c^*, (see expression (12) which is the solution of (10)[9]) takes into account the tariff's impact on the subsequent choice of R&D that is below the (first–best) social optimum, and so t_c^*, besides its profit shifting role, also has the function of stimulating R&D investment (see Žigić, 2000):

$$t_c^* = \frac{(A-\alpha)(1+2x'f'[x_c^*]) + \beta f[x_c^*] - 3x' + (3-2\beta+\beta^2) f[x_c^*] x' f'[x]}{3-\beta x' f'[x_c^*]} \quad . \qquad (12)$$

The impact of a tariff on the subsequent R&D investment is captured by the term $x' f'(x)$ (where $x' \equiv dx_c^*/dt$ and $f'(x) \equiv \partial f(x)/\partial x$). Note that when $x' = 0$, t_c^* collapses to t_{nc}^*. Thus, in the absence of an R&D subsidy, the tariff, t_c^*, assumes part of the R&D subsidy's role and acts not only as a trade policy but also as an industrial or technological policy instrument. As we saw, the optimal tariff, t_{nc}^*, does not have this role.[10]

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[9] Note that (12) gives only an implicit tariff since $f[x_c^*] = f[x^*(t)]$ is an implicit function of the tariff.

[10] It is interesting to note that both t_c^* and t_{nc}^* have the function of countering the IPR violation since an increase in β that measures an increase in the IPR violation leads to a higher tariff, that is, $\partial t_{nc}^* / \partial \beta = f(x)/3 > 0$ and $\partial t_c^* / \partial \beta > 0$ in general (see Žigić, 2000).

A rigorous proof that $t_c^* \geq t_{nc}^*$ is not possible with a general form of the R&D production function, but the left hand sides of the two first order conditions for welfare maximization in commitment and non-commitment regimes (that is, dW_{nc}^*/dt and dW_c^*/dt given by the expressions 10 and 11) can serve as a rough indication of the relative magnitudes of the corresponding tariffs. The terms that appear in the expression of dW_c^*/dt but not in dW_{nc}^*/dt are

$$\frac{\partial S^*}{\partial x}\frac{dx_c^*}{dt} + t\,\frac{\partial q_f^*}{\partial x}\frac{dx_c^*}{dt}. \tag{13}$$

The first term describes the impact of R&D on the consumer surplus caused by an increase in the tariff and is always positive (see Žigić, 2000). The sign of the second term dealing with the impact of x on tariff revenue is not *a priori* clear but the first term always dominates the second so (13) is always positive (see Appendix 1). However, note that the two expressions, dW_{nc}^*/dt and dW_c^*/dt, cannot be directly compared since each is evaluated at a different optimal value of R&D and consequently at different optimal quantities. Nevertheless, the additional positive terms in dW_c^*/dt that do not figure in dW_{nc}^*/dt suggest that the accompanying tariff, t_c^* is higher than t_{nc}^*.

Presumably, the lower tariff and generally larger R&D in the case of a non-committed government would lead to higher welfare in general in the non-commitment regime, that is $W_{nc}^* \geq W_c^*$. It is possible to prove this conjecture only in the case of a concrete functional form for the R&D production function. As in Žigić (2000), we use the functional form: $f(x) = (g\,x)^2$ where the parameter g explicitly captures R&D efficiency (see also Chin and Grossman, 1991).

As shown in Žigić (2000), for a duopoly to be an equilibrium market structure, it cannot be optimal for the domestic firm to pursue strategic predation, (a strategy that leads to the elimination of the foreign competitor) in either of the two regimes. As already mentioned, this requirement puts certain restrictions on the R&D production function. In particular, R&D investment is assumed to be not “too efficient” or alternatively, overinvestment in R&D, sufficient to induce exit of the foreign firm, should not be profitable. Technically, the best response of the foreign firm should be such that $q_f^* \geq 0$ holds in equilibrium. Moreover, it is also assumed that it is never optimal for the government to erect a prohibitive tariff, that is a tariff higher than or equal to a critical level, (labelled as t_p), which is just sufficient to eliminate the competitor from the market.[11]

The set of parameters consistent with profit and welfare maximization in both regimes is displayed in Figure 1 as a shaded area. Solving the equation $q_f^*(.) = 0$ in the commitment regime for the threshold level of R&D efficiency (denoted g_{cr}) defines a g_{cr} curve:

$$g_{cr}(\beta) = \frac{9}{[(2-\beta)(-2(-2+\beta)+(7-7\beta+4\beta^2)^{1/2})]} \;. \tag{14}$$

Finally, comparison of $W_c^*(t^*)$ with the welfare obtained under the domestic monopoly gives the other critical curve g_{cc} (see Appendix 1). The line g_{cc} is relevant only if $\beta > 2$ since it is easy to demonstrate that welfare in a monopoly is never higher than welfare in a duopoly if

[11] Note that the highest sensible tariff is the one at which the domestic firm would achieve an unconstrained monopoly position. We label this tariff as t_m (see Žigić, 2000), so the range of prohibitive tariffs is given by $t \in [t_p, t_m]$.

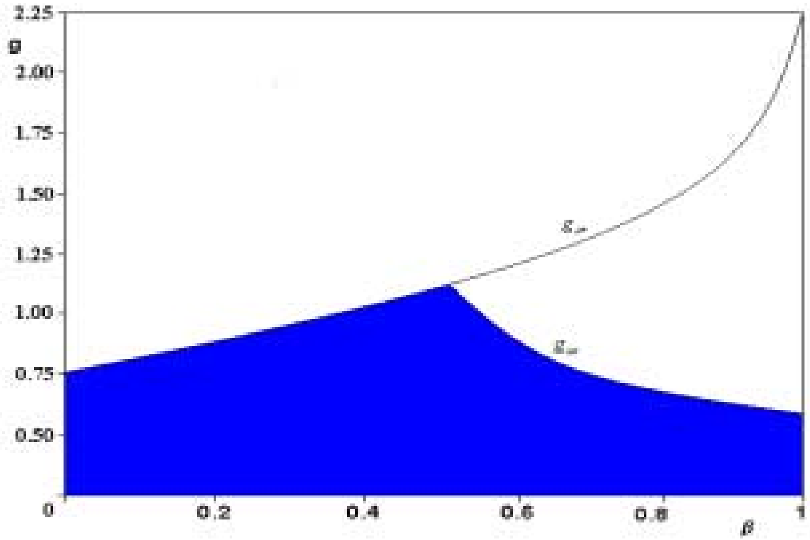


Figure 1. The region of parameters ($g < g_{cr}$ and $g < g_{cc}$) consistent with the duopolistic competition in both regimes.

$\beta < 2$. A similar procedure was performed for the non-commitment regime but since it gave the broader regions of the parameters, the intersections of the two feasible regions coincide with the feasibility region of the commitment regime.

3.3. Tariffs comparison in the two regimes

When $f(x) = (g\,x)^2$, the corresponding levels of tariffs in the two regimes are given by

$$t_{nc}^* = \frac{(A-\alpha)(27-4g(1-\beta)(3-\beta))}{81-4g(3-\beta)^2}, \tag{15}$$

and

$$t_c^* = \frac{(A-\alpha)(27+g(10+g(-2+\beta)(1-\beta)^2-11\beta)(-2+\beta))}{81-g(32-g(3-2\beta)(2-\beta)-10\beta)(2-\beta)}\ . \tag{16}$$

Lemma 1

$t_{nc}^* < t_c^*$ for all $g > 0$ and all $\beta \geq 0$.

Proof:

See Appendix 2.

As already mentioned (see footnote 10), when spillovers are strictly positive, the tariff, t_{nc}*, among other things, serves as an instrument to counteract IPR violations. However, without spillovers (β = 0), (15) collapses to (15.1)

$$t_{nc}^{*}(\beta = 0) \;=\; \frac{(A - \alpha)}{3} \qquad (15.1)$$

and the optimal tariff becomes a pure, profit shifting tariff (see Bhattacharjea 1995). (Note also that the more general expression for the tariff, t_{nc}*, given by (7) reduces to 15.1 when β = 0). Thus, the tariff, t_{nc}*, can have two roles at best: profit shifting and countering an IPR violation if β >0.

We now turn to the optimal tariff when the government can make a commitment, t_c*. Unlike t_{nc}*, this tariff has an additional technological function aimed at boosting R&D investment. This function is clearly seen if we evaluate (16) at β = 0 to get

$$t_{c}^{*}(\beta = 0) \;=\; \frac{(A - \alpha)(27 - 20g + 4g^2)}{81 - 64g + 12g^2} \qquad (16.1)$$

and observe that dt_c*/dg > 0.[12]

Finally, both (15) and (16) reduce to pure, profit shifting tariffs when β = g = 0.

3.4. Comparison of R&D levels in the two regimes

The corresponding R&D levels in the two regimes are given by the expressions (17) and (18) below:

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

$$x_{nc}^* = \frac{64(A-\alpha)^2(3-\beta)^2 g}{(81-4g(3-\beta)^2)^2} \; ; \tag{17}$$

$$x_c^* = \frac{(A-\alpha+t_c^*)^2(2-\beta)^2 g}{(9-g(2-\beta)^2)^2} \; . \tag{18}$$

The relationship between the two R&D levels is a bit less clear-cut than between the corresponding tariff levels. The reasons for this have already been discussed. On the one hand, the domestic firm in the non-commitment regime has a strategic motive to overinvest in order to induce a higher tariff and this motive is not present in the commitment regime. On the other hand, however, the ability of the government to commit before R&D is in place enables the government to influence the level of R&D. As it turns out, the presence or absence of spillovers is a decisive factor in determining whether x_{nc}* is bigger or lower than x_c*.

Lemma 2

$x_{nc}^* > x_c^*$ provided that the level of spillovers exceeds a threshold level β^r (g).

Proof: See Appendix 3

More precisely, when spillovers are zero or very small, $x_c^* > x_{nc}^*$, holds, but as soon as a certain relatively low level of β is reached, the reverse is true. This suggests that x_{nc}* declines more slowly than x_c* as the level of spillovers increases. Indeed, this holds already from the level β = 0 (see Appendix 3). The intuition for this is that the firm in a non-commitment regime, which has an additional motive to overinvest (to induce a higher tariff), is less sensitive to spillovers than the firm in the commitment regime which does not have this motive.

3.5. Welfare comparison in the two regimes

The above discussion of tariffs and R&D levels in the two regimes was in fact only a prelude (although an insightful one) to the key comparison of relative welfare. Similarly to the case of R&D, it can be shown that $W_{nc}^* > W_c^*$ as long as certain critical levels of g and β are reached (see Appendix 4).

Proposition 1

The social welfare in the "non-commitment" regime exceeds the social welfare in the "commitment" regime as soon as spillovers exceed the critical level, β^W*. Consequently, for* $\beta > \beta^W(g)$*, social welfare in the "non-commitment" regime is always higher than the welfare in the corresponding free trade world.*

Proof: See Appendix 4

As seen from Figure 2, it is sufficient that, independently of the value of the efficiency parameter, g, the level of spillovers exceeds a small threshold level (that is, $Max[\beta^W(g)])=0.039$) in order for $W_{nc}^* > W_c^*$ to hold. Notably, this critical level is even smaller than in the case of R&D implying that a sufficient condition for $W_{nc}^* > W_c^*$ is $x_{nc}^* > x_c^*$. This is not surprising once we realized that social welfare is an increasing function of R&D investment at either of the optimal levels x_{nc}^* and x_c^*. In other words, the marginal social benefit exceeds the marginal social costs at x* (where "x*" stands for either x_{nc}^* or x_c^*). Thus, a "small" increase in x beyond x* generates more social welfare by increasing consumer surplus than the resulting social welfare loss due to the fall in the firm's profit and a possible decline in tariff revenue.[13] To prove this, note that a positive marginal welfare (that is, $dW^*(x^*)/dx > 0$), requires that the marginal impact of R&D on consumer surplus and tariff revenue at point x* has to be positive. In other words, $dS^*(x^*)/dx + dR^*(x^*)/dx > 0$ has to hold in both regimes in order to have $dW^*(x^*)/dx > 0$. (Note that $d\Pi^*(x^*)/dx = 0$ by the first order condition of profit maximizing in each regime.) Thus, in the non-commitment regime we get

$$\frac{dW_{nc}^*(x_{nc}*)}{dx} = \frac{(6(A-\alpha)+25(A-\alpha)\beta+(9-6\beta+28\beta^2)f[x_{nc}^*])f'[x_{nc}^*]}{81} > 0.$$

By the same token, $dW_c^*(x_c^*)/dx > 0$ holds as well (see Žigić, 2000).

However, it is interesting that W_{nc}^* dominates W_c^* at lower levels of R&D than in the

[13] It is easy to check that tariff revenue increases in x provided that $\beta > 1/2$.

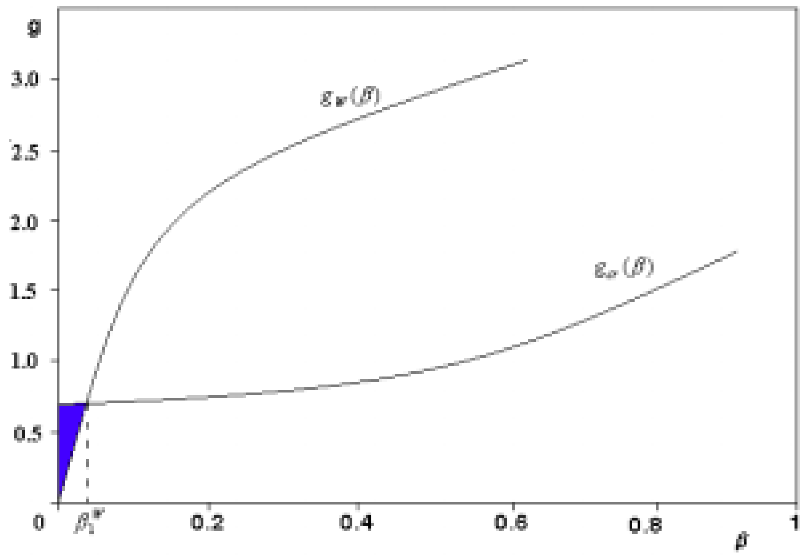


Figure 2. The region of parameters ($g < g_{cr}$ and $g < g_W$) for which $W_{nc}^* > W_c^*$

commitment regime. Intuitively, this has to be attributed to the lower tariff in the non-commitment regime and consequently to its smaller distortionary effects. Namely, the lower optimal tariff in the non-commitment regime is expected to have less distortional effect on consumer surplus and tariff revenue although the domestic firm would welcome a higher tariff. Thus, the first two effects dominate the third one as soon as $\beta > \beta^W(g)$.

To summarise, the common wisdom that a committed government is able to achieve a higher level of welfare than its non-committed counter–part proves correct in the absence of spillovers. However, if spillovers exceed a small critical level of $\beta^W(g)$, the reverse is true. The summary of the empirical work on spillovers by Griliches (1992) finds that typical values of β range between 0.2 and 0.4, far above any possible value of $\beta^W(g)$. Thus, the proposition that a non-committed government can generate higher welfare in the prevalence of spillovers can be considered as a general case.

4. The first best policy

We now turn to first-best policy considerations. Since in our second-best setup the key strategic variable— R&D investment— is undersupplied, the principle objective of the first best policy is to remove this inefficiency by some other policy instrument. A natural policy tool for this purpose would be an R&D subsidy to the domestic firm. Thus, the relevant framework is now a four-stage game that adds one initial stage to the game considered in the previous section: a government commitment to a level of R&D subsidy. Again, we can, following Neary and Leahy (2000), consider this game as basically a two–stage game where in both stages the government is restrained to commit intra-temporally; thus, in the first stage the government selects an R&D subsidy before the domestic firm chooses its level of R&D, whereas in the second stage the government commits to the tariff before the firms choose their quantities. Since the rest of the game is already solved, we turn immediately to the first stage and to the government's choice of optimal subsidy.

The objective function of the government that conducts the first best policy is now given by the expression (19):

$$W^{*}_{fb}[x^{*}(s),t^{*}(x^{*}(s),s),s] = \Pi^{*}(\cdot) + S^{*}(\cdot) + R^{*}(\cdot) - sx^{*}(s) \qquad (19)$$

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

Differentiating (19) with respect to the subsidy and using the domestic firm's first order condition, (envelope theorem) yields

$$\frac{dW^{*}_{fb}(\cdot)}{ds} = \frac{\partial \Pi^{*}}{\partial s} + \frac{\partial S^{*}}{\partial t}\frac{\partial t}{\partial x}\frac{\partial x}{\partial s} + \frac{\partial S^{*}}{\partial x}\frac{\partial x}{\partial s} + \frac{\partial R^{*}}{\partial t}\frac{\partial t}{\partial x}\frac{\partial x}{\partial s} + \frac{\partial R^{*}}{\partial x}\frac{\partial x}{\partial s} - x^{*} - s\frac{\partial x}{\partial s} . \qquad (20)$$

By equating (20) to zero and noting that $\partial\Pi^{*}/\partial s = x^{*}$, we get expression (21) for the optimal first–best subsidy:

$$s^{*} = \frac{\partial S^{*}}{\partial x} + \frac{\partial S^{*}}{\partial t}\frac{\partial t}{\partial x} + \frac{\partial R^{*}}{\partial x} + \frac{\partial R^{*}}{\partial t}\frac{\partial t}{\partial x}. \qquad (21)$$

A positive optimal subsidy requires that the positive impact of R&D on consumer surplus dominates the possible negative impact (which occurs only if $\beta < 2$) on tariff revenue. In other words, the right hand side of (21) has to be positive. Indeed, substituting the relevant values obtained by differentiating expressions (5) and (6) into (21) gives

$$s^* = \frac{(A-\alpha)(6+25\beta)+(9-6\beta+28\beta^2)f(x_s^*))f'(x_s^*)}{81} > 0. \qquad (22)$$

Clearly, the optimal subsidy is positive, stimulating investments in R&D. Moreover, as seen from (21), the optimal subsidy removes the distortion between the privately and socially desirable R&D investment levels ensuing investment to be at the social optimal level, x_S*.

The optimal, first best tariff is given by

$$t_{fb}^* = \frac{A-\alpha+\beta f(x_s^*)}{3}, \qquad (23)$$

which obviously has the same functional form as the tariff in the non-commitment regime since the tariff is no longer an instrument supporting R&D investment. However, as long as $\beta > 0$, the optimal subsidy exhibits (at least indirectly) a profit shifting role by affecting the optimal tariff through R&D investment. (Note that when $\beta = 0$, R&D has no impact on the optimal tariff and once again the tariff has only a profit shifting role). Thus, in the presence of spillovers, the clear division of labor between the two instruments is somewhat blurred. This seems to be a robust finding since a similar phenomenon was also noticed by Leahy and Neary (1999) in a different framework with spillovers and international competition.

We now turn to the calculation of the optimal, first- best subsidy and tariff when f(x) = $(g\ x)^2$. Substituting $(g\ x)^2$ into the expressions (22) and (23) respectively, we obtain the expressions for the optimal subsidy and tariff:

$$s^* = \frac{6+\beta(25-4g(1-\beta)(3-\beta))}{9(6+\beta)}\ ; \qquad (24)$$

$$t_{fb}^* = \frac{(A-\alpha)(6-g(1-\beta)(3-\beta))}{18-g(9-6\beta+4\beta^2)}. \tag{25}$$

It is interesting to note that the optimal subsidy is increasing in the level of spillovers. This may seem counter–intuitive at first glance since for a larger β and x , the larger would be the R&D output appropriated by the foreign firm. R&D subsidies are, however, an industrial policy instrument with a primary role of enhancing socially insufficient R&D investment, while the other instrument (the optimal tariff) has (among other roles) an IPR violation offsetting role (note that $dt_{fb}^*/d\beta > 0$). Since the optimal R&D subsidy increases with spillovers, it also triggers an increase in the tariff that thwarts research output appropriated by the foreign firm, defined as $F[x_s^*(s),t] \equiv \beta f(x_s^*) q_f^*(x_s^*, t)$, by diminishing the optimal output of the foreign firm. Moreover, as long as spillovers are "not too high," the investment in R&D makes the domestic firm "tough" and the increase in R&D induced by an R&D subsidy directly reduces the research output appropriated by the foreign firm through the reduction in the optimal output of the foreign firm.[14] This lead us to the last proposition.

Proposition 2

The optimal, first– best subsidy, s, is always positive, irrespective of the level of spillovers and irrespective of whether R&D investment makes the domestic firm "tough" or "soft."*

Larger spillovers mandate larger R&D subsidies even if the beneficiaries are foreign, not because the home government cares about foreign profits, but because it wishes to offset the negative disincentives to investment arising from non-appropriability (see Leahy and Neary, 1999) and because it aims to spur better exploitation of scale economies by the domestic firm

[14] Note that when spillovers exceed a certain critical level, the investment in R&D makes the domestic firm "soft" calling for a "puppy dog" strategy (see Fudenberg and Tirole, 1984).

(see Žigić, 2000). The difference from the standard results in Cournot competition where first–best subsidy is negative (i.e., an R&D tax is optimal) stems primarily from the different specification of the welfare function. If we neglect consumer surplus and tariff revenue, then as is clear from (21) the optimal subsidy will be zero.[15] The reason for this is that in a such situation both the firm and the government have the same ability to commit so the firm can achieve the most advantageous strategic position on its own (see also Neary and Leahy, 2000).

Finally, we briefly comment on an "R&D subsidy only" second-best policy since this or a similar setup is discussed at length elsewhere (see for instance, Spencer and Brander, 1983; Bagwell and Staiger, 1994; Maggi, 1996; and Leahy and Neary, 1997). In the absence of a tariff, expression (21), characterizing the optimal subsidy, reduces to:

$$s^*_{sb} = \frac{\partial S^*}{\partial x} = \frac{(1+\beta)(2(A-\alpha)+(1+\beta)f(x_{sb}))f'(x_{sb})}{9} > 0, \tag{26}$$

indicating that s^*_{sb} is larger than s^*_{fb} since the remaining effects in (21), that is, the indirect impact of R&D on tariff revenue and consumer surplus and the direct effect of R&D on tariff revenue are negative in sum. Indeed, calculating the explicit second–best tariff when f(x) = $(g\ x)^2$ yields

$$s^*_{sb} = \frac{(6-g(1-\beta)(2-\beta))(1+\beta)}{18} > s^*_{fb} .$$

This is in line with findings emphasising the robustness of the R&D subsidy (see for instance, Brander,1995; Bagwell and Staiger,1994; Leahy and Neary 1997; Hinloopen,1997; and Neary and Leahy, 2000) since the R&D subsidy has to boost the inefficient R&D investment and act as a surrogate for the unavailable tariff.

5. Conclusion

We analyzed the effect of different degrees of government commitment on social welfare

[15] However, this is not the case any more if the foreign firm also invests in R&D.

in a duopoly game where domestic and foreign firms compete in quantities on the imperfectly competitive domestic market and there are R&D spillovers from the domestic to the foreign firm. More specifically, we distinguish between "commitment" and "non-commitment" policy regimes where a “committed" government selects the policy instrument before the strategic choice of the domestic firm while its "non-committed" counterpart sets the policy instrument only after the strategic variable of the domestic firm is already in place. The latter presumes only the government’s intra-temporal commitment (and consequently, the absence of its inter-temporal commitment).

Concerning government policy, we made a distinction between the "first–best" and "second–best" policy. The first best policy in principle includes more than one policy instrument in order to induce socially desirable levels of all choice variables. In many circumstances, however, the government may be constrained to a smaller number of policy instruments than the number of targets. Such a constrained policy enviroment is called a "second–best" policy world. In particular, there may be only one instrument at the government's disposal. Since, in our context, the domestic firm has two choice variables— the level of R&D investment and the quantities to be produced— the second–best policy implies either an R&D subsidy or import tariff (but not both of them).

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

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

Appendix 1:

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

Social welfare in the commitment regime is labelled as W^*_c while social welfare in the situation when the domestic 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 $W^*_m \geq W^*_c$ lead us, after some simple algebraic manipulation of the above inequality, to the following inequality:

$$36+g^4(2-3\beta+\beta^2)^2-2g(43-40\beta+52\beta^2)-4g^3(2-\beta)(1-\beta)(5+\beta(-5+2\beta))+ g^2(111+8\beta(-25+\beta(21+\beta(-9+2\beta)))) \geq 0.$$

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 here in the text. Thus, if $g > g_{cc}(\beta)$, the monopoly welfare exceeds the welfare from duopoly.

Appendix 2:

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

$$g_t(\beta) = \frac{24+\beta(220+\beta(-286+85\beta))}{8(1-\beta)(2-\beta)^2(3-\beta)\beta} - \frac{\sqrt{(2-\beta)}\sqrt{(288-\beta(-240+\beta(-1040+\beta(-1416+5\beta(78+149\beta)))}}{8(1-\beta)(2-\beta)^2(3-\beta)\beta},$$

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

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

delineates the upper border of the duopoly's feasability region when $\beta < 2$ and it is obtained by solving the equation $q_f^*(.) = 0$. Consequently, the whole feasibility region for the duopoly market structure is a proper subset of the region $g(\beta) \leq g_t(\beta)$, implying $t_c^* - t_{nc} > 0$ will hold in the whole duopoly region.

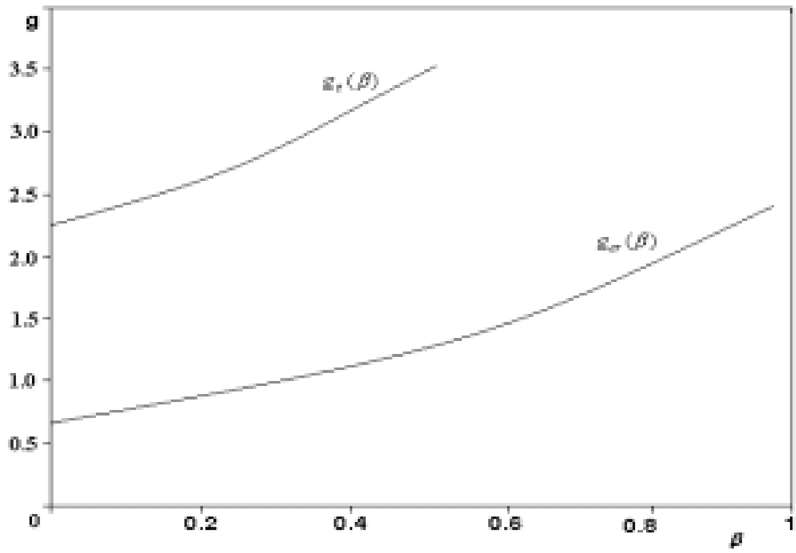
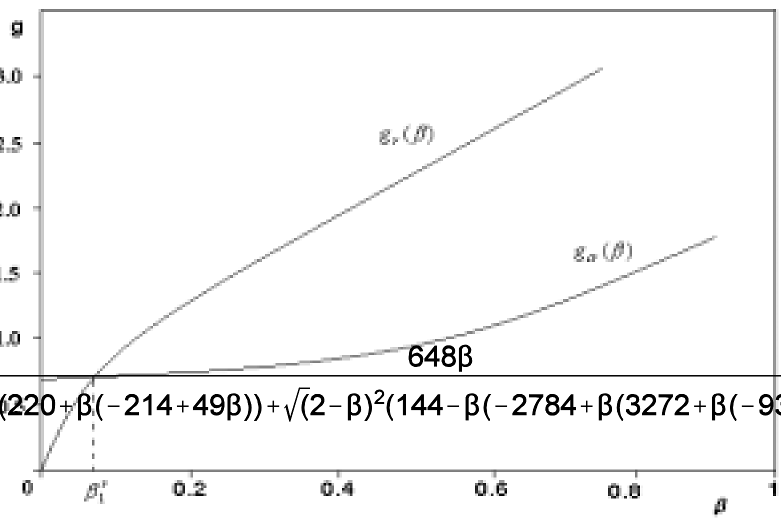


Figure 1 A

Appendix 3:

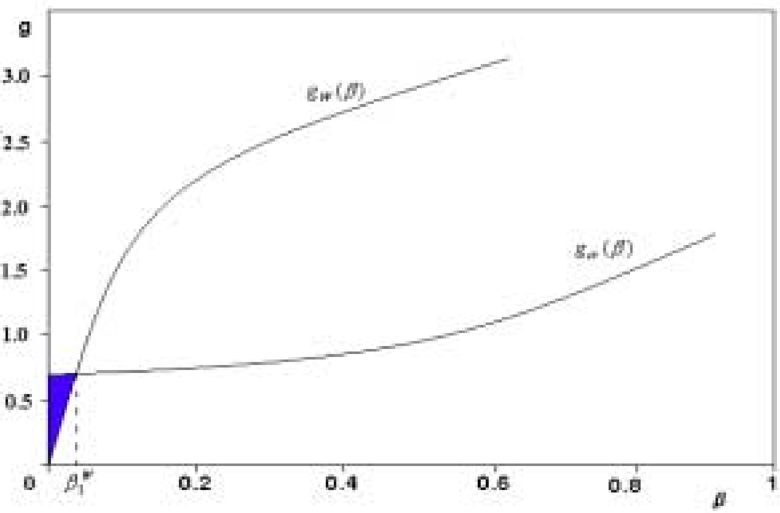


Solving $x_{nc}^* - x_c^* = 0$ for the critical value of $g_r(\beta)$ yields:

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

where $g_r(\beta)$ represents an upper border below which $x_{nc}^* > x_c^*$. Adding the upper contour of the duopoly feasibility region, $g_{cr}(\beta)$, shows that there is a non-empty intersection for which (shaded area in Figure 2A) $x_c^* > x_{nc}^*$. The critical value of the $\beta^r(g)$ is obtained by inverting the function $g_r(\beta)$. Note that irrespectively of the value of g, $x_{nc}^* > x_c^*$ for any β such that $\beta > \beta_1^r$ where the value $\beta_1^r = 0.0909393$.

Figure 2A



Furthermore,

$=> \frac{-128(}{(}$ ... $g))$ > 0.

note that

In other words, both x_c* and x_{nc}* monotonically decline in β, however, x_{nc}* declines more slowly over the whole range of $\beta \in [0,1]$.

Appendix 4:

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

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

Figure 3A

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

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

Since the solution is extremely messy, it will not be reproduce in the text. The graphical representation of the $g_w(\beta)$ and $g_{cr}(\beta)$ yields a small shaded area for which $W_c^* > W_{nc}^*$. The critical value of β^W (g) is obtained by inverting $g_w(\beta)$. Note that irrespectively of the value of g, $W_{nc}^* > W_c^*$ for any β such that $\beta > \beta_1^W$ where $\beta_1^W = 0.03909$. The graphical representation of W_{nc}^*, W_c^* and W_{ft}^* (social welfare in a free trade regime) is given in Figure 4A below.

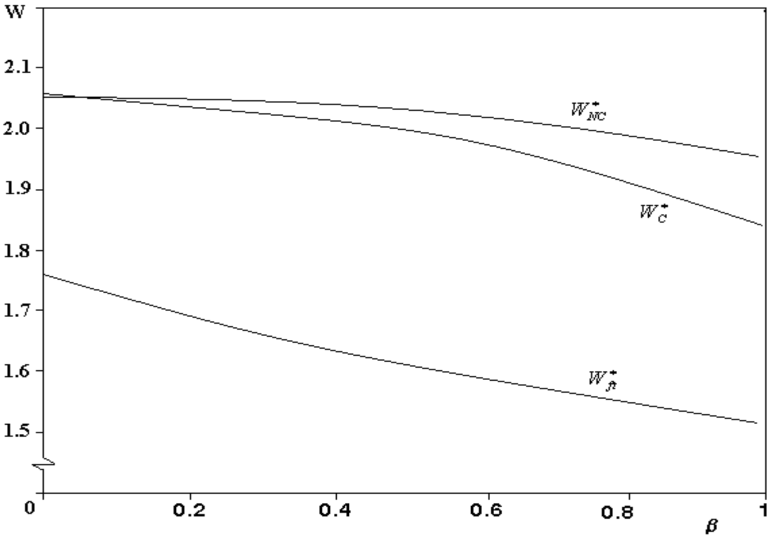


Figure 4A

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