SECOND-BEST TRADE POLICIES, R&D SPILLOVERS AND GOVERNMENT (IN)ABILITY TO PRECOMMIT IN AN INTRA-INDUSTRY TRADE FRAMEWORK

Krešimir Žigić

CERGE-EI

Charles University
Center for Economic Research and Graduate Education
Academy of Sciences of the Czech Republic
Economics Institute

WORKING PAPER SERIES (ISSN 1211-3298)
Electronic Version

427

Working Paper Series 427
(ISSN 1211-3298)

Second-Best Trade Policies, R&D Spillovers and Government (In)ability to Precommit in an Intra-Industry Trade Framework

Krešimir Žigić

CERGE-EI
Prague, November 2010

ISBN 978-80-7343-228-7 (Univerzita Karlova. Centrum pro ekonomický výzkum a doktorské studium)
ISBN 978-80-7344-216-3 (Národohospodářský ústav AV ČR, v.v.i.)

Second-Best Trade Policies, R&D Spillovers and Government (In)ability to Precommit in an Intra-Industry Trade Framework*

Krešimir Žigić[†]

Abstract

We introduce an intra-industry setup in order to reconsider the consequences of government (in)ability to precommit to its policies when it is constrained to only one policy instrument (second-best policies). This setup nests the standard frameworks of strategic trade policy—the "third-market" and the "home-market" framework. We also analyze how robust the signs of particular policy instruments (R&D subsidies) are when passing from the "second-best" to the "first-best" policy and show that in the considered setup this issue is closely related to the issue of the government commitment. The policy instruments under consideration are import tariffs and export and R&D subsidies, and there are R&D spillovers from the domestic firm to the foreign firm.

JEL Classification: F13, L11, L13, O31
Keywords: government commitment, optimal tariffs and R&D subsidies, first-best versus second-best strategic policy, R&D spillovers

*I am very grateful to Levent Celik and Vilem Semerak for their valuable comments and I would also like to thank Robert Staiger, Elie Appelbaum, Alan Deardorff, Peter Neary, Avner Shaked and Anu Kovarikova Arro for numerous comments on earlier drafts of this paper. All errors remaining in the text are the responsibility of the author.

[†] CERGE-EI is a joint workplace of the Center for Economic Research and Graduate Education, Charles University, and the Economics Institute of Academy of Sciences of the Czech Republic.
Address: CERGE-EI, P.O. Box 882, Politických vězňů 7, Prague 1, 111 21, Czech Republic
e–mail: Kresimir.Zigic@cerge-ei.cz

Abstrakt

Prezentujeme modifikovaný model vnitro-odvětvové směny, ve kterém revidujeme tradiční dopady (ne)schopnosti vlády zavázat se předem ke svým politikám v situaci, kdy jsou omezeny na ovlivňování pouze jednoho nástroje (second-best policies). Tato konfigurace v sobě zahrnuje jak tradiční rámec pro analýzu strategické obchodní politiky – „třetí trh", tak rámec, v němž neabstrahujeme od dopadů na „domácí trh". Také analyzujeme, jak robustní jsou znaménka nastavení konkrétních nástrojů (dotace na výzkum a vývoj) při přechodu od „second-best" k „first-best" politikám, a ukazujeme, že v našem uvažovaném modelu je tato problematika úzce spjata se schopností vlády se k dané politice zavázat. Analyzujeme nástroje hospodářské politiky ve formě dovozních cel, exportních dotací a dotací na výzkum a vývoj a předpokládáme existenci vedlejších dopadů (spillovers) investic domácí firmy do výzkumu a vývoje na firmu zahraniční.

1. Introduction

The "third-market" approach (in which domestic firms compete with foreign firms at a third, neutral market) used to be a standard setup to analyze the impacts of strategic trade policies and, subsequently, to study the issues of timing in the decisions of firms and governments. Notably, this approach ignores consumer surplus (and possible tariff revenue). At the center of such an approach is a standard three-stage duopoly game in which a domestic firm undertakes some kind of strategic investment (say, in R&D) prior to market competition and the domestic government sets a policy instrument (usually an export subsidy). The important issue of timing then arises: whether the government can set its policy instrument prior to the firm's investment.[1] In other words, the problem of timing enters here via the issue of the government's ability to commit to its action since this (in)ability determines the timing of the moves between the government and the domestic firm.

Note that in the context of dynamic games where the domestic firm has more than one choice variable (e.g. the level of R&D and the level of output), there is a distinction between the "first-best" and the "second-best" policy. The first-best policy in principle includes more than one policy instrument in order to induce socially desirable levels of all choice variables. In many circumstances, however, the government may be constrained to a smaller number of instruments or even only to one instrument. Such constrained policies we refer to as "second-best" policies (see Neary and Leahy, 2000). There are usually several second-best policies that can be contrasted and ranked against the benchmark stemming from the first-best policy. For instance, a standard second-best policy in the above third-market setup is the policy of export support via export subsidies or indirectly

[1] See for instance Goldberg (1995), Karp and Perloff (1995), Neary and O'Sullivan (1997), Grossman and Maggi (1998), Neary and Leahy (2000) and Ionaşcu and Žigić (2005).

via R&D subsidies. The first-best policy obviously includes both export subsidies and R&D subsidies.

As for the normative aspect of such second-best policies in the third-market approach, some of the most important results can be summarized as follows: a) Export subsidies lead to overinvestment in the strategic variable (that is, in R&D) from the first-best point of view irrespective of the government's ability to precommit. b) The social welfare in free trade can be higher than the social welfare under a strategic trade policy when the government is unable to precommit to its actions ("non-committed government"). c) The policy in which the government can commit to act prior to the strategic action of the domestic firm always generates higher welfare than its non–committed counterpart. d) The R&D subsidies that turn out to be non-negative in the second-best setup become negative (that is, R&D taxes) when the first-best policy is employed.

Point d) is rather important from the policy point of view since providing R&D subsidies was considered a robust policy instrument unlike output policies like tariffs and export subsidies (see Bagwell and Staiger, 1994 and Maggi, 1996); we pay special attention to this point in the analysis.

However, as Helpman and Krugman (1989) point out, the "third-market approach is useful for isolating strategic interactions but is a terrible guide to policy". So an analysis of the home-market setup seems to be indispensable given the policy relevance of this setup. Thus, Žigić (2007) shifted the focus from the "third-market" to the "home-market" setup (in which home and foreign firms compete in the home-market) to test the robustness of the above "third-market setup" propositions. He found that all of the above propositions are reversed in the home-market setup provided that there are some R&D spillovers stemming from the domestic to the foreign firm. The problem with Žigić's (2007) approach, however, is that the third-market and the home-market setups are not directly comparable and so each setup requires different first-best and free-trade benchmarks. Most notably, there is no consumer surplus in the social welfare function of the third-market setup.

In order to overcome this comparability problem, we put forward an integrated framework that would in a natural way include consumer surplus in both frameworks and nest both setups enabling the common and the unique (both the free-trade and the first-best policy) benchmark. More specifically, we allow for intra-industry trade. That is, the domestic firm competes with the foreign firm on both the domestic and the foreign market (see Brander and Krugman, 1983 or Krugman, 1984 for a similar setup). Thus, a typical second-best home-market policy in this setup would be a one-instrument policy in which the home government protects its market by means of tariffs. This policy would have, however, an impact on the export market in favor of the domestic firm and lead to "export promotion as import protection" (see Krugman, 1984). Also notice that in such a framework the (constrained) first-best policy would entail three policy instruments: export subsidies, R&D subsidies and import tariffs.

We also assume the presence of unilateral R&D spillovers in the above framework making our analysis suit the North-South (or East-West) intra-industry trade setup. Indeed there is empirical evidence about North-South horizontal intra-industry trade characterized with important bilateral intra-industry trade between Northern and Southern countries in a number of products[2] (see, for instance, Tharakan and Kerstens, 1995 or Fidrmuc, et al. 1999 for East-West intra-industry trade).

The two main goals of this paper are i) to reconsider in this new, integrated framework the issue of the government's commitment to typical second-best policies and

[2] Tharakan and Kerstens (1995) showed econometrically that North-South intra-industry trade in toys is of a horizontal type. That is, toys are close or perfect substitutes rather than being differentiated by quality.

ii) to check the above-mentioned robustness of the sign of R&D subsidies when passing from the second- to the first-best policy.

In such an integrated framework, the latter issue is closely related to the former since the sign of the R&D subsidy depends on the government's (in)ability to precommit to its policy instrument. In particular, if in the first-best framework, the government cannot precommit to neither export subsidies nor tariffs, then indeed the sign of the R&D subsidies in the first-best setup will not be very robust vis-à-vis its sign in the second-best setup. That is, R&D subsidies would turn into optimal R&D taxes in the first-best setting unless the intensity of spillovers is rather strong. If, on the other hand, the government is able to precommit to export subsidies and tariffs in the first-best setting, then R&D subsidies will remain positive also in the first-best setup unless the intensity of spillovers is rather low. In other words, while the level of social welfare in the first-best setting is always the same (maximal), the level of a particular first-best instrument differs depending on the given sequencing.

Another key insight from our integrated framework is that the presence of unilateral R&D spillovers may lead to the reversal of the standard result in which the committed government is always superior (in terms of social welfare) to the non-committed government. Interestingly enough, this reversal occurs in both home-market and third-market policies under consideration. More specifically, in the home-market policy setup social welfare in the government regime without commitment is bigger than in the corresponding commitment regime at already very small spillovers, while in the case of third-market policies larger spillovers are needed for this to take place.

To illustrate and to contrast as clearly as possible the effects of the particular trade policy instruments, we stick to a simple dynamic Cournot duopoly. Like in most papers using a third-market setup, the strategic variable is investment in cost reduction[3] (see, for instance, Karp and Perloff, 1995 or Grossman and Maggi, 1998). As already indicated, we allow for R&D spillovers from the domestic to the foreign firm. The rationale for introducing R&D spillovers stems from the fact that innovations, in general, are subject to R&D spillovers. In particular, as we already claimed, our extended setup could fit well into a North-South intra-industry trade setup in which the domestic Northern firms innovate and the Southern firms imitate or, in other words, benefit from R&D spillovers through trade in both markets.[4] The presence of R&D spillovers in this context seems to be even more natural than in a single market setup since firms interact on both markets and there may be more opportunity for foreign firms to capture the R&D output of domestic firms. As Tharakan and Kerstens (1995) note ”the presence of American, Japanese and European firms stimulated the South-East Asian producers to do more research and imitate the dominant styles and products in demand in the high income countries.”

The rest of this paper is organized in the following way: in Section 2 we briefly survey the related trade literature. In Section 3 we describe the basic setup, its underlying assumptions and define the second-best policy regimes under consideration as well as the first-best benchmark. In Section 4, we analyze the positive and normative aspects of the second-best policy regimes in the home-market policies (tariffs) while in Section 5 we briefly review the analogous aspects and findings from the third-market policies (export subsidies). In Section 6, we explore the robustness of the R&D subsidies in the first-best as opposed to the second-best policies. Finally, Section 7 is devoted to concluding remarks.

---

[3] Market-expanding investment or investing in product innovation where the investments shift the demand function is effectively identical with cost-reducing investment (see, for instance, Leahy and Neary, 2001).

[4] The importance of R&D spillovers and imitation and the economic implications in both North-South trade and in general seems to be well and broadly documented in both theoretical and empirical literature (see, for instance, Chin and Grossman, 1990; Griliches,1992; Deardorff, 1992; Žigić, 1998 and 2000; Coe and Helpman, 1995; Lai and Qui, 2003; Qui and Lai, 2004 and Grossman and Lai, 2004 among many others).

2. Survey of the literature

Here we briefly review the trade literature on the issue of timing and commitment and put it into perspective. Using a third-market setup, Carmichael (1987) was one of the first authors who turned attention to the issue of government commitment and the consequent timing in a decision. A firm that anticipates a subsidy has an incentive to inflate the price since the size of the subsidy is usually positively related to the price. In these circumstances, trade policy loses its strategic dimension, and it is a rather responsive device in that governments try to offset an excessive increase in the domestic price.[5] Thus, there is a pure transfer of rents from the government to the domestic firm without any strategic impact and so without any change in effective export prices and domestic social welfare. Consequently, the government will lose nothing if it can precommit to free trade.

Carmichael's (1987) analysis sparked discussion and research about the mode and timing of trade policy. One of the crucial features of this discussion is the distinction between the announcement of a policy program and its actual implementation. Thus, the government's decision about the design of a policy program may precede the selection of the actual level of such a selected policy, splitting a single stage of the game into two stages. Moreover, different timings of the policy choice (and different policies themselves) usually result in various degrees of policy flexibility, pointing to a trade-off between flexibility and commitment (see, for instance, Cooper and Riezman, 1989, Arvan, 1991 and Shivakumar, 1993). Thus, for instance, Hwang and Schulman (1993) allow a government to explicitly commit to "non-intervention" (that is, to free trade, in our terminology) and investigate when the commitment to free trade yields larger social welfare.

[5] In fact, in Carmichael (1987), domestic firms have an incentive to inflate prices to infinity, and so equilibrium prices are obtained as a "corner solution" determined by the price cap set by the policy makers. However, this problem disappears if, as assumed by Gruenspecht (1988), the opportunity cost of raising a unit of government revenue is larger than one. See also Neary (1991) and Neary (1994).

It is important to recall that the above issue of strategic intervention versus commitment to free trade is an example of rules versus discretion in the sense described first by Kydland and Prescott (1977). Since trade policy is, by its nature, of a second-best character, it is plagued with the time consistency problem and so the above dilemma of rules versus discretion is likely to be relevant here (see, for instance, Staiger and Tabellini, 1987 and 1989 and Staiger, 1995 for a survey of the literature that deals with rules versus discretion issues in the context of trade policy).

Inquiry into the impact of timing in subsequent strategic trade policy literature is conducted in a somewhat richer and (for the purposes of our analysis) more important context, yet still within the third-market framework. As already mentioned above, in this setup, domestic firms undertake some kind of strategic investment prior to market competition (see for instance, Goldberg, 1995; Karp and Perloff, 1995; Neary and O'Sullivan, 1997; Grossman and Maggi, 1998; Neary and Leahy, 2000 and Ionaşcu and Žigić, 2005). The intriguing and non-standard case is the one in which firms commit to their investment before the government sets, say, export subsidies. The reason why the strategic investment of the firm can precede the government's action is the fact that the policymakers may lack credibility with the firms whose behavior they try to influence (see Neary and Leahy, 2000) or there may be an already noted time lag between the announcement of a trade policy program and the implementation of the trade policy instrument at the concrete level. Much like in an initial Carmichael (1987) setup, both of these reasons give an incentive to the domestic firm to influence (or manipulate) the government's policy response.

In these circumstances, precommitment to free trade looks even more attractive than in Carmichael's (1987) simple setting in which trade policy and free trade are equivalent in terms of social welfare. As we already mentioned, the point is now that domestic firms are inclined to overinvest in a strategic variable (e.g. in R&D capital) that may be socially costly and inefficient. In turn, it can lead to lower social welfare compared to the corresponding social welfare under free trade (see, for instance, Karp and Perloff, 1995; Neary and O'Sullivan, 1997; Grossman and Maggi, 1998; Neary and Leahy, 2000 and Ionaşcu and Žigić, 2005). This socially undesirable overinvestment occurs, among other things, when the cost of capital is not excessively large since high costs of capital neutralize the incentives for overinvesting.[6]

It is worth stressing once again that all of the conclusions from the above literature are obtained within a "third-market setup". As already mentioned, Žigić (2007) is an exception, but there the comparison between the third-market and home-market was not performed on a common, directly comparable platform.

3. The basic setup

3.1. Assumptions and Model

We employ a standard and simple dynamic setup in which the domestic firm invests in a strategic variable prior to the market competition stage in which the domestic and the foreign firms set their respective output levels simultaneously at both domestic and foreign markets. As for the home government, it can ideally set three policy instruments: import tariffs, export subsidies and R&D subsidies, which we denote as "t", "s" and "s_y", respectively. In Sections 3 to 5, we assume that the government is constrained to only one policy instrument. More specifically, we mainly focus on the so-called "output policies" where only import tariffs or export subsidies are available. Clearly we are confined only to the subset of second-best policies or second-best regimes (see, for instance, Neary and Leahy, 2000).

---

[6] Surveying the empirical evidence on the international comparison of the costs of capital, Karp and Perloff (1995) informed us that the U.S. has substantially higher costs of capital than other developed countries (double that of Japan, 89 percent more than in Germany and 29 percent more than in the United Kingdom in 1988). Yet "according to some empirical studies, even in the United States, real capital costs are low enough so that strategic U.S. subsidies may cause excessive U.S investment" (Karp and Perloff, 1995).

Concerning the government's ability to precommit, we consider three such government second-best regimes: (1) The commitment regime in which the government is capable of committing to both a policy intervention and a particular policy instrument (tariffs or subsidies) prior to the domestic firm's choice of strategic variable (henceforth the "C" regime). (2) The non-commitment regime in which the government announces trade policy in the first stage (for example, due to the lag in the announcement and implementation of the policy or due to lack of credibility) but imposes the actual level of its policy instrument only after it observes the domestic firm's choice of strategic variable (henceforth the "NC" regime). (3) The free–trade regime is a situation in which the government commits to non–intervention, that is, to no tariff or subsidy program. In our setup this is equivalent to committing to zero tariff or export subsidy (henceforth the "FT" regime).[7] Following Neary and Leahy (2000) and Leahy and Neary (2001), we assume that the government can always precommit to R&D subsidies.

As already mentioned, we do not explore all possible second-best policies. The reason for this is that, we believe, it suffices to focus only on the simplest cases with one policy instrument to grasp the difference between the third-market and the home-market policies and the accompanied government's (in)ability to precommit. Even if we reasonably restrict the second-best policies by assuming that the government's inability to precommit to an export subsidy also implies its inability to precommit to tariffs, there will be in total eleven different second-best policies given the above assumption that the government always commits to an R&D subsidy. This, however, does not mean that the

[7] In a more complex setup, setting an instrument to zero may not be equivalent to committing to free trade due to the different strategic implications of these two situations (see, for instance, Gruenspecht,1988 or Arvan, 1991). For the whole spectrum of possibilities of commitment patterns between firms and the government in a dynamic games setting under the third-market assumption, see Leahy and Neary (1996).

second-best policies that are not under consideration are not interesting *per se.* This is certainly not the case and we briefly comment on this issue in the conclusion.

As for the technical details of the basic models, much like in the related literature (see, for instance, Grossman and Maggi, 1998; Neary and Leahy, 2000 and Ionaşcu and Žigić, 2005), we make use of the "linear-quadratic" example. More specifically, we assume the inverse demand functions in both markets to be linear and, for simplicity, with the same intercept A (with units chosen such that the slope is one). That is, $P = A - Q$ where $Q = q_d + q_f$ and $P_e = A - Q_e$ where $Q_e = q_e + q_{fd}$. The parameter A captures the size of each market and q_d and q_f denote the domestic and foreign firm outputs on the home market, respectively, while q_e stands for the home firm's export to the foreign country and q_{fd} stands for the foreign firm's output in its domestic market.

The strategic variable that we label y can assume various interpretations, like upfront investment in capital or knowledge as in Grossman and Maggi (1998), or a variable related to R&D investment ("R&D cost function" as in Žigić, 2004 or Ionaşcu and Žigić, 2005). The point is that in each of these interpretations, these investments are assumed to reduce the marginal costs of the domestic firm by y. We assume that the "R&D cost function" has a quadratic form, y^2/g, where g is a parameter capturing the efficiency of marginal cost reduction (the parameter g is directly related to the parameter k used in Grossman and Maggi, 1998 or Karp and Perloff, 1995, who interpret it as the cost of capital or investment, with g = 1/k). We stick to the specific functional form of the R&D cost function to state our results as sharply as possible.

The domestic firm is assumed to have initial constant unit variable costs of production α, with $A > \alpha$, where parameter α can be thought of as pre-innovative constant unit costs describing an old technology initially accessible to both domestic and foreign firms. We assume that α is always big enough so that $y \leq \alpha$ holds in equilibrium.

Consequently the post-innovative unit cost[8] of the domestic firm is now expressed as $c_d = \alpha - y$ and the corresponding unit cost of the foreign firm is $c_f = \alpha - \beta y$, where $\beta \in [0,1]$ stands for the R&D spillovers parameter.

Social welfare (W) in the considered second-best setting always contains the domestic firm's profit (Π_d) and domestic consumer surplus (S_d). The consumer surplus is defined as $S_d(q) = \int_0^q P(z)dz - qP(q)$ that in the case of a linear demand reduces to $S_d = (½)(q_f + q_d)^2$. If the second-best policy is of the export-support kind (that is, a third-market policy), or of the R&D-support type, then the subsidy expenditures $T = sq_e$ and R&D subsidies $T_y = s_y \frac{y^2}{g}$ have to be subtracted from social welfare. In the case of import protection (that is, a home-market policy), tariff revenue $R = tq_f$ has to be added to domestic profit and consumer surplus. Finally, the domestic and foreign firms' profits (that nest all three policy instruments) are respectively given as:[9]

$$\Pi_d = (A - Q)q_d + (A - Q_e)q_e - c_d(q_d + q_e) + sq_e - (1 - s_y)\frac{y^2}{g}$$

$$\text{and } \Pi_f = (A - Q)q_f + (A - Q_e)q_{fd} - c_f(q_f + q_{fd}) - tq_f .$$

As for the other model assumptions and restrictions, they are primarily concerned with the issue of the existence and viability of a duopoly on both the home and the foreign markets and the well-defined maximization problems that in turn require constraints on the R&D cost function, y^2/g. For a duopoly to be a viable market structure in every regime, it is necessary that a strategy leading to the elimination of the foreign competitor— "strategic predation"— would be too expensive and is never optimal for the

---

8 In the rest of the paper, we use the term "unit costs" instead of the more correct "unit variable costs".
9 Subscript "d" is omitted when it is obvious that we deal with domestic profit.

domestic firm.[10] Thus, the marginal cost of the unit cost reduction, 2y/g, has to be "steep enough" so that its intersection with the accompanying marginal benefit occurs at a level of y^* such that $0 < y^* < y^p \leq \alpha$, where y^* is the optimal unit cost reduction in a duopoly and y^p is the level of unit cost reduction that leads to zero output of the foreign firm in equilibrium. More specifically, it means that the size of the parameter g should not be "too large" implying an upper bound on g such that for all values of g below this upper bound all problems and variables under consideration would be well defined (e.g. the duopoly is both feasible and socially an optimal market structure, all relevant values are positive, second-order conditions are satisfied, etc.).[11] The conditions on g and β that satisfy the above restrictions are derived in Appendix 1 for all the setups under consideration. We assume further that both g and β take these feasible values.

3.2. The non-commitment, commitment and Free-Trade regimes and the first-best setup

Given our current framework in which the government relies on trade policy, it could be argued that the assumption of a non-committed government is a natural one and the one that is easier to justify than its committed counterpart. As noted by Kydland and Prescott (1977), the necessary condition for a government to lack commitment ability is that it finds itself in a second-best situation. This is a typical situation with trade policy since a reliance on trade policy in general implies that the government for some reason does not have other, less distortionary instruments at its disposal (see Staiger, 1995). In such circumstances the government has an incentive to surprise firms by unexpected

[10] Similarly, we assume that it is not feasible for the domestic government to set either tariffs or subsidies so high as to attain domestic-firm monopoly on any of the considered markets. This, for instance, would trigger the reaction of the foreign government, and thus would not ever be optimal to undertake.

[11] Following an alternative interpretation (e.g. Grossman and Maggi, 1998 or Karp and Perloff, 1995) the upper bound on g is equivalent to the lower bound on the cost of capital, k. The reason is that the low cost of capital may lead to high investment in R&D that in turn results in drastic innovation and the exit of the foreign firm.

policies. For instance, in our setup the policy makers are tempted to announce a "high" tariff to enhance the domestic firm's incentive to invest in socially insufficient R&D investment (or unit cost reduction). Then if the domestic firm believes this announcement and makes the corresponding R&D investment, it becomes optimal for the government to renege *ex post* on its promise and set a lower, less distortionary tariff. Finally, the fact that the government in our setup relies on strategic trade policy whose successful application requires a high degree of flexibility and discretion, reinforces the case of the non-committed government.[12]

The above setup implies strategic interaction between the domestic government, the domestic firm, and the foreign firm, and it can be depicted by means of a sequential, three-stage game. The first stage of the game is the one in which the domestic firm strategically chooses its innovation effort and consequent unit cost reduction. In the second stage, the non-committed government sets the tariff on imports or export subsidy after it observes the firm's choice of y. Finally, in the last stage, the firms select quantities and consequently, profits and welfare are realized.

If, on the other hand, we assume that the government somehow possesses the ability to commit to its policy prior of any strategic move (investment) by the domestic firm, we speak about a C regime. Much like the above case, this can again be captured by an appropriate three-stage game. The only formal difference from the NC regime is that the first two stages are reversed. Thus, the government now credibly commits to either tariffs or export subsidy levels in the first stage of the game. In the second stage, the domestic firm strategically chooses its innovation effort and the consequent unit cost reduction. Finally, in the last stage the firms choose their equilibrium quantities.

[12] Ultimately, the (in)ability of the government to commit to its policy depends on the strength of the country's institutional and political setup.

In the case of free trade, the government is assumed to be able to commit to non-intervention, and in our setup this is equivalent to precommitment to zero tariffs, export subsidies or R&D subsidies (see Footnote 7).

As for the first-best setup, it refers here to the situation in which the government, besides tariffs and export subsidies, also sets R&D investment subsidies (taxes), and among other things, the R&D and the output levels in this setup serve as benchmarks for over/underinvestment and over/underproduction, respectively. Before we proceed, it should be made clear that the term "first-best" is not completely appropriate in this setup.[13] We nonetheless stick to the term "first-best" to distinguish it from the one-instrument "second-best" policy and also because the idea of the first-best policy was already used in related literature (see, for instance, Neary and Leahy, 2000, which, in an analysis of a third-market setup, calls the combination of two instruments like output and R&D subsidies the "first-best" policy).

4. Home-market policies—import tariffs

4.1. NON-COMMITMENT REGIME: TARIFFS, R&D AND WELFARE

The only policy instrument under consideration here is the import tariff. We proceed by solving the game backwards. In the last (third) stage, the firms choose the equilibrium quantities. The domestic firm maximizes

$$\underset{q_d, q_e,}{Max}[\Pi_d] = (A - Q)q_d + (A - Q_e)q_e - c_d(q_d + q_e) - \frac{y^2}{g}, \tag{1.a}$$

[13] The "true" first-best policy would involve four policy instruments: an import tariff, an output subsidy, an export subsidy and a R&D subsidy or tax. However, the optimal output subsidy would in our setup induce the domestic firm to produce at the point where marginal costs equal price, which in turn would imply that the domestic firm alone serves both the home and foreign markets. That is, the optimal market structure would be a domestic monopoly on both markets. Since the duopoly interaction between the domestic and foreign firms on both markets is at the core of our analysis, the issue of an optimal output subsidy naturally has to be disregarded. More generally, the output subsidy is considered to be unrealistic (Dixit, 1988) and due to its heavy informational content often an infeasible and impractical instrument (Bhattacharjea, 1995).

given q_f and q_{fd}. The first-order conditions for an interior maximum are $\partial\Pi_d / \partial q_d = 0$ and $\partial\Pi_d / \partial q_e = 0$ yielding $A - 2q_d - q_f - c_d = 0$ and $A - 2q_e - q_{fd} - c_d = 0$.

The maximization problem for the foreign firm is

$$\underset{q_f, q_{fe}}{Max}[\Pi_f] = (A - Q)q_f + (A - Q_e)q_{fd} - c_f(q_f + q_{fd}) - tq_f, \quad (1.b)$$

given q_d, q_e and t. The first-order conditions are $A - 2q_f - q_d - c_f - t = 0$ and $A - 2q_{fd} - q_e - c_f = 0$.

Solving the reaction functions yields the Cournot outputs as a function of y and t:

$$q_d(y,t) = \frac{(A + c_f(y) - 2c_d(y) + t)}{3} \quad (2.a)$$

$$q_f(y,t) = \frac{(A - 2c_f(y) + c_d(y) - 2t)}{3} \quad (2.b)$$

$$q_e(y) = \frac{A + c_f(y) - 2c_d(y)}{3} \quad (2c)$$

$$q_{fd}(y) = \frac{A - 2c_f(y) + c_d(y)}{3}. \quad (2d)$$

Substituting (2.a), (2.b), (2c) and (2d) into (1.a) yields the domestic firm's profit function expressed in terms of R&D and tariffs:

$$\Pi_d^*(y,t) = \frac{(A + c_f(y) - 2c_d(y) + t)^2 + (A + c_f(y) - 2c_d(y))^2}{9} - y^2/g. \quad (3)$$

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

$$W(t) = \Pi(t) + S_d(t) + R(t), \tag{4}$$

where consumer surplus, $S_d(t)$ and tariff revenue $R(t)$ are respectively given by

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

and

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

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

The constraints on g and β (see Appendix 1) ensure an interior maximum such that $t_{nc}^* < t_p$ and the optimal tariff t_{nc}^* is obtained by solving $\partial W / \partial t = 0$, yielding

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

There are several interesting observations to be made about the above optimal tariff t_{nc}^*. First, note that it is independent of the functional form of the R&D cost function. Second, when β=0, the expression for t^*_{nc} is a pure profit-shifting tariff[14] (see Bhattacharjea, 1995) and it does not depend either on the domestic unit cost (α in (7) represents foreign firm unit costs), or on the domestic strategic variable y.[15] The latter is rather important for us because it indicates that the manipulation of the government by the domestic firm (in the form of overinvesting in y) is not possible here without spillovers. Finally, given the fact that in an NC regime, the government lacks the ability to precommit to the tariff before the firm chooses y; the tariff t^*_{nc} is time consistent.[16]

In the first stage of the game, the domestic firm selects the optimal level of marginal cost reduction, y, taking into account the subsequent impact on the foreign rival's behavior. By substituting t^*_{nc} into (3) we obtain:

$$\Pi^{\circ}_{d}\left(y, t^*_{nc}(y)\right) = \Pi^{\circ}_{d}(y) = \frac{4([2(A-\alpha)+(3-\beta)y]^2 + 9((A-\alpha)+(2-\beta)y)^2}{81} - \frac{y^2}{g}. \qquad (8)$$

Maximizing (8) with respect to y gives the optimal y^*_{nc} and by substituting it into (5), (6), and (8) and summing these three items, we obtain the optimal social welfare in terms of the model parameters in the NC regime (see Appendix 2 for all optimal values expressed in model parameters).

4.2. Commitment regime, free-trade regime and the first-best setup

[14] More precisely, it is equivalent to the standard strategic tariff that leads to improvement in terms of trade and to production efficiency gains (see Helpman and Krugman, 1989).

[15] The reason for this lies in the property of linear inverse demand. In the case of linear demand, the unit costs of the domestic firm cannot be influenced by the firms' actions after the tariff is set (see Bhattacharjea, 1995 and Baghdasaryan and Žigić, 2010). Therefore the optimal non-commitment tariff is $t^*_{nc} = (A - c_f)/3$, regardless of c_d. Thus, if the foreign firm's unit cost does not depend on y, then neither does t^*_{nc}. This result is, however, not true for a general demand function, where the presence of spillovers re-establishes a general link between tariffs and R&D.

[16] A sufficient and standard procedure that we apply to solve for a time-consistent tariff is the concept of subgame perfect equilibrium (see Fesrthman,1989).

We now briefly characterize the optimal tariff, unit cost reduction and social welfare in the C regime, free-trade, and first-best framework and then make relevant comparisons across the regimes.

a) The commitment regime

The maximization of (3) with respect to y gives the first–order condition that determines the optimal y (but now as a function of the tariff):

$$\frac{2}{9}\left((A-\alpha+(2-\beta)y)(2-\beta)+(2-\beta)(A-\alpha+(2-\beta)y+t)\right)=\frac{2y}{g}. \tag{9}$$

Label it as $y_c^*(t)$ and the explicit value of unit cost reduction is now

$$y_c^* = \frac{(2(A-\alpha)+t_c^*)(2-\beta)g}{9-2g(2-\beta)^2}. \tag{10}$$

Straightforward substitution of $y_c^*(t)$ into the social welfare function yields the government objective function $W_c^*(y_c(t_c),t_c)$ to be maximized in the first stage. Setting $dW_c^*/dt=0$ yields the optimal tariff t_c and then it is straightforward to calculate the optimal social welfare in the C regime as a function of the model parameters (see Appendix 2 for optimal values expressed in model parameters). The restriction on g and β makes sure that the tariff t_c^* lies between zero and the corresponding predatory tariff t_p.

b) Free Trade

As for the free-trade regime, it is equivalent to precommitting to zero tariffs, so obtaining the respective comparable equilibrium values (that we label with subscript "ft'') is straightforward (see Appendix 3 for the optimal values expressed in model parameters).

c) The first-best outcome

Recall that in the first-best setup the government can select all three available instruments: tariffs, export subsidies and R&D subsidies. Thus, the government would maximize $W_{fb}^{*}(s, s_y, t) = \Pi(.) + S(.) + R(.) - T(.) - T_y(.)$ with respect to s, s_y and t. This optimization gives the first-best R&D and the resulting social welfare as a function of the model parameters (that we label with subscript "fb"; see Appendix 3 for optimal values expressed in model parameters).

A conspicuous feature of our setup is that even in the first-best framework the government may or may not be able to precommit to their output policies, s and t. The direct consequence of this would be that the optimal value of all R&D policy instruments under consideration will be different depending on that government's commitment capability. However, optimal tariffs, export subsidies, social welfare and optimal R&D in the first-best framework would be the same irrespective of the government's ability to commit. We elaborate more on this in Section 6.

4.3. COMPARISON ACROSS THE REGIMES

a) Unit cost reduction and consequent R&D investment

We start with a comparison of unit cost reduction and consequent R&D investment. The direct comparison reveals that the first-best setup yields the largest unit cost reduction while the free-trade regime exhibits the lowest unit cost reduction. As for the ranking of y in the NC and C regimes, it depends on the level of spillovers.

LEMMA 1

Unit cost reduction and consequent R&D investment in any of the regimes (NC, C, FT) are below the corresponding first-best outcome. The optimal unit cost reduction is the biggest in the NC regime provided that R&D spillovers are above a critical level of β^r.(g). The lowest unit cost reduction is in the regime of free trade. Thus $y_{fb}^{*} > y_{nc}^{*} > y_{c}^{*} > y_{ft}^{*}$ for $\beta > \beta^r(g)$. Moreover, $\beta^r(g) < 0.05$ irrespectively of the value of g, (see Appendix 4 for proof).

The relationship between y_c* and y_{nc}* is not obvious *a priori.* On the one hand, the government in the C regime can affect the socially insufficient level of R&D via tariffs, stimulating investment that leads to a higher reduction in unit costs. However, this "technological function" of tariffs is of a limited power due to its offsetting negative side since an increase in tariffs leads to a price increase in equilibrium and thus has an adverse direct effect on consumer surplus. On the other hand, in the NC regime the technological function of tariffs is absent but the Northern firm has an additional, manipulative incentive to invest in R&D in order to elicit a higher tariff from its government that would in turn harm the foreign competitor by increasing its unit costs and thus be beneficial for the domestic firm in both of its markets. This additional motivation to boost a firm's R&D investment, which is not present in the C regime, is aimed towards the domestic government and not directly towards the foreign firm. Thus, roughly speaking, these "manipulating" investments are therefore less vulnerable to spillovers. Consequently, the overall R&D investment in the NC regime (that can conceptually be broken up into two parts: strategic and manipulating R&D investment) is less sensitive to spillovers than the corresponding R&D (and unit cost reduction) in the C regime (where there is only a strategic effect aimed at the competitor). Indeed, $\left|dy_c^*/d\beta\right| > \left|dy_{nc}^*/d\beta\right|$ for all $\beta \in [0,1]$ and for all feasible g(β) (see Appendix 5 for the proof at $\beta = 0$). Moreover, the difference between y_c^* and y_{nc}^* is rather "small" at $\beta = 0$ so the crossing of y_c^* and y_{nc}^* occurs at a low level of spillovers.[17]

Since a tariff ensures a larger market share for the domestic firm at both markets compared to free trade, and thus enhances the firm's incentive to invest in R&D, the respective value in free trade, y_{ft}, assumes the lowest value (see Appendix 4).

b) Tariffs in the C and NC regimes

[17] As a consequence of such different sensitivity, the switch from the top-dog strategy to lean and hungry look strategy occurs at a larger level of spillovers in the NC regime than in the C regime.

As for tariffs in the two "tariff" regimes, they are generally different due to the somewhat different functions that they perform. Namely, a distinctive characteristic of the tariff in the C regime is its "technological function". The committed government that sets the tariff, t_c^*, takes into account the tariff's impact on the subsequent choice of the domestic firm's R&D (note that $dy_c / dt > 0$). Thus, t_c^*, besides its profit shifting role, also has the function of stimulating R&D investment and the more so the larger the efficiency of the R&D investment. Since t_c^* increases in g (note that t_{nc}^* increases in g only if β >0 but at a lower rate than t_c^*), in the absence of a R&D subsidy, 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. This additional role of the tariffs in the C regime indicates that their optimal values may exceed the optimal values of their counterparts in the NC regime given that in the NC regime R&D investment is already in place when the tariff t_{nc}^* is set. So t_{nc}^* has no direct impact on the firm's choice of R&D. Moreover, it is straightforward to check that at β =0, the optimal NC and first-best tariffs are close to each other for spillovers around zero (and equal to each other for β =0, see Appendix 6)

Finally, note that the tariffs in both regimes have an extra role to indirectly boost domestic export (at the expense of the foreign firm) through inducing higher R&D. In other words, we have here a typical Krugman "import protection as export promotion" (see Krugman, 1984).

LEMMA 2

The optimal tariff in the C regime always exceeds the optimal tariff in the NC regime.

A straightforward comparison between the two tariffs reveals that $t_{nc}^* < t_c^*$ for all permissible values of $g > 0$ *and* $\beta \geq 0$. We, however, only prove that it holds for "small" spillovers (see Appendix 6) because it would be sufficient for the purpose of the upcoming social welfare comparisons.

Finally, it is also important to note that the appearance of spillovers triggers an increase in optimal tariffs in both regimes with the corresponding increase being larger in the C regime (that is, $dt_c^* / d\beta > dt_{nc}^* / d\beta > 0$ at $\beta = 0$; see Appendix 6) .

4.4. SOCIAL WELFARE AND R&D SPILLOVERS: NON-COMMITMENT VERSUS COMMITMENT REGIME

It is common wisdom in economics that there is a value in a government's ability to commit to its policy instruments. This value is reflected in the larger social welfare of such a policy capability compared with the situation when this ability is absent. The striking result here, however, is that this common wisdom ceases to be robust in our setup as long as there is only a tiny dose of R&D spillovers.

Proposition 1

Social welfare in the non-commitment regime exceeds the social welfare in the commitment regime as soon as spillovers exceed a rather small threshold level of $\beta^{wt}(g)$. *More specifically,* $W_{nc}^* > W_c^*$ *for a range of parameters* g *and* β *determined by* $g < g_{wt}(\beta)$ *(the threshold level of* β^{wt} *is obtained by inverting -* $g_{wt}(\beta)$*). Social welfare in free trade is always the lowest for all feasible values of the param*eters (*see Appendix 8).*

In order to see why and how the appearance of spillovers leads to a change in respective social welfare rankings, we have to disentangle the marginal effect of spillovers on social welfare, $\frac{dW_i^*(\beta)}{d\beta}$, from its components. Differentiating W^* with respect to β yields:

$$\frac{dW_i^*(\beta)}{d\beta} = \frac{\partial W_i^*}{\partial y}\frac{dy_i}{d\beta} + \frac{\partial W_i^*}{\partial t}\frac{dt_i^*}{d\beta} + \frac{\partial W_i^*}{\partial \beta}, \tag{11}$$

where subscript i stands for either NC or C. From the previous section, we know that $t_{nc}^*(\beta) < t_c^*(\beta)$ and that $dy_i^* / d\beta < 0$ with $|\ dy_c^* / d\beta\ | > |\ dy_{nc}^* / d\beta\ |$ but $y_{nc}^* < y_c^*$ at β = 0. Furthermore, it is easy to check that $W_{nc}^* < W_c^*$ at $\beta = 0$.

It is straightforward to show that the first part of the first term of (11) is positive indicating that the firm's optimal choice of y is below the first-best optimal level in both regimes.[18] This, in turn, implies that the whole first term in (11) is clearly negative. Consequently, the presence of spillovers further exacerbates the socially insufficient level of y and thus negatively affects social welfare.

As for the respective magnitudes of the first terms in the two regimes, the adverse effect is larger in the commitment regime and the gap between $\frac{\partial W_{nc}^*}{\partial y}\frac{dy_{nc}^*}{d\beta}$ and $\frac{\partial W_c^*}{\partial y}\frac{dy_c^*}{d\beta}$ widens as β increases due to the higher sensitivity of R&D to spillovers in the commitment regime (see Appendix 7).

As for the second term in (11), note that in NC regime, the whole second term vanishes since the non-commitment tariff is set at the point where the negative marginal effect of the tariff on consumer surplus and tariff revenue exactly balances the marginal positive effect of the tariff on profit, that is, $\partial W_{nc}^* / \partial t = 0$ holds. This is not the case in the commitment regime where the optimal tariff is, like in the first-best framework, set at the point where the government takes into account the tariffs' influence on a firm's R&D, that is, $\frac{\partial W_c^*}{\partial y}\frac{dy^*}{dt} + \frac{\partial W_c^*}{\partial t} = 0$ has to hold. Since clearly $\frac{\partial W_c^*}{\partial y}\frac{dy^*}{dt} > 0$, the marginal effect of tariffs on social welfare has to be negative at the optimum in the commitment regime,

[18] Evaluating the social marginal welfare, $\partial W_i^*/\partial y$, at the corresponding optimal values of t_i^* and y_i^*, indicates that $\partial W_i/\partial y>0$ in both regimes where i={"c","nc"}.

implying $\partial W_c^* / \partial t < 0$ and indicating again that $t_{nc}^*(\beta) < t_c^*(\beta)$. Thus, the second term in (11) in the C regime, that is, $\frac{\partial W_c^*}{\partial t}\frac{dt_c^*}{d\beta}$, is negative (at least for "small" spillovers) since $dt_c^* / d\beta > 0$ at $\beta = 0$.[19]

Finally, the third term in (11) is negative and of the same order in both regimes. The corresponding negative effect of spillovers on profits slightly offsets the direct positive effects of spillovers on consumer surplus and tariff revenue.[20] The difference between these last effects in (11) in the two reg$\frac{1}{81}(A-\alpha)(6+25\beta)+\gamma(9-6\beta+28\beta^2)$imes turns out to be negligible and thus of second order.

Summarizing the above analysis, it turns out that the key to understanding the intuition behind Proposition 1 stems mostly from the different sizes of the first effects of (11) in the two regimes. The very appearance of spillovers has a bigger adverse effect on R&D investment in the C regime due to its larger R&D sensitivity, causing the whole first part of (11) to fall more in the C regime. On the top of that, the very appearance of spillovers also triggers an increase in the commitment tariff and further exacerbates social welfare (recall that this effect is not present in either the NC regime or in the first-best framework). This effect is, however, of small size (see Footnote 19).

All in all, the very appearance of spillovers leads at the margin to comparatively larger social costs in the commitment regime due to the rising tariff distortion and decreased social gain from the technological role of the tariff (recall that optimal tariffs in the NC and the first-best setup regimes are the same at β=0 and lower than tariffs in the C

[19] In the situation where the domestic firm earns profits on both markets, however, the second term in (11) turns out to be negligible since it is the product of two small numbers.

[20] If the domestic firm operated only on the home market, then the combined effects of spillovers would overcome the negative effect on profit and the last term in (11) would be positive. Note that $\partial S_i^*/\partial\beta > 0$ since an increase in spillovers increases total output *ceteris paribus*. Furthermore, $\partial R_i^*/\partial\beta > 0$ since, other things being equal, an increase in spillovers increases the foreign firm's output in equilibrium and consequently tariff revenue.

regime). More technically, $dW_c^* / d\beta < dW_{nc}^* / d\beta$ holds already at β=0, suggesting that there may be a critical level of spillovers beyond which social welfare in the non–commitment regime starts to dominate its commitment counterpart. Moreover, if the initial difference between W_c^* and W_{nc}^* (when β=0) is "small" enough, the reversal in the rank of these two social welfares may occur at a level of spillovers already "close" to zero and this indeed happens to be the case in our setup.

Given that the difference between the direct effects of spillovers on welfare in the two regimes, $\partial W_c^* / \partial\beta - \partial W_{nc}^* / \partial\beta$, is negligible in the whole interval of β, the sufficient condition for social welfare in the non-commitment regime to dominate its commitment analog is that $y_{nc}^* \geq y_c^*$ since $t_{nc}^*(\beta) < t_c^*(\beta)$. By continuity, of course, the critical point of β at which $W_{nc}^* = W_c^*$ is already reached at the point where $y_{nc}^* < y_c^*$ still holds.

5. Third-market policies—export and R&D subsidies

5.1. NC VERSUS C REGIME: EXPORT SUBSIDIES, R&D AND WELFARE

As for to the third-market policy environment, the domestic and foreign firms' profits are now respectively nested in these profit functions:

$$\Pi_d = (A-Q)q_d + (A-Q_e)q_e - c_d(q_d + q_e) + sq_e - \frac{(1-s_y)y^2}{g} \tag{12a}$$

and $\Pi_f = (A-Q)q_f + (A-Q_e)q_{fd} - c_f(q_f + q_{fd})$, (12b)

and the objective function that nests the government's choice is now

$$W_{fb}^* = \Pi_d^*(\cdot) + S^*(\cdot) - s_y y_i^{*2} / g - sq_e . \tag{13}$$

In order to establish a valid comparison with home-market policies, we first focus on simple second-best policies where only export subsidies are available (thus, $s_y = 0$) and we analogously define the commitment and no-commitment regimes (we attach to the relevant variables the subscripts in capital letters C and NC to distinguish them from the analogous variables in home-market setup). Later on, we also briefly discuss the second-best policy with R&D subsidies only.

Before turning to the analysis, recall that in the standard third-market approach, the first-best policy mimics the behavior of the Stackelberg leader. In that case social welfare coincides with domestic profit that is maximized if the domestic firm acts as a Stackelberg leader (in other words, if the domestic firm happens to be the Stackelberg leader then the optimal export and R&D subsidies would both be zero). This, however, is not anymore the case since social welfare contains also consumer surplus and that has to be taken into account in the selection of the optimal policy instruments.

Solving for the equilibrium in the two regimes, we obtain the equilibrium values of R&D and the optimal export subsidies, and the corresponding social welfares in terms of the model parameters (see Appendix 9).

5.2. COMPARISON ACROSS THE REGIMES

a) Export subsidies in the C and NC regimes

We start with a comparison of the optimal subsidies in the two regimes. Unlike in the third-market case where the optimal subsidies in the NC regime always exceed their counterpart in the C regime, this is not the case here.

LEMMA 3

The optimal C export subsidies exceed their NC counterpart as long as spillovers surpass a particular threshold. That is, $s_C^* > s_{NC}^*$, *as long as g and β are such that* $g < g_S(\beta)$. *Moreover, both optimal export subsidies fall monotonically in spillovers with* s_{NC}^* *being more sensitive to spillovers than* s_C^* *(see Appendices 10 and 11).*

As for the optimal subsidies in the NC regime note that both the direct impact of spillovers on the optimal subsidy $(\frac{\partial s^*_{NC}}{\partial \beta})$ and their indirect effect on it via R&D $(\frac{\partial s^*_{NC}}{\partial y}\frac{dy^*_{NC}}{d\beta})$ are negative. The direct impact, $(\frac{\partial s^*_{NC}}{\partial \beta})$, is negative since an increase in spillovers makes the export subsidy a less efficient instrument to shift profit so the optimal response is to decrease it. The sign of the indirect effect $(\frac{\partial s^*_{NC}}{\partial y}\frac{dy^*_{NC}}{d\beta})$ is also negative because the manipulation effect in NC makes export subsidies an increasing function of R&D , that is, $\frac{\partial s^*_{NC}}{\partial y} > 0$, and since clearly $\frac{dy^*_{NC}}{d\beta} < 0$, we have unambiguously that $\frac{ds^*_{NC}}{d\beta} = \frac{\partial s}{\partial y}\frac{dy^*_{NC}}{d\beta} + \frac{\partial s^*_{NC}}{\partial \beta} < 0$.   .

This double negative effect does not appear in the C regime and so it makes the NC export subsidies more sensitive to spillovers than is the case with the export subsidies in the C regime.

Finally, note that in our setup export subsidies in both regimes have an extra role: to protect the domestic market indirectly (at the expense of the foreign firm) through inducing higher R&D. To paraphrase Krugman (1984), we have now "export promotion as import protection".

b) Unit cost reduction and consequent R&D investment in the C and NC regimes

LEMMA 4

The optimal unit cost reduction is the largest in the NC regime followed by the C regime and then the FT regime. That is, $y_{NC}{}^* > y^*_C > y^*_{ft}$ *for all* $\beta \in [0,1]$. *The position of the optimal unit costs reduction in the first-best setup,* y^*_{fb}, *depends on the level of* *spillovers and for spillovers large enough, it exceeds* ${y_{NC}}^*$. *More specifically,* $y^*_{fb} > {y_{NC}}^*$ *when* g *and* β *are such that* $g < g_{R2}(\beta)$ *(see Appendix 12).*

Recall that in the standard third-market setup (see, for instance, Grossman and Maggi, 1998; Neary and Leahy, 2000 and Žigić, 2007), export subsidies always lead to overinvestment in both the C and NC regimes vis-à-vis the first-best social optimum irrespective of the level of spillovers. This is, however, not the case in our more general framework. As for the C regime, there is generally underinvestment in this regime (unless R&D efficiency is large enough and the level of spillovers is zero or very close to it). As far as the NC regime is concerned, even there spillovers large enough lead to underinvestment from the first-best point of view irrespective of the R&D efficiency (see Appendix 12).

The above differences vis-à-vis the standard third-market setup stem from the mutual presence of both consumer surplus and R&D spillovers. In other words, with only R&D spillovers but without consumer surplus in the welfare function, the outcome would be like in a typical third-market setup. That is, R&D in both the C and NC regimes would exceed the one from the first-best setup. Similarly, without (large enough) spillovers but with consumer surplus in the welfare function, there will again be only a standard overinvestment result in equilibrium.

The point is that both the presence of consumer surplus and increasing spillovers tend to reduce and eventually overturn the overinvestment in R&D. First, the manipulating behavior of the domestic firm is beneficial for consumer surplus since $\partial {S_d}^* / \partial y > 0$, so the social optimal level of R&D is clearly higher than in the standard third-market setup. Yet even with consumer surplus considerations, manipulation incentives are so strong that there is still overinvestment in R&D in the NC regime unless spillovers are large enough. The appearance of spillovers dampens these manipulative incentives of the domestic firm due to its obvious disincentive to invest in R&D, and, more importantly, because of their adverse effect on the optimal subsidy. Finally, as we already suspected, there is always underinvestment in the free-trade regime.

5.3. SOCIAL WELFARE AND R&D SPILLOVERS: NC VERSUS C REGIME AND FREE TRADE

Before the comparison of the social welfares, recall the main findings of the standard third-market setup: i) social welfare in free trade exceeds the social welfare in the NC regime when R&D efficiency is "large enough" and spillovers are "low enough" and ii) social welfare in the C regime dominates its counterpart in the NC regime. As is clear from Figure 1, both i) and ii) can occur in the equilibrium in our integrated setup.

The most conspicuous finding in our setup, however, is that for spillovers large enough, social welfare in the NC regime dominates not only social welfare in free trade but also social welfare in the C regime (see Figure 1). Thus, for large spillovers, the relation between the corresponding social welfares is the same as in the standard home-market setup (see Žigić, 2007) and is in sharp contrast with the finding in the standard third-market setup where social welfare in the NC regimes is always inferior to its C counterpart.

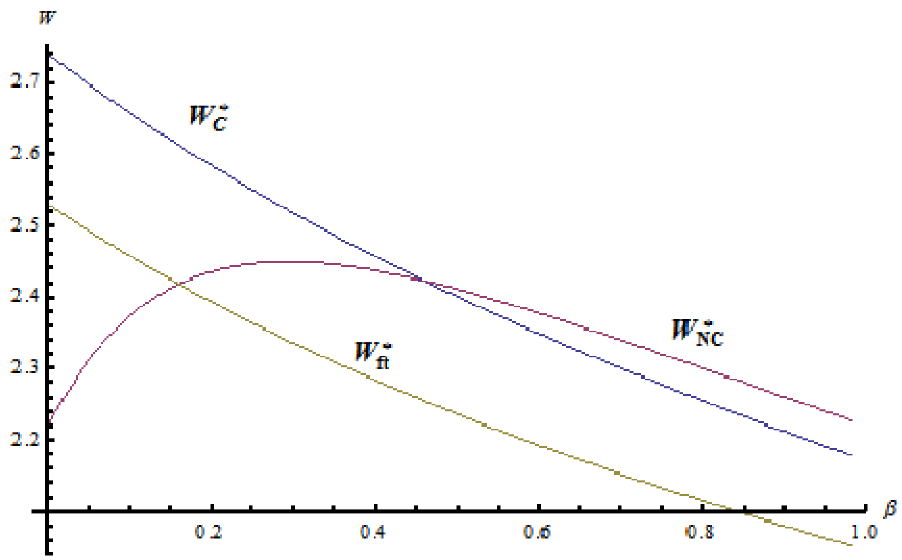

Figure 1

Proposition 2

Social welfare in the NC regime exceeds social welfare in both the free-trade regime and the C regime when R&D spillovers exceed a particular threshold, β^{ws} *. More specifically,* $W_{NC}{}^* > W_C{}^* > W_{ft}^*$ for a range of parameters g and β *determined by* $g < g_{ws}(\beta)$ *(see Appendix 13).*

Recall that an increase in spillovers not only dampens R&D investment but also pushes down the optimal export subsidy in the NC regime. The NC subsidies are manipulative, so they positively depend on the size of R&D. Since spillovers dampen R&D, they also soften the manipulative incentives and lead to a decrease in the optimal subsidy. Moreover, there is a direct negative effect of spillovers on s^*_{NC} since, as we argued, an increase in spillovers makes the export subsidy a less efficient instrument.

Due to the above two negative effects, s^*_{NC} falls below its counterpart in the C regime for spillovers large enough and so becomes closer to the first-best subsidy and thus less distortionary. In the jargon of international trade, such a lower export subsidy causes a smaller worsening of terms of trade and, *ceteris paribus*, is more beneficial for social welfare than the larger s*C subsidy. Thus, $s_{NC}^{\;*} < s_C^*$ is a necessary condition for $W_{NC}^{\;*} > W_C^*$ to hold.

As for the sufficient condition, note that for spillovers large enough, overinvestment gets milder and eventually disappears. Thus $y_{NC}^{\;*}$ intersects y_{fb}^* from above at some point β when spillovers are large enough and, more interestingly, this takes place in the region where g and β are such that $g < g_{ws}(\beta)$.[21] Note also that at the intersection of $y_{NC}^{\;*}$ and y_{fb}^*, we also have that $s_{NC}^{\;*} = s_{fb}^*$. Thus, for $W_{NC}^{\;*} > W_C^*$ to hold it is sufficient to have $y_{NC}^{\;*} \le y_{fb}^*$ (see Appendix13) while for $y_{NC}^{\;*} > y_{fb}^*$ "close enough" to y_{fb}^* (given that $s_{NC}^{\;*} < s_C^*$), $W_{NC}^{\;*} > W_C^*$ would also hold (see Appendix13).

An alternative and more direct way to explain the intuition that $W_{NC}^{\;*} > W_C^*$ for large enough β is to look at the behavior of the elements of social welfare (profits, consumer surplus and subsidy costs) when the level of spillovers changes. Note that for zero or low spillovers and large R&D efficiency, the incentives of the domestic firm to manipulate its government and elicit export subsidies are very strong. Besides the direct effect on subsidy revenue, inducing large subsidies also helps to increase (net of subsidies) the profit and market share of the domestic firm both directly and indirectly on both the domestic and the foreign markets. Thus, without R&D spillovers (or when spillovers are small) the profit is bigger in the NC regime than in the C regime. The dominance of consumer surplus in the NC regime vis-à-vis the C regime is even more pronounced since it holds irrespective of the level of spillovers because consumer surplus is an increasing function in R&D and, as we know, $y_{NC}^{\;*} > y_C^*$ for all $\beta \in [0,1]$. What,

[21] That is, all pairs of β and g are such that $g = g_{R2}(\beta)$, and all these pairs are within the region where $W_{NC}^{\;*} > W_C^*$ holds (see Lemma 4 and Appendix 13).

however, depresses social welfare in the NC regime so much that it might be even inferior to social welfare in free trade are the huge social costs of subsidies measured in terms of the subsidy expenditures of the government. The appearance of spillovers and their further increase softens the manipulation incentives and, as we know, doubly induces a fall in subsidy costs, both via the fall in y and via the fall in s_{NC}. After a particular level of spillovers is attained, these costs fall below the counterpart in the C regime. The profits in the NC regime, however, also fall faster in spillovers than in the C regime and become lower than in the C regime after a certain level of spillovers is exceeded. Nonetheless, when spillovers reach a level large enough, then a larger consumer surplus and lower subsidy costs in the NC regime would more than compensate for the profit difference and result in ${W_{NC}}^* > W_C^*$.[22] Moreover, this occurs irrespective of the size of g, once spillovers reach a level of 0.6 or higher (see Appendix 13).

As for the second-best policy with R&D subsidy only, it is well-known that it is positive in a setup where both firms invest in R&D (see, for instance, Neary and Leahy, 2000 and Karp and Perloff, 1995). This is also the case in our setup. Moreover, since the R&D subsidy is assumed to be the only available instrument in this case, it is larger than in any other setup under consideration. The reason is that the R&D-subsidy-alone policy takes over the role of the missing tariffs and export subsidies in order to improve both domestic and export output of the home firm (profit shifting), besides correcting for insufficient social R&D investment. It is a rather coarse instrument though, so it is no wonder that R&D subsidies and consequently R&D investments are the largest in this

[22] Note that much like in the case of subsidies, the necessary condition for ${W_{NC}}^* > W_C^*$ is that the subsidy costs in the NC regime should be lower than in the C regime. Since ${y_{NC}}^* > y_C^*$ for all $\beta \in [0,1]$, this condition is more restrictive than the condition ${s_{NC}}^* < s_C^*$ (see Appendix 13).

simple setup exceeding R&D subsidies and R&D investments in all regimes as well as in the first-best setup.[23]

6. The first-best policy versus the second-best policy

The second key topic that we now focus on is the robustness test of the sign of the R&D policy instrument when passing from the first- to the second-best policy (or vice versa). More precisely, the previous literature pointed to the non-robustness of the sign of the R&D subsidies in the third-market setup when passing from the second- to the first-best setup (see, for instance, Neary and Leahy, 2000). So it is well known that in that framework (in the benchmark case of Cournot competition) the R&D subsidies are positive in the second-best policy setup (R&D-subsidy-only policy), but then turn out to be negative (R&D tax) when the first-best policy (export subsidy and R&D subsidy) is implemented.

The situation in our integrated, intra-industry trade setup is, however, more complicated since there is more than one second-best policy (in fact, there are five second-best policies containing an R&D subsidy/tax). For instance, the simplest one is where there is only a R&D subsidy, so passage to the first-best policy would imply adding both tariffs and export subsidies. Equally interesting would be a second-best policy with R&D subsidies and either tariffs or export subsidies so that passing to the first-best would require adding only one instrument. Moreover, both of these two policies could come in either commitment or non-commitment form.

Even the first-best setup is not uniquely defined. Given our assumption that the government always pre-commits to R&D subsidies, tariffs and export subsidies can be

[23] In fact, the size of the optimal R&D subsidy is such that it would restrict the upper bound on g much more than any other second-best policies or first-best policy in order for the duopoly to exist. Since we focus on the output of second-best policies we ignore this constraint stemming from the R&D-subsidy-only policy.

chosen either before the firm's R&D choice (commitment case) or after it (non-commitment case). Recall that the underlying framework of the first-best setup could be represented as a four-stage game whereby the government sets an R&D subsidy in the first stage. In the non-commitment case the domestic firm selects R&D in the second stage, the government sets tariffs and export subsidies in the third stage and finally the foreign and domestic firms compete in quantities in the last stage.[24] The commitment case is a similar four-stage game with the third and second stage reversed; that is, the government commits to the export subsidies and tariffs in the second stage while the domestic firm chooses R&D in the third stage.

To illustrate the robustness of the sign of the R&D subsidy in our setup, we take as a point of departure the second-best policy that comprises R&D subsidies and tariffs so the passage to the first-best setup would imply adding only export subsidies. Moreover, we take the non-commitment version of this policy since it contains a manipulation effect via the tariff that pushes investment in R&D upwards. Nonetheless, the R&D subsidy is always positive for any level of spillovers in this setup (implying that it would also be positive in the corresponding commitment regime since there is no manipulation effect in this regime).[25]

As for the first-best setup, it is striking that the different sequencing (stemming from the commitment versus non-commitment issue) may lead to a different sign of the optimal values of the first-best R&D instrument. Of course, the optimal values of the first-best R&D and social welfare are independent of policy sequencing and are the same in both cases. On top of that, the size of the spillovers ultimately determines the sign of the

[24] As we already claimed, this timing reflects the stylized fact that it is easier for a government to commit to an R&D subsidy than to output policies like export subsidies or tariffs (see Carmichael, 1987 and Leahy and Neary, 2001).

[25] Clearly R&D is always positive when the R&D subsidy is the only available policy instrument and it turns to be always negative (R&D tax) when the second-best policy is the one with R&D and NC export subsidy due to a very strong manipulation effect.

optimal R&D instruments in these two setups. Thus if in the first-best setup both export subsidies and import tariffs are set after the domestic firm's choice of R&D (non-commitment case), this would encourage the domestic firm's manipulative behavior and would result in overinvestment from the first-best point of view, unless the level of spillovers is rather high. To prevent this, the government sets an optimal R&D tax to fully offset such behavior so indeed the sign of the optimal policy instrument is not very robust in the absence of government commitment (see Appendix 14). If, on the other hand, the tariffs and export subsidies are set before the firm's choice of R&D, then the manipulative behavior is suppressed so the optimal R&D instrument will be in general positive (R&D subsidies) unless spillovers are rather low. For zero or very low spillovers, however, the R&D tax would be still optimal even if the government commits to both tariffs and export subsidies, since both of these instruments, while targeted on foreign and domestic outputs, respectively, have positive "side effects" on the firm's R&D. Thus, the R&D tax is needed to correct these effects when spillovers are low or zero (see Appendix 14).

Proposition 3

If in the first-best setup the government is able to commit to its output policies (tariffs and export subsidies) and R&D spillovers are large enough, then the R&D subsidy is a robust instrument given that it was positive in the considered second-best policy. If, on the other hand, there is no government commitment to the output policies and spillovers are not very large, then the optimal policy is the R&D tax and thus it is not a robust policy instrument given that the R&D subsidy was optimal in the considered second-best policy (see Appendix 14 for an illustration).

7. Conclusion

The third-market setup used to be a standard setup within a strategic trade policy framework to study normative issues of government commitment and the robustness of a particular policy instrument. The typical policies used in this setup are export and R&D subsidies. There are two conspicuous findings in this framework: i) free trade can be a better choice than an active policy (in terms of social welfare) for a government that has no commitment capability and ii) R&D subsidies is not a robust policy instrument since it is positive if it is the only policy instrument (second-best policy) but then turns out to be an R&D tax when an export subsidy is added (first-best policy). Žigić (2003) and (2007), on the other hand, showed that these findings do not hold in the home-market setup where the considered instruments were R&D subsidies and tariffs. More specifically, the social welfare that the non-commitment government generates always dominates the social welfare in free trade, while the R&D subsidy is always positive (either as the only instrument or in combination with tariffs). Moreover, Žigić (2003) and (2007) finds that social welfare in the non-commitment regime exceeds social welfare in the commitment regime provided that there is only a "small" dose of R&D spillovers.

The home- and the third-market setups cannot be, however, directly compared since each has different free-trade and first-best policy benchmarks. So the main aim of this paper was to develop an integrated platform that nests both the third- and home-market setups and that provides us with a consistent comparison within and among home- and third-market policies. For that purpose, we introduced intra-industry trade between the home and foreign country that, in turn, enabled us to have a unique first-best and free-trade benchmark.

We then stuck to the simple second-best policies, which we divided into home-market (tariffs) and third-market (export subsidies) policies.[26] In both situations the government may or may not be able to precommit to its policy instrument. As for the home-market policy, it turns out that a key relation among social welfares vis-à-vis the

[26] Recall that the standard second-best policy in the third-market setup comes in the form of export subsidies while the home-market second-best policy appears in the form of import tariffs.

government's ability to commit remains qualitatively the same as in the standard home-market setup. Namely, social welfare in the non-commitment regime exceeds its counterpart in commitment regime as soon as a certain small threshold of spillovers is surpassed. As for third-market policies, however, this is not quite the case. In that setup, for spillovers large enough, social welfare in the non-commitment regime dominates not only free trade but also the social welfare in the commitment regime. The reason for the latter, as we saw, is that the optimal export subsidy, and consequently the subsidy costs in the NC regime are lower than in the C regime when spillovers are large enough and at the same time overinvestment in R&D is rather softened.

Finally, the government (in)ability to commit is closely related to the issue of the robustness of the R&D policy when passing from the second- to the first-best setup and that was not the case in the standard home- or third-market environment. If the government is able to commit to its output policies, the optimal R&D subsidy remains positive when passing from the first- to the second-best policy for any spillovers above a rather small threshold. If, on the other hand, the latter is not the case, then the R&D subsidy as an optimal second-best instrument turns into an R&D tax unless spillovers are rather large.[27] The intuition is that the lack of commitment would lead to incentives for overinvestment in R&D and overproduction, and an R&D tax curbs these incentives.

Obviously, there is a whole range of other issues concerning the plausible and possibly important second-best policies that we did not study here and that nevertheless deserve attention. For instance, consider the policy in which the government has at its disposal two policy instruments, export subsidies and tariffs, but cannot make a commitment to either of these instruments. The manipulation incentives are now twofold

[27] Although we use a simple, specific model, we manage to illustrate the opposing forces at work that would tilt in one or the other direction of the sign of the R&D subsidy (tax). Changing the functional form is likely to change the specific threshold but it would keep the main insights intact.

since the domestic firm's profits increase in both tariffs and subsidies, and the optimal values of both instruments in turn increase in the firm's R&D investment. Consequently, we can expect large overinvestment and overproduction from the first-best point of view unless spillovers are very high. (Indeed, overinvestment and overproduction is even larger than in the considered second-best policy where there is only the export subsidy and a NC government). It turns out that the government in this setup could be better off if it could constrain itself to only import tariffs provided that spillovers are not too large[28] (irrespective of whether or not the government can precommit to such tariffs). The reason for this result is a high subsidy bill that the above second-best policy with the two instruments induces.

[28] An increase in spillovers, however, reduces these expenditures (via a decline in both optimal subsidies and optimal R&D) and only for very large spillovers the policy with the two instruments would be superior to the single-instrument policy with import tariffs only.

R E F E R E N C E S

Arvan, L., 1991. "Flexibility versus commitment in strategic trade policy under uncertainty: A model of endogenous policy leadership", *Journal of International Economics* 31, 341-355.

Baghdasaryan, D. and Žigić, K. 2010. "Tariffs, Market Conduct, and Government Commitment: Policy Implications for Developing Countries", *Economics of Transition,* 17. 1-32.

Bagwell, K. and R.W. Staiger, 1994. "The Sensitivity of Strategic and Corrective R&D Policy in Oligopolistic Industries," *Journal of International Economics* 36: 133-150.

Bhattacharjea, A. 1995. "Strategic tariffs and endogenous market structures: Trade and industrial policies under imperfect competition", *Journal of Development Economics*, Vol.47, 287-312

Brander, J. 1995. "Strategic Trade Policy", in G.M. Grosman and K.Rogoff editors, *The Handbook of International Economics,* vol. 3. North-Holland, Amsterdam.

Brander, J. Krugman, 1983. "A 'reciprocal dumping' model of international trade," *Journal of International Economics*, Vol. 15(3-4), 313-321.

Carmichael, C .1987. "The Control of Export Credit Subsidies and Its Welfare Consequences," *Journal of International Economics* 23:1-9.

Chin J. C. and G. M. Grossman. 1990. "Intellectual Property Rights and North-South Trade." In R. W. Jones and A. O. Krueger, eds. *The Political Economy of International Trade: Essays in Honor of Robert E. Baldwin*. Cambridge, MA: Basil Blackwell.

Coe, D. and E. Helpman, 1993. "International R&D Spillovers." *European Economic Review*, 39(5), 859-887.

Cooper, R., and Riezman, R., 1989. “Uncertainty and the choice of trade policy in oligopolistic industries”, *Review of Economic Studies*, 56, 129-140.

Deardorff, A.V., 1992. "Welfare Effects of Global Patent Protection." *Economica* 59, 35-59.

Dixit, A. 1980. “Role of Investment in Entry–Deterrence,” *The Economic Journal*, 90, 95-106.

——— 1988. "Anti–dumping and Countervailing Duties under Oligopoly," *European Economic Review* 32: 55-68.

Fersthman, C. 1989. "Fixed Rules and Decision Rules, Time Consistency and Subgame Perfection," *Economic Letters* 30: 191-194.

Fidrmuc, J., Grozea-Helmenstein, D., and A. Wörgötter, 1999: “East-west intra-industry trade dynamics,” *Review of World Economics (Weltwirtschaftliches Archiv),* 135(2), 332-346.

Goldberg, P.K. 1995. “Strategic export promotion in the absence of government precommitment” *International Economic Review*, 36, 407-426.

Griliches, Z. ,1992. "The search for R&D spillovers," *Scandinavian Journal of Economics* 94, S29-S47.

Grossman, G., Lai, E. (2004). International Protection of Intellectual Property. *American Economic Review*, 94(5), 1635-1653.

Grossman, G. M. and G. Maggi. 1998. "Free Trade versus Strategic Trade: A Peek into Pandora's box." in R. Sato, R.V. Ramachandran and K. Mino (eds.), Global Competition and Integration, Kluwer Academic Publishers, Boston/Dordrecht/London, 9-32.

Gruenspecht, H.,K. 1988. ”Export Subsidies for Differentiated Products”, *Journal of International Economics*, 24, pp 331-344.

Helpman, E. and P.R. Krugman, 1989. *Trade Policy and Market Structure*, Cambridge, Mass. and London: MIT Press.

Hinloopen, J. 1997. "Subsidizing Cooperative and Noncooperative R&D in Duopoly with Spillovers", *Journal of Economics,* Vol. 66, No.2. pp 151-175.

Hwang, H., and Schulman, C. T., 1993. “Strategic non–intervention and the choice of trade policy for international oligopoly”, *Journal of International Economics*, 34,73-93.

Ionaşcu, D. and Žigić, K. 2005. “Free Trade versus Strategic Trade as a Choice between Two “Second–Best” Policies: A Symmetric versus Asymmetric Information Analysis”*, International Economic Journal*, Vol. 19, No. 3, 417-446.

Karp, L.S. and J.M. Perloff, 1995. "The failure of strategic industrial policies due to manipulation by firms," *International Review of Economics and Finance 4*, 1-16.

Krugman, P.R 1984. “Import Protection as Export Promotion” in H. Kierzkowsky, editor, *Monopolistic Competition and International Trade.* Oxford. Blackwell.

Kydland, F.E and E.C Prescott, (1977). “Rules rather than discretion: The inconsistency of optimal plans,” *The Journal of Political Economy*, Vol. 85, No.3, 473-492.

Lai, E.L.-C., Qiu, L.D., 2003. “The North’s intellectual property rights standard for the South?” *Journal of International Economics,* 59, 183–209.

Leahy, D. and J.P. Neary. 1996. "International R&D rivalry and industrial strategy without government commitment," *Review of International Economics*, 4, 322-338.

——— 1997. "Public Policy Towards R&D in Oligopolistic Industries." *American Economic Review* 87: 642-662.

——— 1999. “R&D spillovers and the case for industrial policy in an open economy”, *Oxford Economic Papers*, 51. 40-59.

——— 2001. "Robust rules for industrial policy in open economies," *Journal of International Trade and Economic Development*, 10:4, 393-409.

Maggi, G. 1996. “Strategic Trade Policies with Endogenous Mode of Competition,” *The American Economic Review* 86(1): 237-258.

Neary, J.P. 1991. “Export Subsidies and Price Competition” in E. Helpman and A.Razin (eds.): International Trade and Trade Policy, Cambridge, Mass., MIT Press, 80-95.

——— 1994. "Cost Asymmetries in International Subsidy Games: Should government help winners or losers", *Journal of International Economics*, 37, 197-218.

Neary, J.P. and D. Leahy, 2000. "Strategic trade and industrial policy towards dynamic oligopolies," *Economic Journal* ,100, 484-508.

Neary, J.P. and P. O'Sullivan, 1999. "Beat 'em or join 'em?: Export subsidies versus international research joint ventures in oligopolistic markets," Discussion Paper No.1916, London, CEPR.

Qiu, L. D., and E.L.-C. Lai, 2004. "Protection of Trade for Innovation: The Roles of Northern and Southern Tariffs." *Journal of Japan and World Economy*, 16, 449–470.

Shivakumar, R., 1993. “Strategic trade policy: Choosing Between export subsidies and export quotas under uncertainty”, *Journal of International Economics*, 35, 169-183.

Spencer, B.J. and J.A. Brander, 1983. "International R&D rivalry and industrial strategy," *Review of Economic Studies*, 50, 707-722.

Staiger, R. W, 1995. "International Rules and Institutions for Trade Policy," in Gene M. Grossman and Kenneth Rogoff (eds.), *The Handbook of International Economics*, vol 3, North Holland, Amsterdam.

Staiger, R. W & G. Tabellini, 1987. "Discretionary Trade Policy and Excessive Protection," *American Economic Review*, vol. 77(5), pages 823-37.

——— 1989. "Rules and Discretion in Trade Policy", *European Economic Review*, 33: 1265-1277.

Tharakan, P.K. M., and B.Kerstens, 1995. "Does North-South horizontal intra-industry trade really exist? An analysis of the toy industry," *Review of World Economics (Weltwirtschaftliches Archiv)*, 131(1), 86-105.

Žigić, K. 1998. "Intellectual Property Rights Violations and Spillovers in North–South Trade," *European Economic Review* ,Vol .42, 1779-1799.

——— 2000. "Strategic trade policy, intellectual property rights protection, and North–South trade", *Journal of Development Economics*, Vol. 61: 27–60.

——— 2003. "Does "Non–Committed" Government always generate lower social welfare than its "committed" counterpart?" CEPR Discussion Paper, No. 3946.

——— 2007. "Government's (In)ability to Precommit and Strategic Trade Policy: The "Third Market" versus the "Home Market" Setup", CERGE-EI Working Paper No.319

Appendix 1: Viability of duopoly—feasible values of g and β

For duopoly to exist in any setup under consideration, it is crucial for the output of the foreign firm to be positive on both home and foreign markets.

i) For R&D spillovers zero or small, the most restrictive condition for duopoly to exist stems from the requirement that foreign output on the foreign market has to be positive when the domestic government imposes export subsidies and lacks the ability to commit. This is expected since for zero or low spillovers, the optimal NC subsidy is large, leading to huge overinvestment in R&D and consequently to suppressed output of the foreign firm on its own market. Evaluating $q^*_{fd}(.) = \frac{(A - s - \alpha - y(1-2\beta))}{3}$ at $y = y^*_{NC}$ and $s = s^*_{NC}$, and solving $q^*_{fd}(.) = 0$ for g, gives us the condition $g_{fs1}(\beta) = \frac{9}{13(2-\beta)(1-\beta)}$.

(ii) For a bit larger spillovers, the feasibility of duopoly stems from the requirement that the foreign output (on the home market) in the first-best setup has to be positive. Thus, evaluating $q^*_{f}(.) = \frac{(A - 2t - \alpha - y(1-2\beta))}{3}$ at $y = y^*_{fb}$ and $t = t^*_{fb}$, and solving $q^*_f(.) = 0$ for g gives us the condition $g_{fs2}(\beta) = \frac{8}{(22-5\beta)(1-\beta)}$.

(iii) Finally, for the rest of the spillover range, the most restrictive condition for duopoly to exist stems from the requirement that $q^*_f(.) > 0$ when the domestic government is able to commit to tariffs (C regime). Thus, evaluating $q^*_f(.)$ at $y = y^*_c$ and $t = t^*_c$, and solving $q^*_f(.) = 0$ for g, gives us the condition

$$g_{fs3}(\beta) = \frac{18}{30 - 5(7-2\beta)\beta + (2-\beta)\sqrt{69 - 4(27-16\beta)\beta}}$$.

The values of $g > 0$ and $0 \le \beta \le 1$ that satisfy the above restrictions are defined as the intersection of the regions $g < g_{fs1}(\beta)$, $g < g_{fs2}(\beta)$ and $g < g_{fs3}(\beta)$ (see Figure 1A) that we refer to as the duopoly feasibility condition *(fs)*

$g < g_{fs}(\beta) = Min[g_{fs1}, g_{fs2,} g_{fs3}]$.

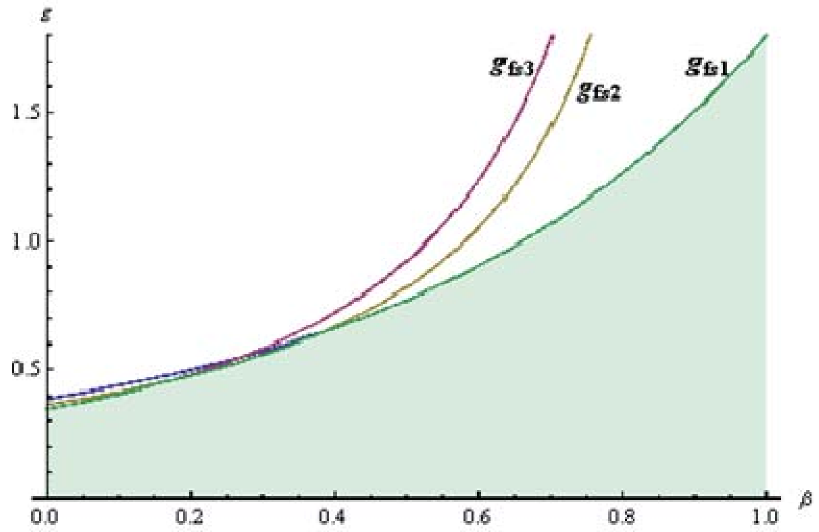

Figure 1A

Appendix 2: Optimal values of R&D, social welfare, and tariffs: the case of the home-market policy

Non-commitment regime

Maximizing the social welfare function $W(t(y), y)$ with respect to t yields the optimal tariff:

$$t_{nc}^{*}(y_{nc}) = \frac{A - \alpha + \beta y_{nc}}{3}, \tag{2A.1}$$

while maximizing the profit function (see expression (8) in the main text) with respect to y gives the optimal y_{nc}^{*}:

$$y_{nc}^{*} = \frac{g(A-\alpha)(42-17\beta)}{81 - g(72-(60-13\beta)\beta)}. \tag{2A.2}$$

Substituting y_{nc}^{*} back into (2A.1) yields the optimal tariff:

$$t_{nc}^{*} = \frac{(\mathrm{A} - \alpha)(27 - 2\,\mathrm{g}\,(12 - 5\beta)(1 - \beta))}{81 - \mathrm{g}(72 - \beta(60 - 13\beta))}. \tag{2A.3}$$

The restriction *(fs)* ensures that $q_{f}^{*} > 0$ and, consequently, that the tariff t_{nc}^{*} lies in the interval $t_{nc}^{*} \in (0, t_{p})$.

By substituting (1a) and (2a) into $W(t(y), y)$ one obtains the optimal social welfare in the NC regime:

$$W_{nc}^{*} = \frac{(A-\alpha)^2(59049 + g^2(1-\beta)^2(16164-(13476-2813\beta)\beta) - 18g(3816-(4380-1189\beta)\beta)}{18(81-g(72-(60-13\beta)\beta))^2}.$$

(2A.4)

Commitment regime

Substituting $y_c^*(t) = \dfrac{(2(A-\alpha)+t_c^*)(2-\beta)g}{9-2g(2-\beta)^2}$ (see expression (10) in the main text) into the social welfare function yields the government objective function, $W_c^*(t) = W_c^*(y_c(t_c), t_c)$, which is to be maximized in the first stage. Setting $dW_c^* / dt = 0$ and solving for t yields:

$$t_c^* = \frac{3(A-\alpha)(81-2g(33-g(7-5\beta)(1-\beta)(2-\beta)-30\beta)(2-\beta))}{729-g(2-\beta)(612-252\beta-g(2-\beta)(127-(106-19\beta)\beta))} \quad . \tag{2A.5}$$

Again, the restriction *(fs)* makes sure that $t_c^* \in (0, t_p)$.

The resulting optimal R&D is

$$y_c^* = \frac{\mathrm{g}\,(\mathrm{A}-\alpha)\,(189-2\,\mathrm{g}\,(37-17\,\beta)(2-\beta))\,(2-\beta)}{(729-\mathrm{g}\,(2-\beta)\,(612-252\,\beta+\mathrm{g}\,(2-\beta)\,(127-\beta\,(106-19\beta)))}. \tag{2A.6}$$

Consequently, social welfare in the C regime is given by (6a):

$$W_c^* = \frac{(A-\alpha)^2(729-4g(97-11g(1-\beta)^2(2-\beta)-77\beta)(2-\beta))}{2(729-g(2-\beta)(612-252\beta-g(2-\beta)(127-(106-19\beta)\beta)))}. \tag{2A.7}$$

Appendix 3: Free-trade and first-best Setup: Optimal values of R&D, social welfare, and policy instruments

Free Trade

The free-trade regime is equivalent to committing to zero tariffs and subsidies. Thus obtaining the respective comparable equilibrium values is straightforward:

$$y^*_{ft} = \frac{2g(A-\alpha)(2-\beta)}{9-2g(2-\beta)^2} \tag{3A.1}$$

and

$$W^*_{ft} = \frac{2(A-\alpha)^2(18-g(10-g(1-\beta)^2(2-\beta)-8\beta)(2-\beta))}{(9-2g(2-\beta)^2)^2}. \tag{3A.2}$$

The first-best outcome

The government selects optimally all three available instruments: tariffs, export and R&D subsidies. Thus, it maximizes $W^*_{fb}(s,s_y,t) = \Pi(.) + S(.) + R(.) - T(.) - T_y(.)$ with respect to *s, s_y* and *t*. This optimization gives the first-best R&D:

$$y^*_{fb} = \frac{g(A-\alpha)(42-5\beta)}{72-g(72-5(12-5\beta)\beta)}, \tag{3A.3}$$

while the resulting optimal first-best tariffs and export subsidies are given as:

$$t^*_{fb} = \frac{2(A-\alpha)(12-g(12-5\beta)(1-\beta))}{72-g(72-5(12-5\beta)\beta)} \tag{3A.4}$$

and

$$s_{fb}^{*} = \frac{(A-\alpha)(18+g(1-\beta)(3+5\beta))}{72-g(72-5(12-5\beta)\beta)} \ , \qquad (3A.5)$$

respectively.

The values of the optimal R&D subsidies depend on whether the government can or cannot precommit to its output policies *s* and *t* (see Appendix 14).

Finally, social welfare in the first-best setup is given by:

$$W_{fb}^{*} = \frac{(A-\alpha)^2(74-25g(1-\beta)^2)}{2(72-g(72-5(12-5\beta)\beta)}. \qquad (3A.6)$$

Appendix 4: Comparison of unit cost reduction in the NC and C regimes in

the case of home-market policies

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

$$g_r(\beta) = \frac{648\beta}{24 + \beta(400 - 103(4-\beta)\beta) + \sqrt{(2-\beta)^2(144 + \beta(4080 + \beta(76 + (15452 - 6527\beta)\beta)))}}$$

,

where $g_r(\beta)$ represents an upper border below which $y_{nc}^{*} > y_{c}^{*}$ (see Figure 4A). Adding the upper contour of the duopoly feasibility region, $g_{fs}(\beta)$, shows that there is a small non-empty intersection (shaded area in Figure 4A) for which $y_{c}^{*} > y_{nc}^{*}$. The critical value of $\beta^{r}(g)$ is obtained by inverting the function $g_r(\beta)$. Note that irrespective of the value of g, $y_{nc}^{*} > y_{c}^{*}$ for any β such that $\beta > \beta_1^{r}$ where the value of $\beta_1^{r} = 0.0458$.

Using the same approach as above, it is straightforward to show that R&D is always the smallest in the free-trade setup and always the largest in the first-best setup irrespective of the level of spillovers. That is, the region of g and β for which $y_{ft}^{*} > y_{i}^{*}$ obtained by solving $y_{i}^{*} - y_{ft}^{*} = 0$ for g (where i = {“nc”,”c”, “fb”}), is an empty set.

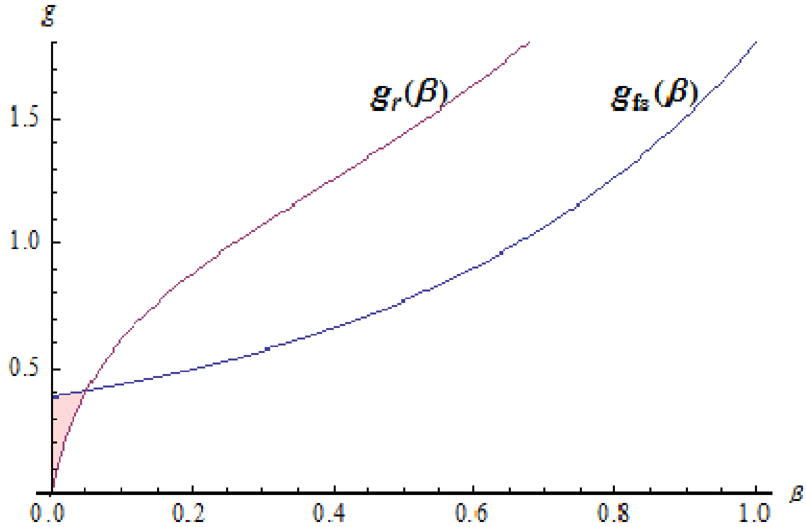

Figure 4A

Appendix 5: Spillover impact on the optimal R&D at β=0

Direct comparison shows that $\left|\frac{\mathrm{d}y_c^*}{\mathrm{d}\beta}\right| > \left|\frac{\mathrm{d}y_{nc}^*}{\mathrm{d}\beta}\right|$ for all feasible values of g and β (that is, $g < g_{fs}(\beta)$). The corresponding expressions are, however, long and non-transparent so we only show that this relationship holds for small spillovers since it suffices for the purpose of our analysis. More specifically, we show that $\left|\frac{\mathrm{d}y_c^*}{\mathrm{d}\beta}\right| > \left|\frac{\mathrm{d}y_{nc}^*}{\mathrm{d}\beta}\right|$ at β=0 for all $g < g_{fs}(\beta = 0) = 0.346$.

Differentiating y_c^* with respect to β and evaluating it at $\beta = 0$ we obtain

$$\frac{\mathrm{d}y_c^*}{\mathrm{d}\beta}\Big|_{\beta=0} = -\frac{(\mathrm{A}-\alpha)\,\mathrm{g}\,(137781 - 4\mathrm{g}\,(31104 + (14463 - 14104\mathrm{g})))}{(729 - 4\,(306 - 127\mathrm{g})\,\mathrm{g})^2} < 0.$$

Repeating the above procedure for $y_{nc}^{\cdot}$ yields:

$$\frac{\mathrm{d}y_{nc}^*}{\mathrm{d}\beta}\Big|_{\beta=0} = -\frac{(\mathrm{A}-\alpha)\,\mathrm{g}\;(17 + 16\,\mathrm{g})}{(9 - 8\mathrm{g})^2} < 0.$$

Define $B(g) \equiv \left|\frac{\mathrm{d}y_c^*}{\mathrm{d}\beta}\right| - \left|\frac{\mathrm{d}y_{nc}^*}{\mathrm{d}\beta}\right|$ at $\beta = 0$.

Thus, $B = (A-\alpha)g\left(\frac{\mathrm{g}\,((17 + 16\,\mathrm{g})}{(9 - 8\,\mathrm{g})^2} + \frac{(137781 - 4\,\mathrm{g}\,(31104 + (14463 - 14104\,\mathrm{g})\,\mathrm{g}))}{(729 - 4\,(306 - 127\mathrm{g})^{\;2}}\right) > 0$
for all $g < g_{fs}(\beta = 0) = 0.346$

Appendix 6: The comparison of optimal tariffs in the C and NC regimes and spillover impact on the optimal tariffs at β=0

Direct comparison shows that $t_c^* > t_{nc}^*$ for all feasible values of g and β (that is, $g < g_{fs}(\beta)$). For the purposes of our analysis, it would be sufficient to show that $t_c^* > t_{nc}^*$ around a "small" level of spillovers. That is, we show that $t_c^* > t_{nc}^*$ at $\beta = 0$ for all $g < g_{fs}(\beta = 0) = 0.346$.

So $\mathrm{t}_\mathrm{c}^*\big|_{\beta=0} = \dfrac{3(A-\alpha)(81-4g(33-14g))}{729-4g(306-127g)}$ and $\mathrm{t}_\mathrm{nc}^*\big|_{\beta=0} = \dfrac{(A-\alpha)}{3}$.

It is now straightforward to see that $\mathrm{t}_\mathrm{c}^*\big|_{\beta=0} - \mathrm{t}_\mathrm{nc}^*\big|_{\beta=0} = \dfrac{4(A-\alpha)g(9-g)}{3(729-4g(306-127g))} > 0$.

Note also that $dt_c^*/dg > 0$ due to its technological function while $dt_{nc}^*/dg > 0$ only if $\beta > 0$ and its increase in g is always lower than dt_c^*/dg.

Evaluating dt_{nc}^*/dg and dt_c^*/dg at $\beta = 0$ gives

$$\frac{\mathrm{dt}_\mathrm{c}^*}{dg}\bigg|_{\beta=0} = \frac{(A-\alpha)\,36\,(243 - 2\,\mathrm{g}\,(27+62\,\mathrm{g}))}{(729-2(612-254g)g)^2} > 0$$

$\mathbf{dtc/d\beta(\beta = 0)} = \dfrac{(A-\alpha)6g(22899-2g(16917-23784g+6283g^2))}{(729-2(612-254g)g)^2}$ and $\dfrac{\mathrm{dt}_\mathrm{nc}^*}{dg}\bigg|_{\beta=0} = 0$.

Thus, for small spillovers the difference between t_c and t_{nc} widens as g increases. Note that $\mathrm{t}_\mathrm{nc}^*(\beta=0) = \mathrm{t}_\mathrm{fb}^*(\beta=0) = \dfrac{(A-\alpha)}{3} < \mathrm{t}_\mathrm{c}^*(\beta=0)$.

Finally, to prove that $dt_c^* / d\beta > dt_{nc}^* / d\beta > 0$ at $\beta = 0$, we define the ratio $RA(g,\beta) = \frac{dt_c^* / d\beta}{dt_{nc}^* / d\beta}$ and evaluate it at $\beta = 0$. So, it has to be shown that $RA(g,\beta = 0) > 1$ for all $g < g_{fs}(\beta = 0) = 0.346$. Thus

$RA(g,\beta = 0) = \frac{27\,(9 - 8\,g)\,(22599 - 2\,g\,(28917 - 23754\,g + 6256\,g^2))}{7\,(729 - 4\,g\,(306 - 127\,g))^2} > 1$ (see Figure 6A).

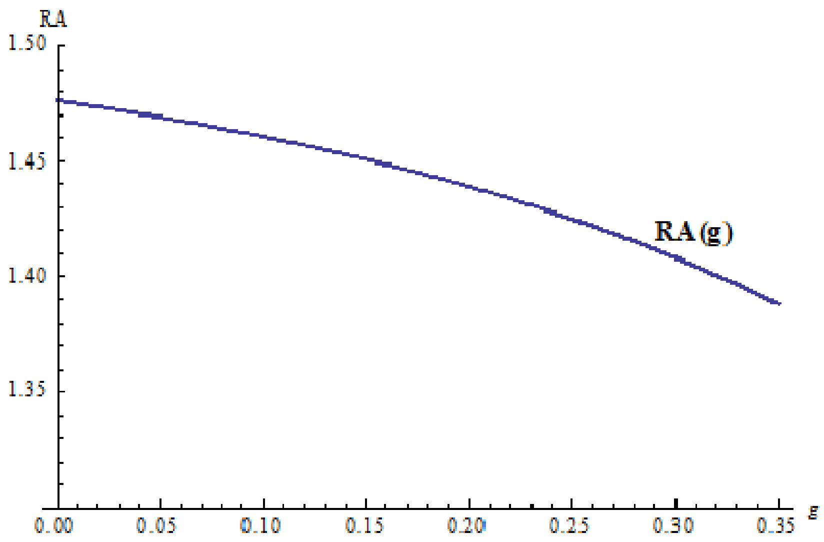

Figure 6A

Appendix 7: Proof that $\left|\frac{\partial W_c^*}{\partial y}\frac{dy_c^*}{d\beta}\right| - \left|\frac{\partial W_{nc}^*}{\partial y}\frac{dy_{nc}^*}{d\beta}\right| > 0$ at β=0

First, define D as $D(g,\beta) \equiv \left|\frac{\partial W_c^*}{\partial y}\frac{dy_c^*}{d\beta}\right| - \left|\frac{\partial W_{nc}^*}{\partial y}\frac{dy_{nc}^*}{d\beta}\right|$. Much like in Appendix 6, the expression for D is extremely long and it can be shown by simulation (or by graphical representation, see Figure 7A1 below) that D is positive for all permissible values of β and g. Therefore, we again prove that this holds for a spillover level around zero since this is the relevant region under consideration. Thus, we have

$$\left|\frac{\partial W_c^*}{\partial y}\frac{dy_c^*(\beta=0)}{d\beta}\right| = \frac{(A-\alpha)^2\ (9\text{ - }8\,\mathrm{g})\,(18\text{ - }2\,\mathrm{g})\,\mathrm{g}\,(137781\text{ - }2\,\mathrm{g}\,(62208+28926\,\mathrm{g}\text{ - }28208\,\mathrm{g}^2))}{3\,(729\text{ - }2\,(612\text{ - }254\,\mathrm{g})\,\mathrm{g})^3}$$

and

$$\left|\frac{\partial W_{nc}^*}{\partial y}\frac{dy_{nc}^*(\beta=0)}{d\beta}\right| = \frac{(A-\alpha)^2\ 2\,(9\text{ - }\mathrm{g})\,\mathrm{g}\,(17+16\,\mathrm{g})}{27\,(9\text{ - }8\,\mathrm{g})^3}.$$

Now it is relatively straightforward to show that $D(g,\beta=0)>0$ for all $g < g_{fs}(\beta=0) = 0.346$ as can also be seen from Figure 7A2 below.

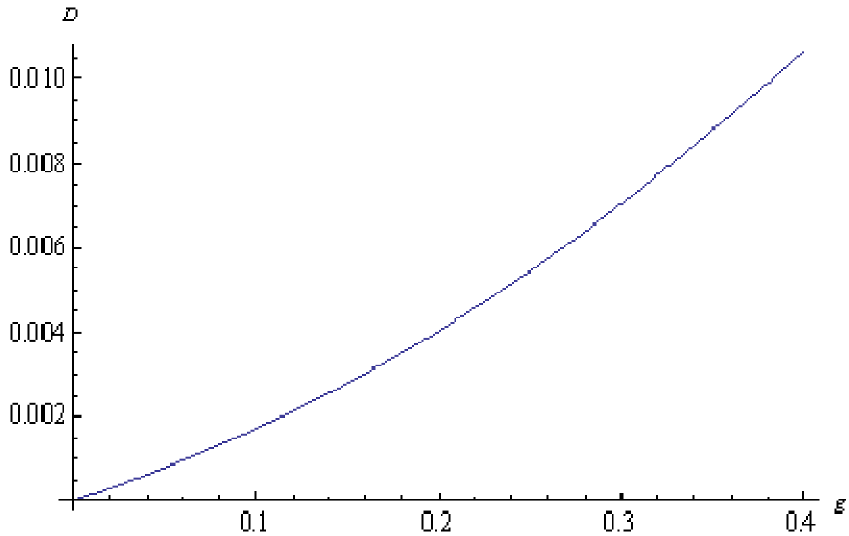

Figure 7A1

Using graphical analysis, we can also show for the general case that $\frac{\partial D(g,\beta)}{\partial \beta} > 0$.

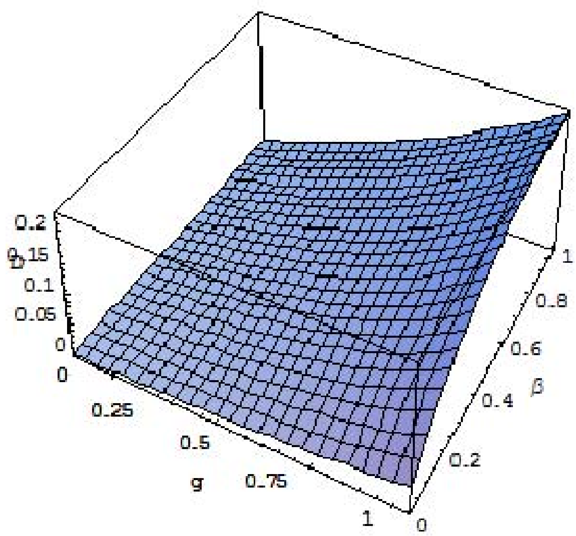

Figure 7A2

Appendix 8: Comparison of social welfare in the C and NC regimes in the case of home-market policies

To find the critical values of β and g beyond which $W^{*}_{nc} > W^{*}_{c}$, we could solve the equation $W^{*}_{nc} - W^{*}_{c} = 0$ (expressed in terms of the parameters of the model, see expressions (2A.4.) and (2A.7) in Appendix 2), for, say, the critical value of $g_{wt}(\beta)$ and then find the region of g and β for which $W^{*}_{nc} > W^{*}_{c}$, taking into account the viability region of the duopoly. The critical value of $\beta^{wt}(g)$ is obtained by inverting $g_{wt}(\beta)$. This approach, although feasible, gives an extremely messy solution. Since W^{*}_{nc} surpasses W^{*}_{c} at a rather small level of spillovers, a more elegant approach would be to find an approximation of $\beta^{wt}(g)$ by linearizing W^{*}_{nc} and W^{*}_{c} at $\beta = 0$. Let us label this approximation as $\beta^{wa}(g)$ that is found by solving

$$W^{*}_{nc}(\beta = 0) + \beta \frac{dW^{*}_{nc}}{d\beta}\Big|_{\beta=0} = W^{*}_{c}(\beta = 0) + \beta \frac{dW^{*}_{c}}{d\beta}\Big|_{\beta=0} .$$

Thus, $\beta^{wa}(g)$ is given by:

$$\beta^{wa}(g) = \frac{(9-8g)(9-g)g(729-4(306-127g)g)}{1594323-g(6121413-2g(4736799-2g(1821825-(682347-96352g)g)))} .$$

The function $\beta^{wa}(g)$ is depicted in Figure 8A below. For all values of β such that $\beta > \beta^{wa}(g)$, $W^{*}_{nc} > W^{*}_{c}$, and this region is represented by the area above the curve $\beta^{wa}(g)$. The critical value of spillovers is increasing in g. So the biggest value of $\beta^{wa}(g)$ is obtained at the border of $g = g_{fs1}$, where $\beta^{wa}(g_{fs1}) = 0.0221$, while the exact value of the highest critical β can be obtained by substituting $g = g_{fs1}(\beta) = \frac{9}{(1-\beta)(2-\beta)}$ in $W^{*}_{nc} - W^{*}_{c} = 0$, which yields $\beta^{w}(g_{fs1}) = 0.019$. Thus, $\beta^{wa}(g)$ can be viewed as an upper border of $\beta^{wt}(g)$.

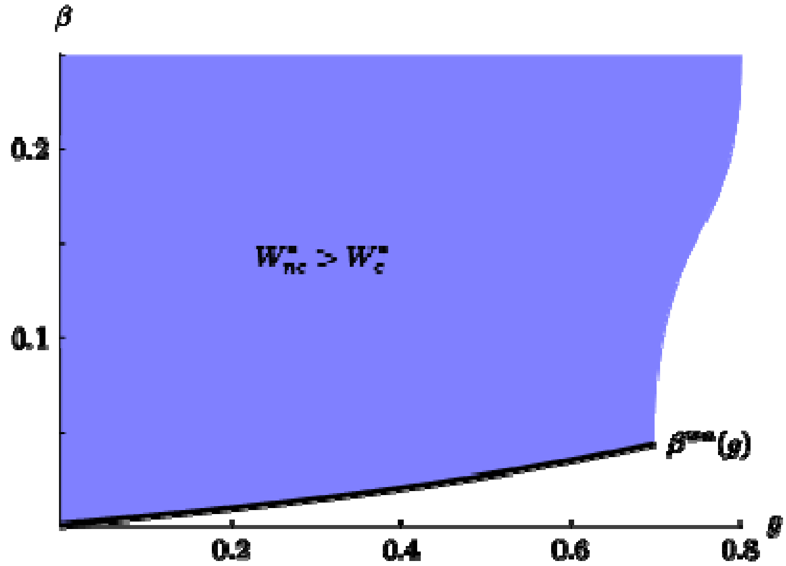

Figure 8A

Appendix 9: Optimal values of R&D, social welfare and tariffs: the case of third-market policies

Non-commitment regime

Maximizing the social welfare function $W(s(y), y)$ with respect to s yields the optimal export subsidy, s^*_{NC},

$$s^*_{NC}(y_{NC}) = \frac{1}{4}(A - \alpha + (2-\beta)y_{NC}), \quad (9A.1)$$

while maximizing the profit function with respect to y gives the optimal y^*_{NC},

$$y^*_{NC} = \frac{13g(A-\alpha)(2-\beta)}{36 - 13g(2-\beta)^2}. \quad (9A.2)$$

Substituting y^*_{NC} in (9A.1) yields the optimal subsidy:

$$s^*_{NC} = \frac{9(A-\alpha)}{36 - 13g(2-\beta)^2}. \quad (9A.3)$$

By substituting (9A.2) and (9A.3) into $W(s(y), y)$ one obtains the optimal social welfare in the NC regime:

$$W^*_{NC} = \frac{(A-\alpha)^2(1188 - 13g(100 - 13g(1-\beta)^2(2-\beta) - 74\beta)(2-\beta))}{2(36 - 13g(2-\beta)^2)^2}. \quad (9A.4)$$

Commitment regime

Substituting the firm's optimal R&D as a function of subsidy $y_C^*(s_C) = \frac{2\,g\,(A - \alpha + s)\,(2 - \beta)}{9 - 2\,g\,(2 - \beta)^2}$ into the social welfare function yields the government's objective function in the form of $W_C^*(s) = W_C^*(y_C(s_C), s_C)$. Setting $dW_C^* / ds = 0$ and solving for s yields:

$$s_C^* = \frac{3(A-\alpha)(27+2g(2-\beta)(9\beta - 2g(1-\beta)(2-\beta)(1+\beta)))}{4(81-g(2-\beta)^2(27-g(7-(10-\beta)\beta)))}. \qquad (9A.5)$$

The resulting optimal R&D is

$$y_C^* = \frac{g(A-\alpha)(45-4g(1-2\beta)(2-\beta))(2-\beta)}{2(81-g(2-\beta)^2(27-g(7-(10-\beta)\beta)))}. \qquad (9A.6)$$

Consequently, the social welfare in the C regime is given by (9A.7):

$$W_C^* = \frac{(A-\alpha)^2(297-8g(11-g(1-\beta)^2(2-\beta)-13\beta)(2-\beta))}{8(81-g(2-\beta)^2(27-g(7-(10-\beta)\beta))}. \qquad (9A.7)$$

Appendix 10: The comparison of the subsidies in the C and NC regimes

Direct comparison shows that for spillovers small enough optimal subsidies in the NC regime dominate its counterpart in the C regime. Solving $s_C^* - s_{NC}^* = 0$ for the critical value of $g_S(\beta)$ yields:

$$g_S(\beta) = \frac{3(76+\beta(78-(180-61\beta)\beta)-(2-\beta)\sqrt{2068-\beta(3704-\beta(2004+(1036-179\beta)\beta)))}}{52(2-\beta)^3(1-\beta^2)}$$

,

where $g_S(\beta)$ represents an upper border below which $s_C^* > s_{NC}^*$. Adding the upper contour of the duopoly feasibility region, $g_{fs}(\beta)$ shows the area for which $s_C^* > s_{NC}^*$ (shaded area in Figure 10A). The critical value of $\beta^S(g)$ is obtained by inverting the function $g_S(\beta)$. Note that irrespective of the feasible value of g, it is necessary for β to be above 0.08 in order for s_C^* to dominate s_{NC}^*.

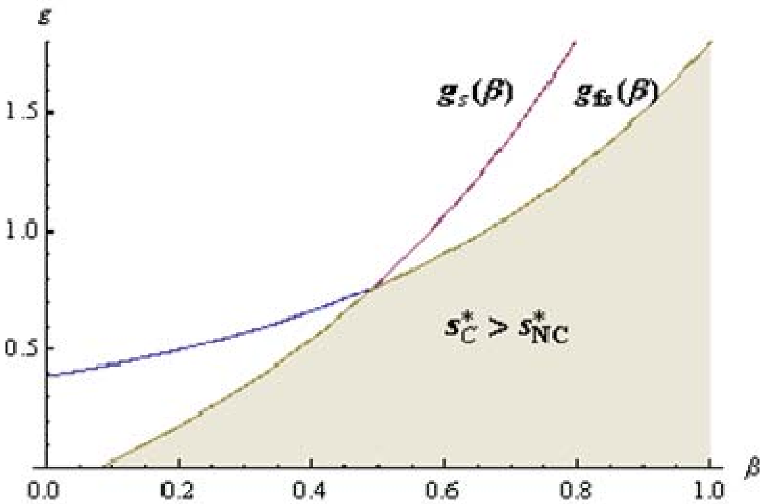

Figure 10A

Appendix 11: Spillover impact on the optimal subsidies at β=0

Direct comparison shows that $\left|\frac{\mathrm{d}s^*_{NC}}{\mathrm{d}\beta}\right| > \left|\frac{\mathrm{d}s^*_{C}}{\mathrm{d}\beta}\right|$ for all feasible values of g and β (that is, for all g such that $g < g_{fs}(\beta)$. The corresponding expressions are, however, long and non-transparent so we only show that this relationship holds for small spillovers. More specifically, we show that $\left|\frac{\mathrm{d}s^*_{NC}}{\mathrm{d}\beta}\right| > \left|\frac{\mathrm{d}s^*_{C}}{\mathrm{d}\beta}\right|$ at β=0 for all $g < g_{fs}(\beta = 0) = 0.346$.

Differentiating s^*_C with respect to β and evaluating it at $\beta = 0$, we obtain

$$\frac{\mathrm{d}s^*_c}{\mathrm{d}\beta}\Big|_{\beta=0} = -\frac{3\,g^2(\mathrm{A}-\alpha)\ (189-4g\,(63-40g))}{(81-4\,g(27-7g)\,)^2} < 0\,.$$

Repeating the above procedure for s^*_{NC} yields:

$$\frac{\mathrm{d}s^*_{NC}}{\mathrm{d}\beta}\Big|_{\beta=0} = -\frac{468\,g\,(\mathrm{A}-\alpha)}{(36-52g)^2} < 0\,.$$

Define $E(g) \equiv \left|\frac{\mathrm{d}s^*_{NC}}{\mathrm{d}\beta}\right| - \left|\frac{\mathrm{d}s^*_{C}}{\mathrm{d}\beta}\right|$ at $\beta = 0$.

Thus, $E(g) = 3g(\mathrm{A}-\alpha)\left(\frac{39}{4\,(9-13\,g)^2} - \frac{g\,(189-4\,g\,(63-40\,g))}{(81-4\,g\,(27-7\,g))^2}\right) > 0$ for all g such that $g < 0.346$.

Appendix 12: Comparison of unit cost reduction in the NC and C regimes in the case of third-market policies

Solving $y_{NC}^* - y_C^* = 0$ for the critical value of $g_R(\beta)$ yields:

$$g_{R1}(\beta) = \frac{108}{20 + (28 - 19\beta)\beta - (2-\beta)\sqrt{-1772 + \beta(380 + 2233\beta)}},$$

implying that the set of g and β for which $y_C^* > y_{NC}^*$ is such that $g > g_R(\beta)$. However, the intersection with the feasibility region $g < g_{fs}(\beta)$ is an empty set implying that $y_{NC}^* > y_C^*$ for all g given that $g < g_{fs}(\beta)$.

The R&D in the free-trade regime is smaller than in any other setup. Since this is a standard result, we only sketch the proof. Much like in the above proofs, it is easy to show that the region of g and β for which $y_{ft}^* > y_i^*$ obtained by solving $y_i^* - y_{ft}^* = 0$ for g, (where i = {“NC”,”C”, “fb”}), is an empty set.

Finally, solving $y_{NC}^* - y_{fb}^* = 0$ for the relevant critical value of $g_{R2}(\beta)$ yields $g_{R2}(\beta) = \frac{9(-10 + 21\beta)}{13(1-\beta)(2-\beta)(3+5\beta)}$ (see Figure 12A below). Thus, for spillovers large enough, the overinvestment effect disappears and R&D in the first-best setup dominates the R&D in the NC regime.

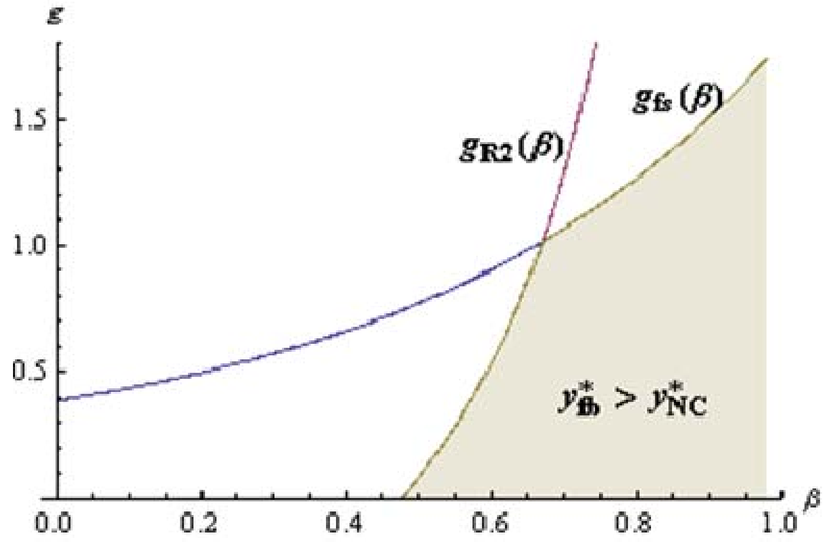

Figure 12A

Appendix 13: Comparison of the social welfare in the C and NC regimes in the case of third-market policies

To find the critical values of β and g beyond which $W^*_{NC} > W^*_C$, we have to solve the equation $W^*_{NC} - W^*_C = 0$ (expressed in terms of the parameters of the model, see expressions (9A.4.) and (9A.7) in Appendix 9) for the critical value of $g_{ws}(\beta)$ and then $g < g_{ws}(\beta)$ defines the region of g and β for which $W^{*}_{nc} > W^{*}_{c}$, taking into account the viability region of duopoly-condition *(fs)*. The solution of $W^*_{NC} - W^*_c = 0$ for g reduces to the following equation:

$$-g\,(2-\beta)\,(676\,g^2\,(2-\beta)^2\,(1-\beta)^2\,(1+\beta)^2 - 156\,g\,(2-\beta)\,(1-\beta)\,(1+\beta)\,(10+19\,\beta) + 9\,(784+(740-611\,\beta)\,\beta)) = 3888\,(2-7\,\beta).$$

The critical value of $\beta^{ws}(g)$ is obtained by inverting $g_{ws}(\beta)$. This approach gives, however, an extremely messy solution so we focus on a graphical analysis.[29] Predictably, for small g slightly above zero overinvestment and overproduction will not be so big, so the dominance of W^*_{NC} starts from spillovers that are not so large (more precisely, it suffices for β to be around 0.3 for a g near zero). For larger g, however, the softening of overinvestment and overproduction requires larger spillovers. Thus, for a level of g that is 0.91 or higher, the minimal required level of spillovers for $W^*_{NC} > W^*_C$ to hold has to be 0.6 (see Figure 13A1). (These values are obtained by equating $g_{fs}(\beta) = g_{ws}(\beta)$.)

Using the same procedure we can find the values of the critical value of $g_{FT}(\beta)$ beyond which $W^*_{NC} > W^*_{ft}$. Thus, solving the equation $W^*_{NC} - W^*_{ft} = 0$ for g gives the region of parameters $g < g_{FT}(\beta)$ for which $W^*_{NC} > W^*_{ft}$ (see Figure 13A1). Again, we do not present this in the text since the resulting expression is prohibitively large.

[29] Unlike the comparison of welfares in the case of home-market policies, using first-order Taylor approximation would be rather imprecise since the relation between W^{*}_{nc} and W^{*}_{c} varies over the large range of β and g.

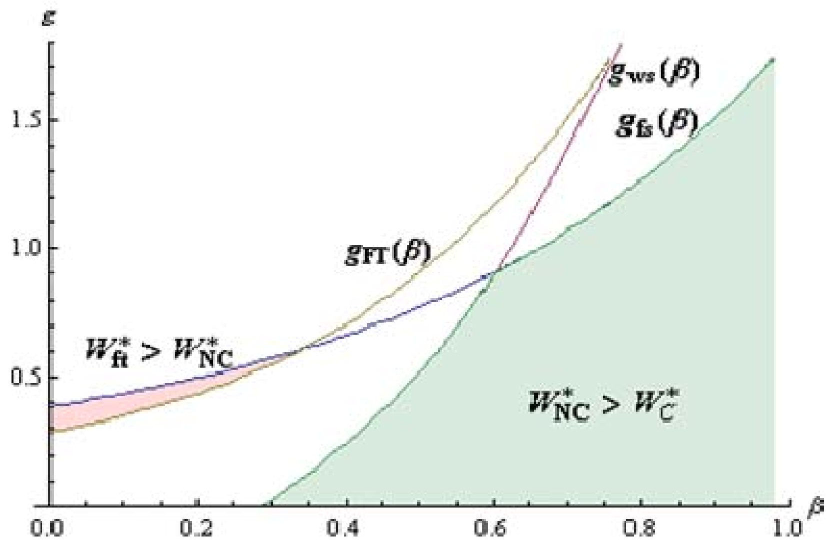

Figure 13A1

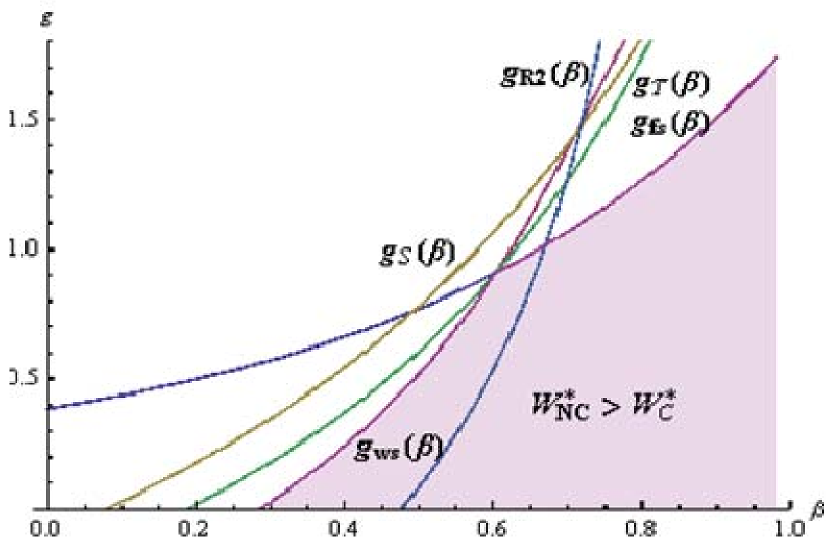

Figure 13A2

Now we add three more curves onto Figure13A1. The first one $g_S(\beta)$ contains all pairs of β and g at which $s^*_C = s^*_{NC}$; the second one $g_T(\beta)$ has all pairs of β and g at which $T_C^* = T_{NC}^*$ (where $T_i^* = s_i^* q_e^*$ and $i = \{NC, C\}$) and the third one, $g_{R2}(\beta)$, has all pairs of β and g such that $y_{NC}{}^* = y_{fb}^*$ (see Figure 13A2). As is clearly seen from Figure 13A2, both $s_C^* > s_{NC}^*$ and $T_C^* > T_{NC}^*$ are necessary conditions for $W_{NC}^* > W_C^*$, while $y_{NC}{}^* \leq y_{fb}^*$ is sufficient for $W_{NC}^* > W_C^*$ to hold. Moreover, by continuity $W_{NC}^* > W_C^*$ holds for $y_{NC}{}^* > y_{fb}^*$ that are "close" to y_{fb}^*. Also recall that $s_{NC}^*(y_{NC}) = \frac{1}{4}(A - \alpha + (2-\beta)y_{NC})$ and

$s_{NC}^*(y_{fb}) = \frac{1}{4}(A - \alpha + (2-\beta)y_{fb})$ so $s_{fb}^* = s_{NC}^*$ when $y_{NC}{}^* = y_{fb}^*$.

It can be shown by simulation that for each $y_{NC}(g^z, \beta^z)$ such that $y_{NC}{}^* > y_{fb}^*$ and $W_{NC}^* > W_C^*$, the Euclidean distance between the R&D in the NC regime and the R&D in the first-best setup is smaller than the distance of the corresponding R&D between the C regime and the first-best R&D. That is, $\left|y_{NC}(g^z, \beta^z) - y_{fb}(g^z, \beta^z)\right| < \left|y_C(g^z, \beta^z) - y_{fb}(g^z, \beta^z)\right|$ for all $y_{NC}{}^* > y_{fb}^*$ such that $W_{NC}^* > W_C^*$. The converse, however, is not true.

Appendix 14: The first-best R&D subsidy/tax and the government's (in)ability to commit to output policies

The optimal first-best R&D subsidies in the two considered scenarios of timing are given as follows:

a) The first-best R&D subsidy when a government commits to both tariffs and export subsidies before the domestic firm's choice of R&D:

$$s^*_{y\_fbc} = \frac{10-53\beta+2g(2-\beta)(1-\beta)(1+10\beta)}{3(-42+5\beta)}.$$

So $s^*_{y\_fbc} > 0$ when $g < g_{fbc}(\beta) = \dfrac{-10+53\beta}{2(1-\beta)(2-\beta)(1+10\beta)}$ and as seen from Figure 14A1, β has to be above 0.188 for this to happen (taking also into account the feasibility region of β and g).

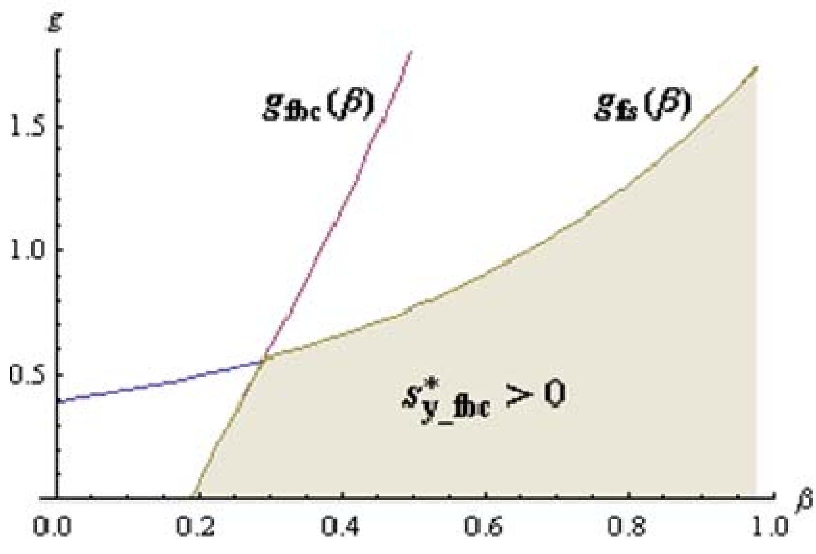

Figure 14A1

b) The first-best R&D subsidy when the government sets tariffs and export subsidies after the domestic firm's choice of R&D:

$$s^*_{y\_fbnc} = \frac{138-181\beta + g(1-\beta)(30+\beta)(131-65\beta)}{9(-42+5\beta)}.$$

So $s^*_{y\_fbnc} > 0$ only when $g < g_{fbnc}(\beta) = \dfrac{138-181\beta}{(1-\beta)(-30-\beta(131-65\beta))}$ and as seen from Figure 14A2, β has to be above 0.76 for this to happen (taking also into account the feasibility region of β and g).

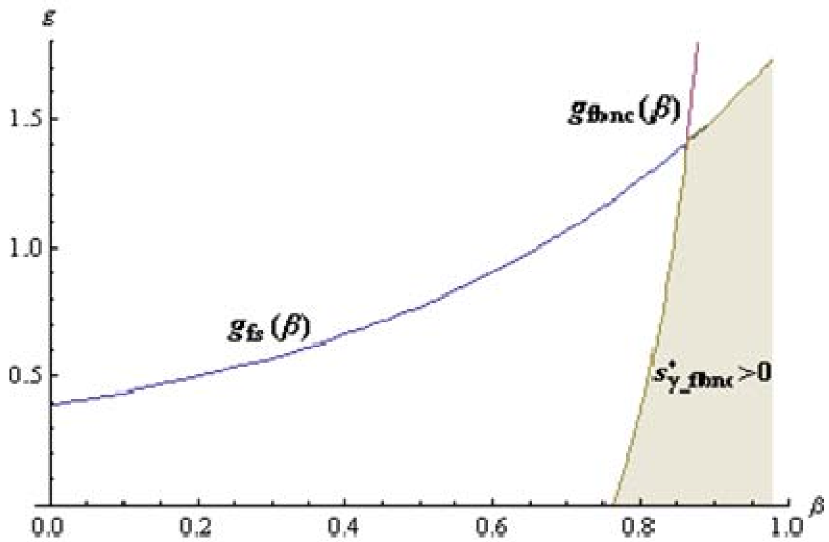

Figure 14A2

Working Paper Series
ISSN 1211-3298
Registration No. (Ministry of Culture): E 19443

Individual researchers, as well as the on-line and printed versions of the CERGE-EI Working Papers (including their dissemination) were supported from the following institutional grants:

- Economic Aspects of EU and EMU Entry [Ekonomické aspekty vstupu do Evropské unie a Evropské měnové unie], No. AVOZ70850503, (2005-2010);
- Economic Impact of European Integration on the Czech Republic [Ekonomické dopady evropské integrace na ČR], No. MSM0021620846, (2005-2011);

Specific research support and/or other grants the researchers/publications benefited from are acknowledged at the beginning of the Paper.

Published by
Charles University in Prague, Center for Economic Research and Graduate Education (CERGE)
and
Economics Institute ASCR, v. v. i. (EI)
CERGE-EI, Politických vězňů 7, 111 21 Prague 1, tel.: +420 224 005 153, Czech Republic.
Printed by CERGE-EI, Prague
Subscription: CERGE-EI homepage: http://www.cerge-ei.cz

Phone: + 420 224 005 153
Email: office@cerge-ei.cz
Web: http://www.cerge-ei.cz

The paper is available online at http://www.cerge-ei.cz/publications/working_papers/.

ISBN 978-80-7343-228-7 (Univerzita Karlova. Centrum pro ekonomický výzkum
a doktorské studium)
ISBN 978-80-7344-216-3 (Národohospodářský ústav AV ČR, v. v. i.)

CERGE-EI
P.O.BOX 882
Politických vězňů 7
111 21 Praha 1
Czech Republic
http://www.cerge-ei.cz