International trade policy towards domestic monopolies and domestic oligopolies

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Abstract

International trade policy has focused mostly on policy choice in the presence of homogeneous good domestic monopolies. It is shown that in a differentiated goods oligopoly, where firms invest in process innovation and later compete in the market, optimal trade policy and welfare outcomes are strikingly different. Welfare can increase over free trade and taxing (or subsidizing) output may even become a dominant strategy for both countries. The prisoners dilemma nature of policy games under domestic monopolies is never observed for domestic oligopolies. Policy choice is determined by the number of firms in both countries and the degree of product differentiation. When a country has one domestic firm, (and increasing the number of foreign firms) the choice of policy instrument is always a subsidy or to remain inactive. However, if one increases the number of domestic firms to two, then a country taxes, subsidizes, or may not promote R&D or output depending on the number of firms in the other country and the degree of product differentiation in a non-linear way. Further, the results are robust to Cournot or Bertrand competition.

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1. Introduction:

The model of two (domestic) monopolies competing in a third market (Brander and Spencer (1985), henceforth BS) is based on the premise that the behavior of international oligopolies and the profit shifting argument can be easily studied in such a framework. The main results arising from this model are that unilateral policy choice is beneficial. While, bilateral policy choice has the characteristics of a prisoners dilemma as both the countries are worse off. Extensions of this model have shown that it is sensitive to the nature of market competition (Eaton and Grossman, 1986) and to the distribution of firms across the exporting countries (Dixit,1984). Others have meanwhile criticized the model for being a mercantilist model (see Helpman and Krugman, chapter 5, 1994). Perhaps the most damaging criticism arises due to the sensitiveness of the policy to assumptions on market structure. A policy maker using these models as a guide towards policy faces the baffling question about the nature of market competition and what policy to choose[1].

The sensitiveness of the BS model to market structure has been addressed by Cabral and Kujal (1999) and Bagwell and Staiger (1994). Arguing that investing in a strategic variable prior to the market competition stage captures the notion of entry barriers in oligopolistic industries Cabral and Kujal show that in a such a scenario, and under product differentiation, both exporting governments subsidize domestic monopolies under both price and quantity competition. They argue that in the framework of their model the Eaton Grossman reversal is explained by non-committal on the part of the government. Whether governments choose the policy instrument taking into account, or ignoring, firm investment in the strategic variable (a cost reducing technology) determines the policy reversal under price and quantity competition. If a government is non-committal then the policy outcome is the Eaton-Grossman tax and if the government commits[2] to a policy then the policy outcome is a subsidy. This is true under both price and quantity competition[3]. Bagwell and Staiger, though not directly addressing the role of commitment or policy reversal under output subsidies, show that the nature of R&D policy is independent of market structure. In their model R&D outcomes are uncertain and they do not directly address the question of equilibrium unilateral and bilateral strategies for exporting countries, nor explicitly model product differentiation. It would seem that the degree of product differentiation could be an important determinant for policy makers as it is often seen that policies reflect the degree of competition the domestic industry faces

[1] Helpman and Krugman, for example, conjecture that a reasonable policy should be taxing under both Cournot and Bertrand competition (see chapter-5, 1994).

[2] A government is assumed to be credible.

[3] Maggi (1996) studies the choice of strategic trade policy instruments in a model of endogenous market competition. He shows how Cournot, or Bertrand, outcomes may be a function of whether investment in capacity is *credible (*if capacity expansion is costly), or *non-credible (*if capacity expansion is not costly). If investment in capacity is *non-credible* then Bertrand outcomes are observed, and Cournot outcomes occur if the converse is true. The Eaton-Grossman policy reversal is thus ruled out in such a scenario as price and quantity competition do not occur under the same cost assumptions.

from foreign competitors[4] [5].

In this paper we address the issue of equilibrium unilateral and bilateral strategic trade policy for exporting oligopolies selling a differentiated good. We argue that though domestic monopolies competing in a third market reflect oligopolistic competition, they do not capture export promotion policy towards domestic oligopolies that compete in international markets. Given that many markets are characterized by oligopolies it is of interest to see how policy and welfare may change under such a scenario and whether results differ from the special case of domestic monopolies.

This is a reasonable question for many reasons. First, given that a domestic monopoly is a special case (in terms of market structures) the question of the choice of strategic trade policy in the presence of domestic oligopolies is completely ignored by the exporting domestic monopolies model (though it captures oligopolistic competition in the foreign market). If the choice of trade policy instruments is sensitive to market structures (a domestic oligopoly and/or monopoly) then policy makers should be aware of this aspect. Using the domestic monopoly case as a guide for policy choice towards other market structures could thus be misleading. Further, if changing the market structure alters the structure of payoffs (and hence the resultant equilibrium of the game) then the prisoners' dilemma nature of policy choice in these models (implicitly assumed by most) may have to be reconsidered[6].

Secondly, product differentiation may play an important role in the choice of a policy instrument. Given that the degree of product differentiation reflects the competitiveness of a market, it would be reasonable to argue that the policy instrument may crucially depend upon this. For example, the profit shifting argument may be less relevant if the goods sold by two firms are substantially differentiated. In fact, and as we see in the paper, the incentive to subsidize is a decreasing function levels of product differentiation, and reaches zero for the case of local monopolies. Further, the incentive for the government to use output, or R&D, subsidies may depend on the degree of product differentiation.

The issue of looking at domestic oligopolies is directly related to the numbers critique of the BS models[7]. The numbers critique only argues that trade policy instruments are sensitive to the

[4] The exception being Cabral and Kujal. Bagwell and Staiger (1994) do not explicitly model product differentiation, they have a Hotelling model for price competition and a homogenous goods model for quantity competition.

[5] For example, Cabral, Kujal and Petrakis (1998) show that if a country has to impose a Voluntary Export Restraint it will do so depending on the degree of product differentiation. For low levels of product differentiation the home country may completely want to shut out foreign imports, however, if the goods are significantly differentiated then the optimal quota will correspond to the free trade level of imports.

[6] In fact, a standard introduction to such models presents the choice of strategic trade policy as a prisoners' dilemma game.

[7] The relative asymmetry in the number of firms across countries determine the choice of trade policy instruments. In particular if the difference between home and foreign firms is (less) greater than one then the optimal policy is a tax (subsidy) (see the example in Bhagwati, Panagariya and Srinivasan, 1998). If however, the number of firms at home and abroad are the same then there is no policy change. Also, Krishna and Thursby (1991) look at optimal policies in the presence of n firms.

relative distribution of firms in the foreign and home market[8]. In this context we put the numbers critique in a different light. We frame it as policy choice towards a domestic monopoly, or an oligopoly. We then show that trade policy instruments are sensitive to the number of firms inside a country and to the degree of product differentiation in a non-linear way. Further, across the various market structures that can emerge the monopoly case is shown to be a special case.

Moving away from domestic monopolies to domestic oligopolies, the optimal trade policy can change in two ways. First, increasing the number of firms at home and abroad symmetrically alters the optimal trade policy instrument for both domestic and foreign governments in the same way. Note that this is in contrast to the result where the policy instrument does not change if the number of domestic and foreign firms increases proportionately across both exporting countries. This is important as it shows that the choice of the policy instrument is also sensitive to the *absolute* number of firms in a country and not the relative *difference* across the countries (as shown by the numbers critique). Second, in the standard numbers critique, policy instruments change depending on the relative difference in the number of firms at home and in the foreign country. That is, if n_f is the number of foreign firms and n_h is the number of domestic firms, the sign of the equilibrium subsidy is equal to[9] the sign of $n_f + 1 - n_h$. We show that in equilibrium, a country may or may not engage in active trade policy (an output or a R&D subsidy) and the choice of policy will depend on the degree of product differentiation. If it decides to have an active trade policy, a monopolistic market structure is always subsidized (R&D or output subsidies), while an oligopolistic market structure can be either taxed or subsidized depending on the degree of product differentiation. Oligopolies are always taxed for high levels of product differentiation, and this is true regardless of the relative asymmetry in the distribution of firms. For oligopolistic market structures in both countries, the equilibrium policy is to subsidize R&D or output only for low levels of product differentiation. Further, departing from the case of domestic monopolies, engaging in active policy increases welfare over free trade for the active country. In the case where only one country is active in equilibrium, the inactive country may also increase its welfare over free trade, although in most cases the inactive country obtains a lower welfare than under free trade depending on the degree of product differentiation. This result is robust to price or quantity competition.

Our results are of interest because several results from the monopoly model have been generally accepted as applying to strategic trade policy choice. For example, there has been a general consensus that the choice of subsidies has the characteristics of a prisoners' dilemma. We show that in the case of policy towards R&D this only occurs for the special case of two domestic monopolies, since in that case the equilibrium outcome (both countries subsidize R&D or output) generates a lower welfare than free trade. If the countries use output subsidy, we still get a prisoners' dilemma but only for a low degree of product differentiation.[10] Further, countries may, or may not, choose

[8] The other critiques of this model are: policy reversal under Bertrand competition (Eaton and Grossman, 1986), the inexistence of domestic consumers, the lack of distinction distinction between short-run and long-run variables, etc. (see Grossman (1988) for a critique of these models).

[9] See Bhagwati et al.(1998 p. 397).

[10] To further check the robustness of our model, we need to extend it to include domestic consumption. Note that Helpman and Krugman (1994) (chapter 5) criticize the BS model as a pure mercantilist model as it excludes domestic

policy bilaterally. Bilateral, or unilateral, policy choice will depend on the number of firms in the other country and the degree of product differentiation. Depending upon the degree of product differentiation a government may either subsidize or tax oligopolies and government intervention can be welfare improving. Further, the results are robust to the nature of market competition[11][12].

We use a model where a domestic oligopoly (or monopoly) compete against a foreign oligopoly (or monopoly) selling a differentiated good in a third market. In Section-II we solve the specific model under free trade. In section-III we analyze government incentives to impose a tax/subsidy on R&D unilaterally, or bilaterally, both under Cournot and Bertrand competition[13]. [14]Section-IV concludes. The appendix contains the results for the case of output subsidies.

2. Free Trade

We use a third-country model to consider the case of many firms located in two different countries and producing a differentiated good which they sell in a third country. Denote by n the total number of firms in the world, composed of n_h firms in the home country and n_f in the foreign country. Let H and F be the set of home and foreign firms, respectively. There is a competitive numeraire sector. Firms operate under constant returns to scale and initially have the same marginal costs of production c. Firms can invest in a cost saving technology prior to engaging in market competition and are able to reduce its marginal cost by Δ by spending $\frac{\Delta^2}{2}$. All firms face symmetric demand functions. If firm i is in the home country ($i \in H$), then[15]

$$x_i(\bar{\mathbf{p}}) = \frac{1}{(1-\gamma)(1+(n_h+n_f-1)\gamma)} \left[a\,(1-\gamma) - p_i(1+\gamma(n_h+n_f-2)) + \gamma \left(\sum_{j \in \{H-i\}} p_{jh} + \sum_{j \in F} p_{jf} \right) \right]. \tag{2.1}$$

consumption. We are already working on extensions that include these possibilities plus asymmetric country sizes. Further, the effect of a large number of firms on welfare (see, Krishna and Thursby (1991)) is also of interest but beyond the scope of this paper due to the complexity of the problem.

[11]As in Celia and Kujal (1999) and Bagwell and Staiger (1994).

[12]This is true as the strategic complementarity (substitutability) of prices (output) is not clear in a two stage with endogenous sunk costs. See Maggi (1996) for a discussion on this.

[13]Note that we have also analyzed results under output subsidies. Given that the general results are similar to the R&D subsidy case we only present results for R&D subsidy.

[14]Note, the strategic complementarity between prices and the strategic substitutability between output is the reason a policy reversal is observed from Bertrand to Cournot games. This is generally a part of the introduction to a discussion on strategic trade policy (see for example, Brander, 1995, Helpman and Krugman, 1994, Bhagwati, Panagariya and Srinivasan, 1998 among others).

[15]These are the demand functions of a consumer with utility $u(x_1, x_2, \ldots, x_n) = a(\sum_{i=1}^{n} x_i)$ $-\frac{1}{2}\left(\sum_{i=1}^{n} x_i^2 + 2\gamma \left(\sum_{i \neq j} x_i x_j\right)\right) + m$ with m representing money, generalizing Dixit (1979) for an arbitrary number of goods. Resulting inverse demand is $p_i = a - x_i - \gamma(\sum_{h \neq i} x_h)$.

where x_i is the output produced by firm $i \in H$, $p_{\bullet h}$ and $p_{\bullet f}$ are the prices charged for the home and foreign varieties of the good, respectively and $\bar{\mathbf{p}} = \{p_{1h}, p_{2h}, \ldots, p_{n_h h}, p_{1f}, p_{2f}, \ldots, p_{n_f f}\}$ is the vector of prices[16]. The parameter γ measures the degree of product differentiation, and we assume it between zero and one[17]. As γ approaches zero each firm becomes a local monopolist and as γ approaches one, goods become almost perfect substitutes.

Firms play a two-stage game. In stage one, firms simultaneously decide how much to invest in cost saving R&D (Δ_i). In stage two, given the reduced unit cost, firms simultaneously compete in prices, or quantities. In this context, investment in R&D has a commitment value, as firms can use R&D strategically to improve their position in the subsequent market competition stage. We look for the subgame perfect equilibria of the game.

Note that our interest is to capture a fundamental aspect of entry barriers in oligopolistic industries. We do this by modelling firm investment in innovation in an earlier stage that has strategic value for both firms[18]. Firm investment in a strategic variable prior to market competition captures firm investment in a long run variable (see Grossman, 1988 and Herguera, Kujal and Petrakis, 1997). As argued by Grossman (1988), firm investment in quality, innovation (or any such variable) has commitment value and should have an important effect not only on market competition in the later stages but also on the choice of trade policy instruments. This aspect of modeling oligopolies has not been extensively studied by international trade theorists.

We analyze both quantity competition and the price competition cases.

2.1. Cournot competition

2.1.1. The output choice stage

Firm i chooses x_i to maximize profits, given inverse demand $p_i = a - x_i - \gamma(\sum_{j \in \{H \cup F - i\}} x_j)$ and reduced unit costs $(c - \Delta_i)$. Firm i's problem is:

$$\max_{x_i} \left[(a - x_i - \gamma \left(\sum_{j \in \{H \cup F - i\}} x_j \right) - (c - \Delta_i) \right] x_i - \frac{\Delta_i^2}{2} \tag{2.2}$$

with $x_{j \in \{H \cup F - i\}}$ and Δ_i taken as given. Each firm's reaction function is thus given by:

[16] Note that there are n_h varieties of the home good and n_f varieties of the foreign good, each with a (potentially) different price.

[17] This is a sufficient condition to assure concavity of the utility function.

[18] Note that unlike justifying an oligopoly by exogenously imposing a fixed cost (that has no strategic value in the market competition stage), we endogenize sunk costs (in the sense that the choice of the strategic variable now plays an important role in the market competition stage).

$$x_i(\mathbf{x}_{-i}) = \frac{1}{2}\left(a - c + \Delta_i - \gamma\left(\sum_{j\in\{H\cup F-i\}} x_j\right)\right), \text{for all } i \in \{H \cup F\} \tag{2.3}$$

It is easy to see from the reaction function that the slope of each reaction function is negative decreasing in the degree of product differentiation. Given that the profit transfer effect depends on the output shifting effect it is easy to see that the derivative $\frac{dx_i}{dx_{-i}}$ decreases in γ and zero for $\gamma = 0$. This simple intuition tells us that we can expect the output shifting effect of a policy to be smaller and hence the incentive to subsidize decreases as γ gets smaller.

The intersection of the $n = n_h + n_f$ reaction functions gives us the vector of equilibrium quantities $\mathbf{x} = \{x_{1h}, x_{2h}, \dots, x_{n_h h}, x_{1f}, x_{2f}, \dots, x_{n_f f}\}$, each chosen given the output of the other firm. Equilibrium output and profits (as a function of first-stage R&D expenditures) are, respectively:

$$\hat{x}_i(\mathbf{\Delta};\gamma) = \frac{(a-c)(2-\gamma) + (2+\gamma(n_f+n_h-2))\Delta_i - \gamma\left(\sum_{j\in\{H\cup F-i\}}\Delta_j\right)}{(2-\gamma)(2+(n_f+n_h-1)\gamma)} \tag{2.4}$$

$$\hat{\pi}_i(\mathbf{\Delta};\gamma) = \left[\frac{(a-c)(2-\gamma) + (2+\gamma(n_f+n_h-2))\Delta_i - \gamma\left(\sum_{j\in\{H\cup F-i\}}\Delta_j\right)}{(2-\gamma)(2+(n_f+n_h-1)\gamma)}\right]^2 - \frac{\Delta_i^2}{2}. \tag{2.5}$$

2.1.2. R&D stage

Firm i, given $\mathbf{\Delta}_{-i}$,chooses Δ_i to maximize its profits (defined above). Reaction Functions in R&D expenditures are given by:

$$\Delta_i(\mathbf{\Delta}_{-i}) = \frac{2[2+\gamma(n-2)]\left((a-c)(2-\gamma) - \gamma\left(\sum_{j\in\{H\cup F-i\}}\Delta_j\right)\right)}{8+\gamma[(4-\gamma^2)\gamma + n^2\gamma[2-(4-\gamma)\gamma] - 16] - 2n[(4-\gamma)(2-\gamma)\gamma - 4]}$$

where $n = n_h + n_f$. Solving the system of n reaction functions for R&D and using symmetry we can derive the equilibrium level of R&D spending, output, price and profits for each firm:

$$\Delta^*(\gamma) = \frac{2(a-c)[2+(n-2)\gamma]}{4-\gamma[8-6n-2\gamma(n-3)(n-1)+\gamma^2(n-1)^2]}, \tag{2.6}$$

$$x^*(\gamma) = \frac{(a-c)(2-\gamma)[2+(n-1)\gamma]}{4-\gamma[8-6n-2\gamma(n-3)(n-1)+\gamma^2(n-1)^2]}, \tag{2.7}$$

$$p^*(\gamma) = \frac{a(n-1)\gamma^2 - c(2-\gamma)(1-(n-1)\gamma)(2-(n-1)\gamma)}{4-\gamma[8-6n-2\gamma(n-3)(n-1)+\gamma^2(n-1)^2]}. \tag{2.8}$$

Firms' profits are then given by

$$\pi^*(\gamma) = (a-c)^2 \frac{((a-c)(2-\gamma)[2+(n-1)\gamma])^2 - 2\left((a-c)[2+(n-2)\gamma]\right)^2}{\left(4-\gamma[8-6n-2\gamma(n-3)(n-1)+\gamma^2(n-1)^2]\right)^2}. \tag{2.9}$$

One should note that a firm has more incentive to invest in cost-reducing R&D under Cournot competition than under a pure cost-minimizing strategy, since there is a *positive* strategic effect of R&D on profits.

2.2. Bertrand competition

2.2.1. The price choice stage

Firm i chooses p_i so as to maximize profits:

$$\max\,[p_i - (c-\Delta_i)]\, x_i(\bar{\mathbf{p}}). \tag{2.10}$$

with $\bar{\mathbf{p}}_{-i} = \{p_j\}_{j\in\{H\cup F-i\}}$ and Δ_i taken as given. This defines each firm's reaction function:

$$p_i(\bar{\mathbf{p}}_{-i}) \equiv \frac{a(1-\gamma)+(c-\Delta_i)(1+(n_f+n_h-2)\gamma)+\gamma\left(\sum_{j\in\{H\cup F-i\}} p_j\right)}{2(1+(n_f+n_h-2)\gamma)} \tag{2.11}$$

Once more, the intersection of the n_f+n_h reaction functions determines the vector of equilibrium prices $\bar{\mathbf{p}}$, each chosen given the price of the other firms. As before we can see the effect on the slope of the reaction function as γ becomes smaller. Differentiating p_i with respect any p_{-i} we see that, $\frac{dp_i}{dp_{-i}} = \frac{\gamma}{2(1+(n_f+n_h-2)\gamma)}$. Note that the cross price derivative is positive and increasing in γ ($\frac{d^2p_i}{dp_{-i}\gamma} = \frac{1}{2(1-2\gamma+\gamma n)^2}$) and negative and decreasing in n ($\frac{d^2p_i}{dp_{-i}n} = -\frac{\gamma^2}{2(1-2\gamma+\gamma n)^2}$). This again gives us some intuition on how policy outcomes may be affected by γ and n[19].

Equilibrium prices and profits, as a function of first-stage R&D expenditures are:

$$\hat{p}_i(\mathbf{\Delta};\gamma) = \frac{(2+\gamma(2n-3))(a(1-\gamma)+c(1+(n-2)\gamma)) - (1+(n-2)\gamma)\left[\Delta_i(2+(n-2)\gamma)+\gamma\left(\sum_{j\in\{H\cup F-i\}}\Delta_j\right)\right]}{(2+\gamma(n-3))(2+\gamma(2n-3))} \tag{2.12}$$

and

$$\hat{\pi}_i(\mathbf{\Delta};\gamma) = \frac{\left[(a-c)(1-\gamma)(2+[2n-3]\gamma)+[2+3(n-2)\gamma+(n^2-5n+5)\gamma^2]\Delta_i - \gamma(1+(n-2)\gamma)\left(\sum_{j\in\{H\cup F-i\}}\Delta_j\right)\right]^2(1+(n-2)\gamma)}{(1-\gamma)[2+\gamma(n-3)]^2(1+(n-1)\gamma)[2+\gamma(2n-3)]^2} - \frac{\Delta_i^2}{2} \tag{2.13}$$

[19]Note that in a stage game these derivatives alone do not determine the policy outcome. In a two stage game where firms first invest in a strategic variable it is the net effect from the two stages that determines policy outcomes.

where $n = n_f + n_h$.

2.2.2. The R&D stage

Firm i, given $\mathbf{\Delta}_{-i}$,chooses Δ_i to maximize its profits (defined above). From the first-order conditions and symmetry we obtain optimal R&D spending, output, price and profits for each of the n firms:

$$\Delta^*(\gamma) = \frac{2(a-c)[1+(n-2)\gamma](2+\gamma[5\gamma-6+n(3+[n-5]\gamma)])}{D_1(\gamma)}, \tag{2.14}$$

$$x^*(\gamma) = \frac{\begin{array}{c}[a[4+14(n-2)\gamma+(77-(77-18n)n)\gamma^2+5(n-2)(11+n(2n-11))\gamma^3+ \\ +(89-n[178+n(-119-2(n-15)n)])\gamma^4+2(n-3)(n-2)(n-1)(2n-3)\gamma^5]+ \\ +c(2+(n-3)\gamma)(1+(n-2)\gamma)(1-(n-1)^2\gamma^2)(2+(2n-3)\gamma)]\end{array}}{(1-\gamma)(1+(n-1)\gamma)D_1(\gamma)}$$

$$p^*(\gamma) = \frac{\begin{array}{c}c(2+(n-3)\gamma)(1+(n-2)\gamma)(1+(n-1)\gamma)(2+(2n-3)\gamma)+ \\ +a(n-1)\gamma^2[3+5(n-2)\gamma+(n-3)(2n-3)\gamma^2]\end{array}}{D_1(\gamma)} \tag{2.15}$$

Firms' profits are then given by

$$\pi^*(\gamma) = \frac{\begin{array}{c}(a-c)^2(1+(n-2)\gamma)\times \\ [8+32(n-2)\gamma+(216-216n+50n^2)\gamma^2+2(n-2)(100+n(19n-100))\gamma^3- \\ (439-n[878+n\{-603+2(82-7n)n\}])\gamma^4+(n-2)(139+n[-278+n(179+2(n-20)n)])\gamma^5-(3-2n)^2(n-3)^2(n-1)\gamma^6]\end{array}}{D_1(\gamma)^2}. \tag{2.16}$$

where, $D_1(\gamma) = 4+\gamma(14n-24+2(3n-7)(3n-4)\gamma+[-61+n(108+n(10n-59))]\gamma^2+(n-3)^2(n-1)(2n-3)\gamma^3)$.

It should be noted that a firm has less incentive to invest in cost-reducing R&D under price competition than under a pure cost-minimizing strategy, since there is a *negative* strategic effect of R&D on profits: as a response to firm i's reduction of unit costs, its rival decreases its price, thus shifting i's demand inwards. Firm i then has to reduce its price in order to sell the same output. By lowering its R&D expenditures beyond the cost minimizing level, a firm can commit to softer competition in the subsequent market game.

It can now be clearly seen that firms invest more in R&D under Cournot than under Bertrand competition. Further, due to the competitive nature of the Bertrand game, Bertrand competition results in higher output and lower profits than under Cournot competition.

2.3. Relating n and γ

Given that firms bear sunk costs prior to market competition it is clear that we can obtain a relationship between product differentiation and the number of firms from the profit equations for both price and quantity competition. This relationship is obtained by solving for the locus of n and γ that give zero profits. We show that the maximum number of firms that can be supported in the industry (n), decreases as the good produced becomes increasingly homogeneous. This result is important as it shows that if sunk costs are endogenous then homogeneous goods industries cannot support a large number of firms in the market. For an increasing degree of product differentiation we see that a greater number of firms (local monopolies) can be accommodated in the market. This relationship is shown in figures 2.1 and 2.2.

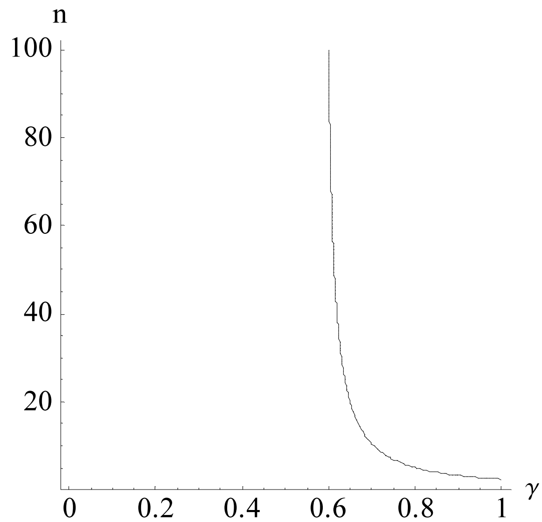

Figure 2.1: **Cournot Competition:** Maximum number of firms (n) that can be sustained for a given degree of product differentiation (γ)

3. R&D subsidies

We look at government policy for R&D subsidies towards domestic monopolies and duopolies under output competition. It is shown that a country, if it decides to engage in active R&D policy, will tax a duopoly if the other country has a monopoly. If the other country also has a duopoly then, in equilibrium, the home country taxes R&D for high levels of product differentiation only[20]. We show

[20]Helpman and Krugman (1992) ask the question on what is the right policy? They argue that the best policy is the one that maximizes welfare. They further argue (p. 102) "*that the case for export subsidies is very fragile indeed.*" Our results agree with what they argue when there are domestic oligopolies in both the countries.

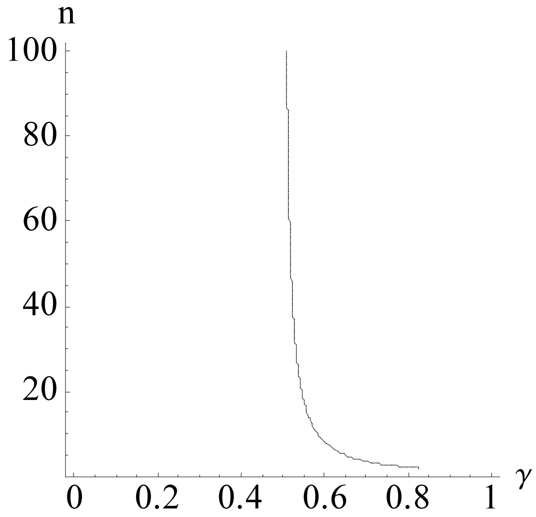

Figure 2.2: **Bertrand Competition:** Maximum number of firms (n) that can be sustained for a given degree of product differentiation (γ)

that increasing the number of firms at home and abroad, symmetrically or asymmetrically, changes the optimal trade policy instrument.[21] However, we show that taxing and welfare improvement (over free trade) is not just an artifact of Bertrand competition. We show this to be true for both quantity and price competition. Though, as shown by Cabral and Kujal (1999) a domestic monopoly is always subsidized if the other country also has a monopoly. Further, even though policy reversal is not to be observed, the prisoners' dilemma nature of policy choice is still observed in the case of domestic monopolies. However, as we will see in the paper this aspect of strategic trade policy does not occur if we consider duopolies.

In this section we first present the results for R&D policy when we have a monopoly in each country under Cournot competition in the third market. Following this we present the case of two duopolies. We finish with the effects of introducing asymmetry in the model by looking at the case of a monopoly in one country and a duopoly in the other. Note that we only present the case of foreign and domestic duopoly. However, similar results are obtained under a symmetric distribution of firms.

3.1. Cournot competition[22]

[21]Thus domestic monopolies do not capture trade policy towards domestic (and international) oligopolies.

First we briefly present the results from Cabral and Kujal (1999) for domestic monopolies. Their main results are that if firms invest in a strategic variable prior to the market competition stage and the government takes into account this investment (credible commitment on the part of the government) then the policy reversal (as shown by Eaton and Grossman, 1986) is not observed. They further show that under low degrees of product differentiation both governments subsidize R&D[23], while output is always subsidized. Thus either instrument dominates depending on the degree of product differentiation.

Then we present results for a R&D subsidy/tax, unilateral or bilateral, for a country with a domestic monopoly or duopoly and solve for the equilibrium in the R&D policy game played in the first stage[24]. We consider this to be the relevant case in our paper as under GATT ruling subsidies to R&D are allowed[25]. We assume that there are firms in two countries selling a differentiated good in a third market. We assume that in the first stage of the game the two governments decide simultaneously whether to engage in active R&D policy, and if so, commit to a subsidy (or tax) on R&D. Given the policy announcement of both governments, firms choose the profit maximizing level of R&D in the second stage. In the third stage they compete in quantities, or prices[26].

3.2. Domestic and Foreign monopoly

Cabral and Kujal (1999) show that if firms first invest in a strategic variable and governments commit to a policy prior to this decision the policy reversal result case due to Eaton and Grossman will not be observed. They present results for both output and R&D subsidy and show that qualitatively similar policy results are obtained under both price and quantity competition.

We will focus on degrees of product differentiation for which we obtain an interior solution. When both countries have just one firm, then under a R&D subsidy (and as shown earlier by Cabral and Kujal) we need to restrict[27] to $\gamma < 0.663916$ for the case of unilateral policy, and to $\gamma < 0.585998$ for the case of bilateral policy[28]. We thus see that the permissible value of γ decreases under bilateral policy for a the case of two monopolies.

We show that (and as shown by Cabral and Kujal) active bilateral policy is observed only for the case when $\gamma < .427853$. That is, for an increasing level of product differentiation both countries

[22] Results for Bertrand competition are available under request. As mentioned earlier the qualitative policy results do not change.

[23] For high degrees of product differentiation, only one country engages in active R&D policy.

[24] At this point we would like to point out that in a two stage we cannot make the convienient symmetry assumption on output that is conventional in one stage games. We need to explicitly solve for the reaction functions for each firm and then solve the problem in the R&D stage. We were unable to achieve this due to analytical complexity. We thus solve the problem only for domestic duopolies.

[25] Later on in the paper we discuss the qualitative differences between subsidizing R&D or output.

[26] Note, as the policy results do not change between quantity and price competition we only present the quantity competition case in the paper. The price competition results are attached in the appendix.

[27] This range ensures that output and R&D choices of the firm in the other country are positive

[28] This restriction prevents imaginary roots for the equilibrium bilateral subsidy.

find it profitable to engage in export promoting policies (R&D subsidies). Further we show that for a range $\gamma \in (0.427853, 0.585998)$ there are two equilibria and in each, *only one* country subsidizes R&D.

Proposition 1 (Equilibrium for R&D subsidies with $(1,1)$ firms). *If we restrict attention to values of γ for which an interior solution exists (i.e. $\gamma < 0.585998$) then the equilibrium of the policy game is as follows:*

- *For $\gamma < 0.427853$ both countries subsidize R&D.*
- *For $0.427853 < \gamma < 0.585998$ we have two equilibria. In each equilibrium one country subsidizes R&D while the other does not engage in active trade policy.*

Proof. Figure a in table 1 shows that countries want to unilaterally subsidize R&D. Figure a in table 2 shows that if both countries engage in active policy, they both subsidize R&D. Note that if country f is not subsidizing, country h prefers to unilaterally engage in active policy rather than remaining on free trade (see figure a - Table 3). On the other hand, if country f subsidizes, country h prefers to subsidize as well (bilateral subsidies) for $\gamma < 0.427853$, otherwise, country h prefers to remain inactive (see figure a - Table 5). ■

Proposition 2 (Welfare under R&D subsidies for $(1,1)$ case). *Restrict attention to values of γ that generate an interior solution. If we compare the equilibrium of the policy game with the outcome under free trade,*

1. *Welfare is lower for both countries when they bilaterally subsidize ($\gamma < 0.427853$)*
2. *Welfare is higher for the subsidizing country and lower for the inactive country in the case of unilateral subsidies ($0.427853 < \gamma < 0.585998$).*

Proof. Free trade is always welfare improving over bilateral subsidies (see figure a - Table 4). However, for $0.427853 < \gamma < 0.585998$ we have an asymmetric equilibrium where one country subsidizes and the other does not. In figure a of table 3 we can see that the country which subsidizes is better that under free trade, but in figure 3.1 we can see that the country that does not subsidize is worse off than under free trade. ■

Note that only for $\gamma < 0.427853$ we have the standard prisoners' dilemma. Thus, even for the case of a monopolistic market structure the classic prisoners' dilemma may not be observed for all γ.

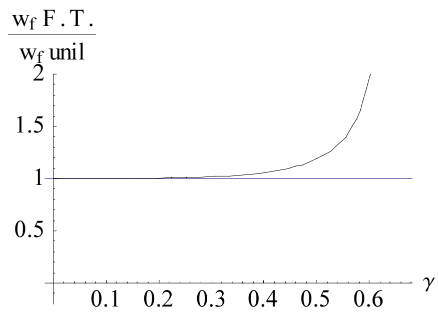

Figure 3.1: Welfare comparison for foreign country and R&D Subsidies: Free trade vs, inactive unilateral subsidies, case $n_h = 1, n_f = 1$.

3.3. Unilateral and Bilateral R&D subsidies–the bilateral duopoly case

The interesting result here is that welfare under bilateral export promotion is greater than under free trade. This result is totally different from the generally accepted prisoners' dilemma nature of these games under bilateral export promotion. Moreover, we observe welfare improvement under quantity and price competition. Further, the optimal policy is a tax for both countries when both of them engage in active policy, otherwise, if only one country is active, it subsidizes R&D.

Now, why does the policy instrument change from the case of two monopolies? To understand this one has to look at the effect on R&D investment and the resulting effect on output (and hence prices). We see that when both countries have two firms, a tax on R&D decreases R&D expenditure for both domestic and foreign firms. As a result the overinvestment in R&D is softened and firms lower output and increase the price, which consequently raises profits (and welfare). Note that a similar intuition is put forth by Helpman and Krugman (1994). They argue that a tax achieves tacit collusion between the firms as it increases prices and decrease output (and R&D expenditure in our model). Further, as the profit transfer effect under bilateral choice is absent, domestic welfare increases. This is precisely what we see under quantity competition in our model. For the case of price competition our results are in the same direction[29]. Our result is of interest because it shows, first, that qualitative results are robust to the nature of market competition. Further, that welfare results are also independent of market structure and the prisoners dilemma nature of policy choice may only be restricted to the case of bilateral monopolies.

We only present the results for the case of bilateral R&D subsidies/taxes. The main difference from our predecessors is that welfare in the equilibrium where both countries subsidize ($\gamma < 0.514708$) is still greater than under free trade. Further, policy choice is shown to be a function of not only whether the domestic market is monopolistic/duopolistic, it is also a function of the degree of product differentiation.

[29]Results for price competition are available upon request.

First we present the results where only the home country subsidizes/taxes. Then we present our results in detail for the bilateral R&D subsidy case and we derive the equilibrium in the policy game. As before, we focus only on the levels of product differentiation that provide interior solutions. For a R&D subsidy and bilateral duopolies we need to restrict[30] to $\gamma < 0.665703$ for the case of unilateral policy, and to $\gamma < 0.586505$ for the case of bilateral policy[31].

3.3.1. Unilateral R&D Subsidies

The output choice stage The domestic country subsidizes, or taxes, its firm(s). Solving for the quantity competition stage we can write the profit maximization problem for the domestic firm as

$$\max_{x_h} \left[(a - x_h - \gamma \left(\sum_{j \in \{H \cup F - i\}} x_j \right) - (c - \Delta_h) \right] x_h - (1 - z_h) \frac{\Delta_h^2}{2}$$

and for the foreign firm as,

$$\max_{x_f} \left[(a - x_f - \gamma \left(\sum_{j \in \{H \cup F - i\}} x_j \right) - (c - \Delta_f) \right] x_f - \frac{\Delta_f^2}{2}.$$

¿From the first order conditions we obtain the reaction functions for the domestic and the foreign firm, respectively,

$$x_i(\mathbf{x}_{-i}) = \frac{1}{2} \left(a - c + \Delta_i - \gamma \left(\sum_{j \in \{H \cup F - i\}} x_j \right) \right), \text{for all } i \in \{H \cup F\} \tag{3.1}$$

Note that as R&D subsidy only enters the first order conditions in the final stage, the reaction functions under an R&D subsidy and under free trade are the same. As before, under free trade the intersection of the $n_h + n_f$ reaction functions gives us the vector of equilibrium quantities $\mathbf{x} = \{x_{1h}, x_{2h}, \ldots, x_{n_h h}, x_{1f}, x_{2f}, \ldots, x_{n_f f}\}$, each chosen given the output of the other firm. Equilibrium output and profits (as a function of first-stage R&D expenditures) are, respectively:

$$\hat{x}_i(\mathbf{\Delta};\gamma) = \frac{(a - c)(2 - \gamma) + (2 + \gamma(n_f + n_h - 2))\Delta_i - \gamma \left(\sum_{j \in \{H \cup F - i\}} \Delta_j \right)}{(2 - \gamma)(2 + (n_f + n_h - 1)\gamma)}. \tag{3.2}$$

R&D choice Substituting the equilibrium quantities into the profit equation we solve for the equilibrium R&D under unilateral subsidies. We obtain the reaction functions for the domestic and foreign firms, respectively.

[30]This range ensures that output, R&D and welfare are positive

[31]This restriction prevents imaginary roots for the equilibrium bilateral subsidy.

$$\Delta_{hi}(\boldsymbol{\Delta}_{-hi}) = \frac{4(1+\gamma)\left((a-c)(2-\gamma) - \gamma\left(\Delta_{hj} + \Delta_{f1} + \Delta_{f2}\right)\right)}{8 - z_h(2-\gamma)^2(2+3\gamma)^2 - \gamma(16-\gamma(16+3(8-3\gamma)\gamma))}, i \neq j, i, j = 1, 2. \tag{3.3}$$

$$\Delta_{fi}(\boldsymbol{\Delta}_{-fi}) = \frac{4(1+\gamma)\left((a-c)(2-\gamma) - \gamma\left(\Delta_{h1} + \Delta_{h2} + \Delta_{fj}\right)\right)}{8 - \gamma(16-\gamma(16+3(8-3\gamma)\gamma))}, i \neq j, i, j = 1, 2. \tag{3.4}$$

and this gives us the equilibrium R&D for the domestic and the foreign firm.

$$\Delta_h^*(\gamma) = \frac{4(1+\gamma)(a-c)(-4+(10-3\gamma)\gamma^2)}{A(\gamma)}$$

$$\Delta_f^*(\gamma) = \frac{4(1+\gamma)(a-c)(-4+(10-3\gamma)\gamma^2 + z_h(2-\gamma)^2(2+3\gamma))}{A(\gamma)}$$

where $A(\gamma) = (4+\gamma^2(-10+3\gamma))(-4+\gamma(-16+3\gamma(-2+3\gamma))) - z_h(-2+\gamma)^2(2+3\gamma)(8+\gamma(20+3\gamma(-4+\gamma(-8+3\gamma)))$.

Unilateral R&D subsidy Substituting the equilibrium R&D into total welfare and maximizing we then obtain the optimal (welfare maximizing) subsidy/tax. Writing the expression for total welfare for country h we get,

$$TW_h = \sum_{i=1}^{2}(\pi_i^* - z_h \frac{\Delta_i^{*2}(\gamma, z_h)}{2})$$

¿From the first order conditions we obtain the welfare maximizing unilateral tax which is,

$$z_h^* = -\frac{\gamma(8+\gamma(4+\gamma(-28+3\gamma(-8+3\gamma(-8+3\gamma)))))}{\gamma(2-\gamma)(2+3\gamma)(-4+\gamma(2+\gamma)(-4+3\gamma))}.$$

Plotting z_h^* with respect to γ we can see (figure d, table 1) that for high levels of product differentiation (low γ) the government taxes R&D, and subsidizes for lower levels of product differentiation. An important implication of this result is that the optimal policy instrument is a function of the degree of competition in the market. Thus models that abstract from product differentiation only look at the special case of a (local) monopoly, or homogeneous good case, and are not a reasonable guide towards policy making.

The unilateral policy is to tax R&D if $\gamma < 0.514708$ and to subsidize it otherwise. Comparing the welfare of the country that unilaterally engages in R&D policy against welfare under free trade we see that a unilateral policy always increases welfare. However, welfare of the non-active country increases if the unilateral policy is a tax but is reduced if the unilateral policy is a subsidy. This is easy to see as the export tax lowers profits for the domestic firms while increasing it for the foreign

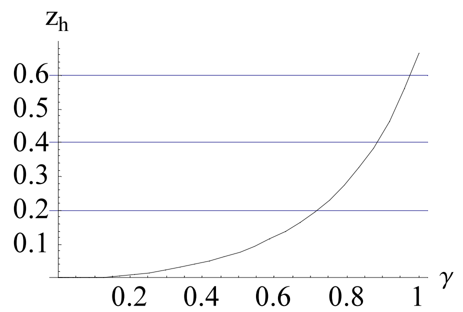

Figure a: $n_h = 1, n_f = 1$

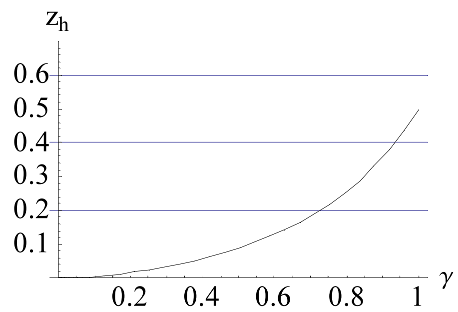

Figure b: $n_h = 1, n_f = 2$

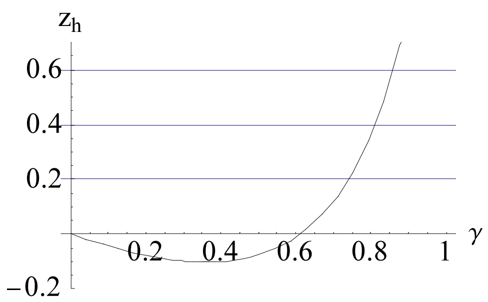

Figure c: $n_h = 2, n_f = 1$

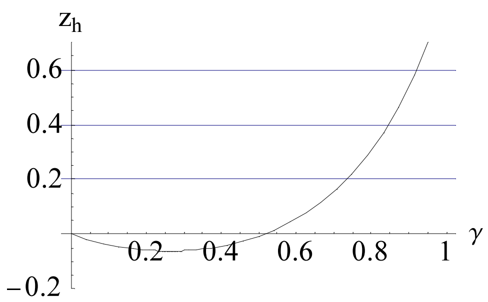

Figure d: $n_h = 2, n_f = 2$

Table 3.1: Cournot: Optimal Unilateral R&D Subsidies (only home country subsidizes)

firms. The welfare of the non-taxing country thus increases by a greater amount relative to the taxing country (the taxed firm sells less at a higher price and the untaxed firms sells more at a lower price). Note, however, that welfare for both the non-taxing, and the taxing country, increases under unilateral taxation. We analyze now the case of bilateral policies.

3.3.2. Bilateral R&D subsidies

The output choice stage Under R&D subsidies the firm maximizes,

$$\max_{x_i} \left[(a - x_i - \gamma \left(\sum_{j \in \{H \cup F - i\}} x_j \right) - (c - \Delta_i) \right] x_i - (1 - z_i) \frac{\Delta_i^2}{2} \tag{3.5}$$

where z_i is the proportion of R&D being subsidized. From the first order conditions we obtain the reaction function,

$$x_i(\mathbf{x}_{-i}) = \frac{1}{2} \left(a - c + \Delta_i - \gamma \left(\sum_{j \in \{H \cup F - i\}} x_j \right) \right), \text{for all } i \in \{H \cup F\} \tag{3.6}$$

The reaction functions can then be used to solve for the equilibrium quantities which are,

$$\hat{x}_i(\mathbf{\Delta};\gamma) = \frac{(a-c)(2-\gamma) + (2 + \gamma(n_f + n_h - 2))\Delta_i - \gamma \left(\sum_{j \in \{H \cup F - i\}} \Delta_j \right)}{(2-\gamma)(2 + (n_f + n_h - 1)\gamma)} \tag{3.7}$$

R&D choice stage

Substituting the equilibrium quantities into the profit equation the maximization problem then becomes,

$$\hat{\pi}_i(\mathbf{\Delta};\gamma) = \left[\frac{(a-c)(2-\gamma) + (2 + \gamma(n_f + n_h - 2))\Delta_i - \gamma \left(\sum_{j \in \{H \cup F - i\}} \Delta_j \right)}{(2-\gamma)(2 + (n_f + n_h - 1)\gamma)} \right]^2 - (1 - z_i) \frac{\Delta_i^2}{2}. \tag{3.8}$$

Maximizing $\hat{\pi}_i(\mathbf{\Delta};\gamma)$ by choice of $\mathbf{\Delta}_i$, we obtain the reaction functions for the domestic and foreign firms, which are exactly the same as equation 3.3 for the home firms and the analog for the foreign firm (which now subsidizes a fraction z_f). The intersection of the $n = n_h + n_f$ reaction functions gives us the equilibrium R&D expenditures as a function of γ.

R&D Subsidy Given the R&D level chosen by the firms, the government i then maximizes total welfare (TW) which is,

$$TW_i = \sum_{i=1}^{2} (\pi_i - z_i \frac{\Delta_i^2}{2})$$

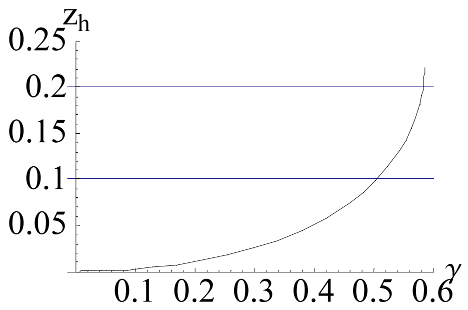

Figure a: $n_h = 1, n_f = 1$

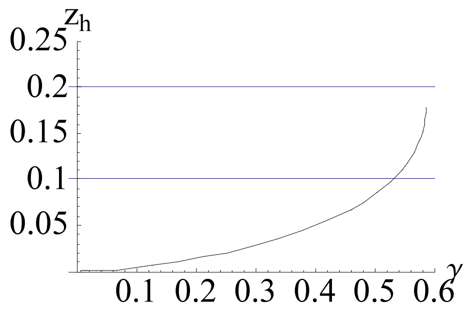

Figure b: $n_h = 1, n_f = 2$

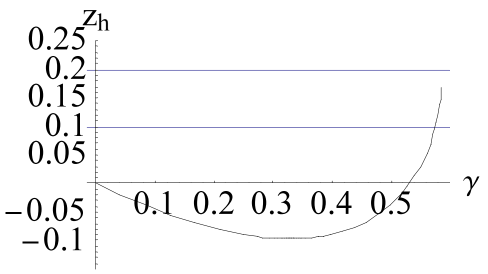

Figure c: $n_h = 2, n_f = 1$

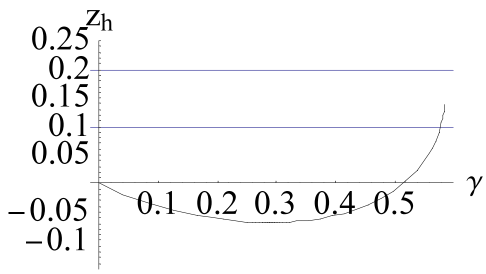

Figure d: $n_h = 2, n_f = 2$

Table 3.2: Cournot: Optimal Bilateral R&D Subsidies

From the focs we obtain,

$$z_i = \frac{2 + 2\gamma - 3\gamma^2 - (1+\gamma)\sqrt{((2-(4-\gamma)\gamma)(2+3\gamma(4+3\gamma)))}}{((-2+\gamma)(2+\gamma)(2+3\gamma)} \tag{3.9}$$

Note that the optimal subsidy is independent of market size and marginal cost (i.e., $a-c$). Plotting, it can be seen that if both countries engage in active policy they tax for the relevant[32] range of $\gamma \in (0, .586505)$ (see figure d in table 3.2).

Substituting the equilibrium R&D values in total welfare we then get total welfare under bilateral R&D subsidies (TW_{RD}).

$$TW_{RD} = (a-c^2)\frac{(-2+4\gamma-\gamma^2+((2+(4-3\gamma)\gamma)(2+(-4+\gamma)\gamma))}{\sqrt{((2-(4-\gamma)\gamma)(2+3\gamma(4+3\gamma)))}}. \tag{3.10}$$

Total welfare is positive for all $\gamma \leq 0.586505$ and bilateral policy choice is better (gives a higher welfare) than free trade for all $\gamma < 0.514708$.[33] However, as we will see in the proposition below, in

[32]We define the relevant range for γ as the range for which profits, output, R&D and welfare is non-negative.

[33]This result is robust to price or quantity competition. As we will show later, the qualitative results under price competition are the same.

the case of only one country engaging in active policy, pursuing that active policy increases welfare over free trade, whereas the country who is not active is worse off than under free trade. This further stresses the importance of using product differentiation models with endogenous sunk costs if one wants to study strategic trade policy towards such industries. Equilibrium policies are not just a function of the number of firms inside a country, they also depend on the degree of product differentiation. Further, given the number of firms inside countries may choose to subsidize or tax, unilaterally or bilaterally, depending on the degree of product differentiation.

Models that abstract from these details can thus be a wrong guide towards policy making. The results are summarized in the following proposition.

Proposition 3 (Equilibrium for R&D subsidies with $(2, 2)$ firms). *Restrict attention to interior solutions ($\gamma < 0.586505$) then the equilibrium of the policy game is as follows:*

- *For $\gamma < 0.514708$ both countries tax R&D.*
- *For $0.514708 < \gamma < 0.585998$ we have two equilibria. In each equilibrium one country subsidizes R&D while the other does not engage in active trade policy.*

Proof. Figure d in table 3 shows that if the other country (in that figure, the foreign country) is not engaged in active policy, then a government always prefers to engage in trade policy unilaterally. Left to show is the best response to the other country being active. Figure d in table 5 shows that if the other country is active, the home country prefers to be active if $\gamma < 0.514708$ and prefers to be inactive otherwise ($0.514708 < \gamma < 0.585998$). As the structure of the policy game is symmetric, we have two equilibria for the latter range. This proves the structure of the equilibria claimed in the proposition.

No turn to the sign of the active policy. In figure d of table 2, we see that under bilateral policy ($\gamma < 0.514708$) we get a negative subsidy (i.e. a tax) for both countries. If we have unilateral policy then figure d of table 1 shows that for that range ($0.514708 < \gamma < 0.585998$) the active country imposes a subsidy. ■

Proposition 4 (Welfare under R&D subsidies for $(2, 2)$ case). *Restrict attention to values of γ that generate an interior solution. If we compare the equilibrium of the policy game with the outcome under free trade,*

1. *Welfare is higher for both countries when they bilaterally tax R&D ($\gamma < 0.514708$)*
2. *Welfare is higher for the subsidizing country and lower for the inactive country in the case of unilateral policy ($0.514708 < \gamma < 0.585998$).*

Proof. Bilateral policy increases welfare over free trade for $\gamma < 0.514708$ (see figure d in table 4). This proves claim 1 in the proposition. When one of the countries prefers to remain inactive ($0.514708 < \gamma < 0.585998$) the active country, which subsidizes R&D, has higher welfare than under free trade (figure d in table 3[34]). Looking at figure 3.2, for $0.514708 < \gamma < 0.585998$ a country is worse off when he remains unilaterally inactive (unil inac). ■

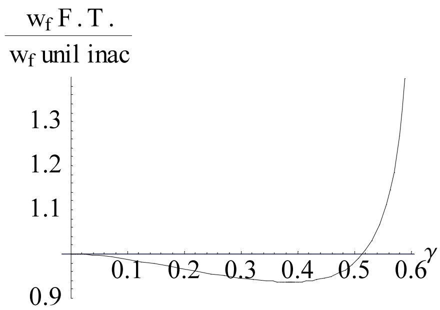

Figure 3.2: Welfare comparison for R&D Subsidies: Free trade vs, inactive unilateral subsidies, case $n_h = 2, n_f = 2$.

Note that we no longer have a prisoners' dilemma for this case as both countries are better off under bilateral policy. The prisoners' dilemma nature of policy choice in these games is only valid for the special case of domestic and foreign monopolies. We also see that unlike the results obtained earlier for oligopolistic market structures the policy choice is always a tax for high degrees of product differentiation ($\gamma < 0.514708$). Further, in our model, policy outcomes and qualitative welfare results are consistent under price or quantity competition.

3.4. R&D subsidies: the (1,2) firms structure

Here we analyze the case of a country having a monopoly and another having a duopoly.[35] We show that the country with one firm subsidizes and the country with two firms taxes R&D. However, depending on the degree of product differentiation, it may be the case that, in equilibrium, not both of them are active at the same time. This result is important as it links the degree of product differentiation to the choice of active government policy towards R&D.

As before, we focus on degrees of product differentiation for which we obtain an interior solution. In this case we need to restrict to $\gamma < 0.627557$ if the country with one firm imposes a unilateral policy[36], to $\gamma < 0.679209$ if the country with two firms imposes the unilateral policy (for the same

[34] As can be seen from that figure, this is true for all γ.

[35] For some permutations we have verified that for a domestic monopoly and increasing the number of foreign firms a domestic monopoly is always subsidized.

[36] This range ensures that output and R&D are positive for the other country

reasons as before), and to $\gamma < 0.587535$ for the case of bilateral policy.[37]

If the country has two firms, the government unilaterally taxes (figure c in table 3.1) for high levels of product differentiation ($\gamma < 0.611472$) and subsidizes for all $\gamma \in (0.611472, 0.679209)$. For the country with one firm welfare and profits are positive for all γ and the government always chooses to subsidize R&D. Unilateral active policy by the government is always profitable. Under unilateral active policy the welfare of the passive country increases only if it is the country with a monopolist. If both countries subsidize (which they do for $\gamma < 0.273545$) then welfare is greater for both countries relative to free trade. This again confirms that there is no prisoners' dilemma structure in this case.

We summarize our results in the propositions below.

Proposition 5 (Equilibrium for R&D subsidies for $(1, 2)$ firms). *If we restrict attention to values of γ for which an interior solution exists (i.e. $\gamma < 0.587535$) then the equilibrium of the policy game is as follows:*

- *For $\gamma < 0.273545$ both countries engage in active R&D promotion: the country with 2 firms (foreign country) taxes R&D, while the country with 1 firm (home country) subsidizes it.*
- *For $0.273545 < \gamma < 0.531453$ the country with 2 firms (foreign country) taxes R&D, while the country with one firm (home country) prefers to remain inactive (no R&D promotion).*
- *For $0.531453 < \gamma < 0.587535$ we have two equilibria:*
  - *Equilibrium I: the country with 2 firms (foreign) taxes R&D, the country with one firm (home) remains inactive.*
  - *Equilibrium II: the country with 2 firms (foreign) remains inactive, while the country with one firm (home) subsidizes R&D.*

Proof. Note that if the country with 2 firms does not engage in active policy, the country with one firm wants to unilaterally subsidize R&D for all γ (see figure b in table 1). On the other hand, if the country with 1 firm does not engage in active policy, the country with two firms wants to tax R&D for $\gamma < 0.611472$ (see figure c in table 1).[38] Figures b and c in table 3 show that, for all γ, these unilateral policies are preferred to remaining inactive if the other country is inactive, so the best response to the other country being inactive is to have an active policy.

Turn next to the best response to the other country having an active policy. If the country with one firm has an active policy, then figure b in table 5 shows that the country with 2 firms (in

[37]This restriction prevents imaginary roots for the equilibrium bilateral subsidy.

[38]Notice that since the case $(n_h, n_f) = (1, 2)$ or $(2, 1)$ are completely symmetric to a change in names. Table 1 only shows unilateral choice of subsidy/tax for the home country in each case.

that figure, the foreign country) also wants to be active for $\gamma < 0.531453$ and inactive otherwise. If the country with two firms has an active policy, then figure c in table 5 shows that the country with one firm (in that figure, the foreign country) wants to be active if $\gamma < 0.273545$ and inactive otherwise.

Putting together these reaction functions we arrive to the structure of the equilibria in the proposition. Figures b and c in table 2 show that in the case of a bilateral active policy ($\gamma < 0.273545$) the country with one firm subsidizes R&D (figure b) while the country with two firms taxes it (figure c). ■

Proposition 6 (Welfare under R&D subsidies for $(1,2)$ case). *Restrict attention an interior solution ($\gamma < 0.587535$). If we compare the equilibrium of the policy game with the outcome under free trade:*

1. *Welfare is higher for both countries when they both engage in active policy ($\gamma < 0.273545$)*
2. *If one country engages in active R&D policy and the other remains inactive ($0.273545 < \gamma < 0.587535$), then*
   - *Both countries are better off when the country with two firms (foreign) is active (taxes output).*
   - *The country with two firms (foreign) is worse off and the country with one firm (home) is better off when the latter is the only one with an active policy of subsidizing output. (Equilibrium II for $0.531453 < \gamma < 0.587535$)*

Proof. Note that in equilibrium, both firms engage in active policy for $\gamma < 0.273545$. In figures b and c in table 4 we can see that, for that range, bilateral policy is better for both countries than free trade. That proves the first claim in the proposition.

For $0.273545 < \gamma < 0.587535$ the country with 2 firms (foreign) taxes R&D and the country with one firm remains inactive. In figure 3.4 we can see that the country with one firm (foreign country in that figure) is better off remaining unilaterally inactive that under free trade. Figure c in Table 3 shows that the country with 2 firms (home in that figure) is better off by unilaterally engaging in active policy.

For $0.531453 < \gamma < 0.587535$ we have an additional equilibrium where, the country with two firms (foreign) is inactive and the country with one firm (home) subsidizes output. Figure b in Table 3 shows that the country with one firm (home country in the picture) is better off by unilaterally engaging in output promotion, while figure 3.3 shows that the country with two firms (foreign country in the picture) is worse off when he remains unilaterally inactive. ■

Once more one of the important results that emerges from our analysis is that policy choice can be welfare improving over free trade when one moves away from monopolistic market structures.

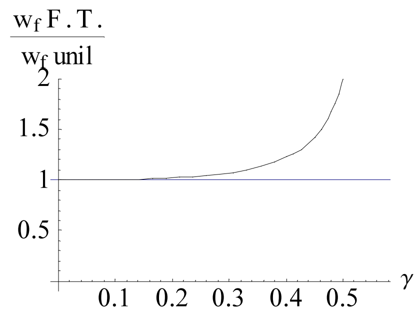

Figure 3.3: Welfare comparisons for foreign country (R&D Subsidies and Cournot compet.): Free trade vs. unilaterally inactive. $n_h = 1, n_f = 2$.

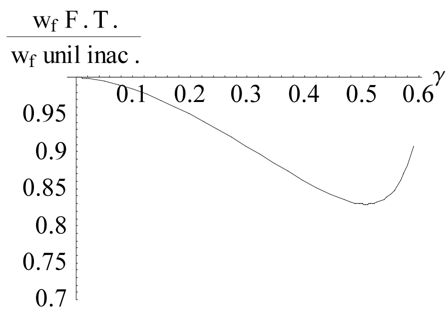

Figure 3.4: Welfare comparisons for foreign country with R&D Subsidies under Cournot competition: Free Trade vs. unilaterally inactive. $n_h = 2, n_f = 1$.

Further, welfare is positive (that is, governments have incentive to subsidize, or tax) and is greater than under free trade for all the cases when a country is actively engaged in policy. A domestic, or foreign monopolist, is always subsidized while a duopoly is always taxed. Once more reaffirming the fact that policy choice cannot be independent of degree of product differentiation, market structure and the nature of (endogenous) sunk costs.

3.5. Discussion

Our results can be explained by a simple intuition. Under a domestic monopoly the government policy only shifts the reaction function of the home firm. Thus, a unilateral subsidy pushes out the reaction function of the domestic monopoly and takes it to the profit maximization point for the Stackelberg leader. The incentive to unilaterally subsidize a domestic monopoly thus exists.

Note that since there are more than one firm at home, the standard result from Cournot markets

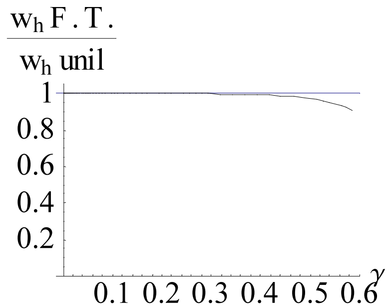

Figure a: $n_h = 1, n_f = 1$

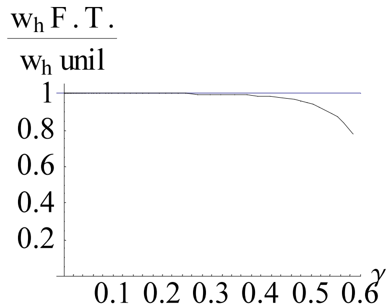

Figure b: $n_h = 1, n_f = 2$

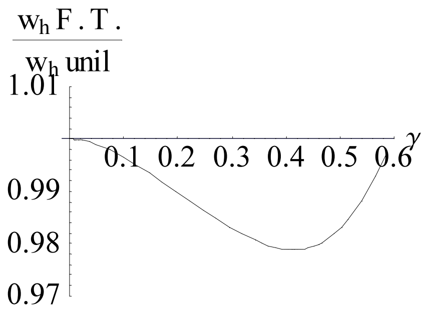

Figure c: $n_h = 2, n_f = 1$

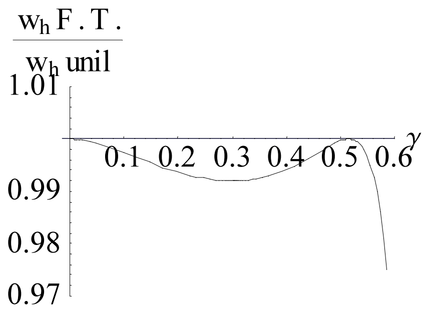

Figure d: $n_h = 2, n_f = 2$

Table 3.3: Cournot: Free Trade vs. Unilateral Active R&D subsidies (only home country subsidizes)

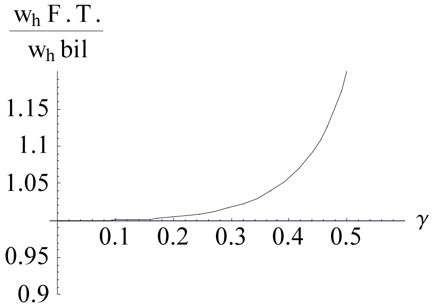

Figure a: $n_h = 1, n_f = 1$

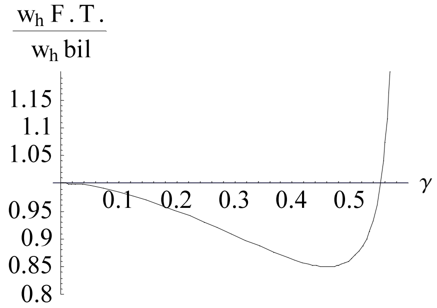

Figure b: $n_h = 1, n_f = 2$

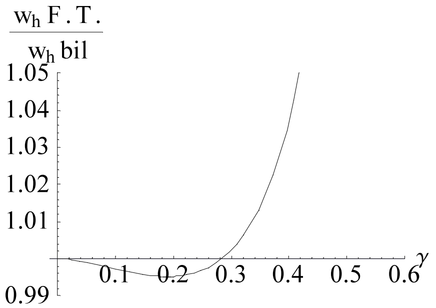

Figure c: $n_h = 2, n_f = 1$

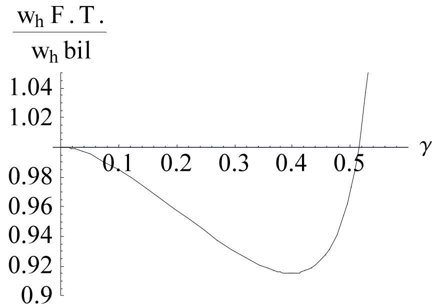

Figure d: $n_h = 2, n_f = 2$

Table 3.4: Cournot: Free Trade vs. Bilateral R&D Subsidies

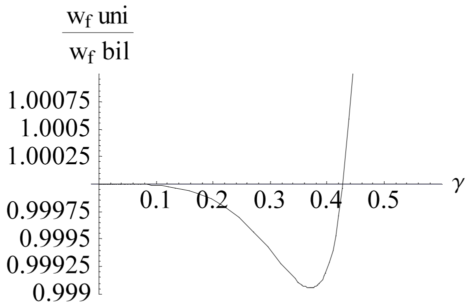

Figure a: $n_h = 1, n_f = 1$

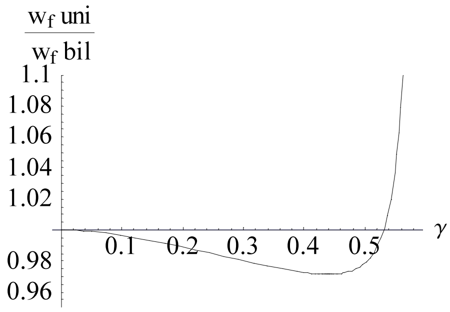

Figure b: $n_h = 1, n_f = 2$

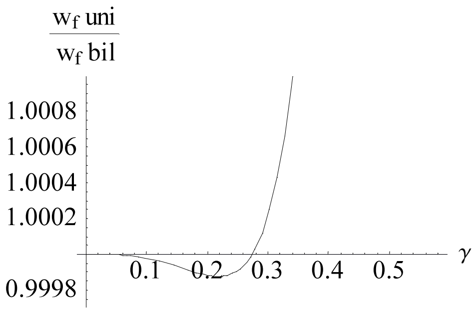

Figure c: $n_h = 2, n_f = 1$

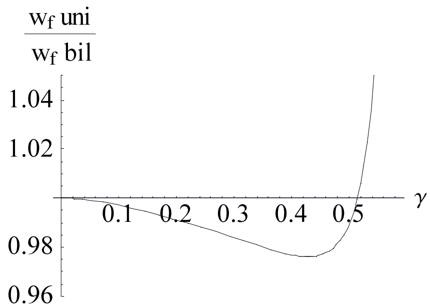

Figure d: $n_h = 2, n_f = 2$

Table 3.5: Cournot: Inactive Unilateral vs. Bilateral R&D subsidies

is that firms produce too much from the point of view of joint profits. Therefore, a government will want to tax a domestic oligopoly to solve the *negative domestic externality.* Now, a government wants to subsidize the domestic firms because of the profit-shifting induced by the subsidy (home firms become more competitive). However, under a domestic duopoly a subsidy, or tax, shifts the reaction function of all the domestic firms. As a result, and imagining that we have one firm on the x-axis and the aggregate output of all the others on the y-axis (including the other domestic firms), a subsidy shifts not only the reaction function of the domestic firm but also the reaction of all the other firms in the market. With both reaction functions shifting out it is easy to see that lower profit outcomes are achieved.. Hence, a subsidy does not achieve the profit transfer effect a tax does. As a result, regardless of market competition and the relative distribution of firms, duopolies are always taxed.

4. Conclusion

This paper shows that optimal trade policy instruments are sensitive to market structures. When deciding on policy, governments should take into account two factors: market structure (i.e., whether the domestic industry is an oligopoly, or a monopoly) and the degree of product differentiation. Market structure is important as the presence of a monopoly (duopoly) engenders a negative (positive) externality on the domestic firms. This externality is smaller or greater depending on the degree of product differentiation. If the domestic market structure is monopolistic then we show that the domestic government always subsidizes and that this result is robust to the price or quantity competition. This happens as government policy can now shift the reaction function of the monopolist to the Stackelberg point. However, in this scenario depending on the degree of product differentiation several equilibria may occur where bilateral, or unilateral, R&D promotion may be undertaken by countries.

Further, we show that (and as shown earlier in the numbers critique) that policy depends on the number of firms that are present inside and outside a country. However, unlike the numbers critique we show that policy depends on the absolute number of firms in both countries and not only on the relative asymmetry in the distribution of firms. The results depend also on the degree of product differentiation γ.

We further show that for symmetric oligopolies taxing dominates for a high degree of product differentiation and welfare under such a tax is always greater than under free trade. Policy choice under a domestic oligopoly does not have the structure of a prisoners' dilemma game (as is the case for a domestic monopoly). Also, we have shown than in some cases the equilibrium involves one country remaining inactive with respect to trade policy, even though its welfare is reduced respect to free trade. Thus, retaliation may not be observed by the competing government.

This paper thus presents some important results. It shows that the optimal policy instruments are not simply sensitive to the relative asymmetry in the distribution of firms in the two exporting countries but also to the market structure and the degree of product differentiation. Moving from two domestic monopolies to two domestic duopolies the countries tax R&D for high degrees of product differentiation, instead of subsidizing it[39]. Second, increasing the numbers of firms at home and abroad, symmetrically or asymmetrically, does not change the policy instrument. Countries with duopolies usually tax R&D[40] and this result is robust to both Cournot and Bertrand competition. Third, under domestic oligopolies policy choice need not always have the characteristics of a prisoners' dilemma: bilateral policies are welfare improving over free trade. Finally, the degree of product differentiation matters on policy as it crucially affects profits (and thus welfare) of a country. Thus generalizing results from domestic monopolies to oligopolistic markets, independent of market structure and the degree of product differentiation, can be misleading.

A. Appendix: Some Results for Output Subsidies

A.1. Case $n_h = 1$, $n_f = 1$

For the unilateral choice of output subsidy, we need to restrict $\gamma < 0.60423$ to assure that $x_f > 0$.

For the bilateral choice of output subsidy, we need to restrict to $\gamma < 0.666594$ to assure $w_h > 0$.

Proposition 7 (Output subsidies with $(1,1)$ firms). *If we restrict attention to values of γ for which an interior solution exists (i.e. $\gamma < 0.60423$) then*

1. *Subsidizing output is a dominant strategy for both countries.*
2. *Therefore, the equilibrium of the policy game involves both countries subsidizing output.*

Proof. Figure a in table 6 shows that each country wants to unilaterally subsidize output. Figure a in table 7 shows that when both countries engage in active policy, they want to subsidize output as well. Note that if country f is not subsidizing, country h prefers to unilaterally subsidize rather than remaining on free trade for all γ (see figure a - Table 9). On the other hand, if country f subsidizes, country h prefers to subsidize as well (bilateral subsidies) for all γ (see figure a - table 10). This establishes that subsidizing output is a dominant strategy for both countries in the output subsidy game, and thus the only equilibrium is a bilateral output subsidy. ■

Proposition 8 (Welfare under output subsidies for $(1,1)$ case). *Restricting attention to values of γ that generate an interior solution, welfare is lower under bilateral subsidies than under free trade.*

[39] Note, in the numbers critique no policy change is observed in this scenario.

[40] Countries with a duopoly always tax (if they engage in active R&D policy at all) when the other country has a monopolist.

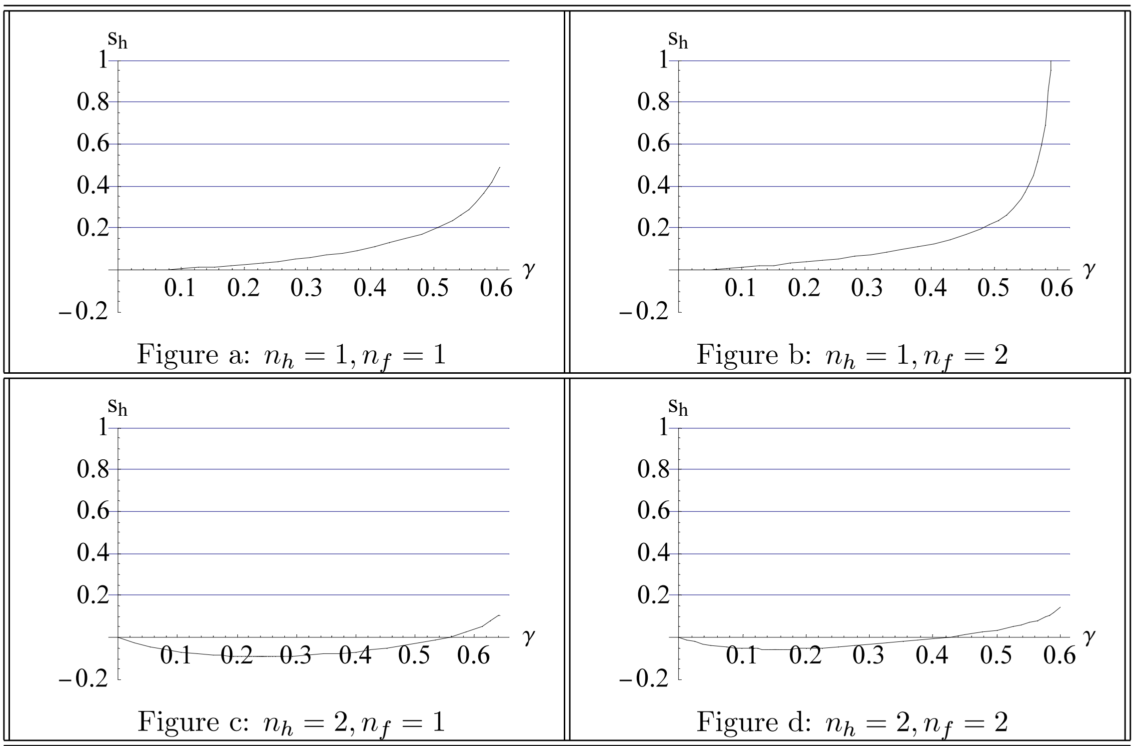

Figure a: $n_h = 1, n_f = 1$

Figure b: $n_h = 1, n_f = 2$

Figure c: $n_h = 2, n_f = 1$

Figure d: $n_h = 2, n_f = 2$

Table A.1: Cournot: Optimal Unilateral Output Subsidies (only home country subsidizes)

Proof. Free trade is always welfare improving over bilateral subsidies (see figure a - Table 4). ■

Remark: Note that for all γ we have the standard prisoners' dilemma in international export promotion highlighted by Helpman and Krugman (1994)

A.2. Case $n_h = 1$, $n_f = 2$

Again, as this case is symmetric to the case $n_h = 2, n_f = 1$ we will use the graphs for both cases for the effects of unilateral policy.

If the country with one firm (home) imposes a unilateral output subsidy/tax, we need to restrict attention to $\gamma < 0.567835$ to ensure $x_f > 0$.

If the country with 2 firms (foreign) imposes a unilateral output subsidy/tax, we need to restrict attention to $\gamma < 0.648183$ to ensure $x_h > 0$.

If both countries decide to engage in active policy (bilateral output subsidies/taxes), then we need to restrict attention to $\gamma < 0.567835$ to ensure $x_f > 0$ and $\Delta_f > 0$.

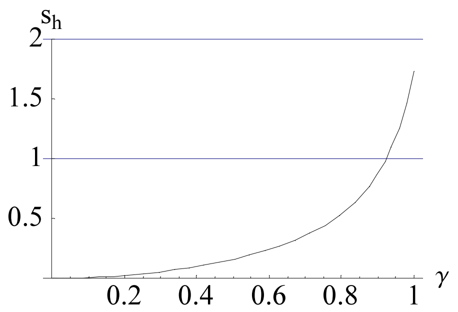

Figure a: $n_h = 1, n_f = 1$

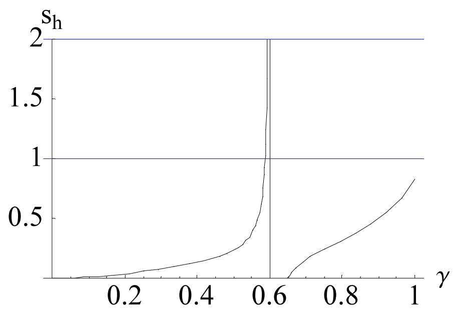

Figure b: $n_h = 1, n_f = 2$

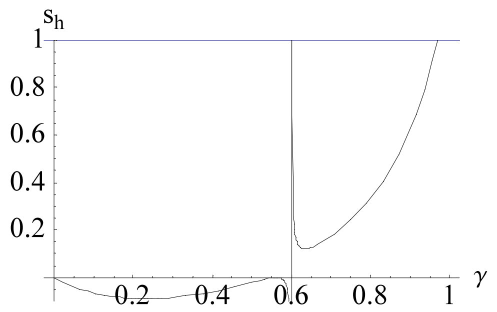

Figure c: $n_h = 2, n_f = 1$

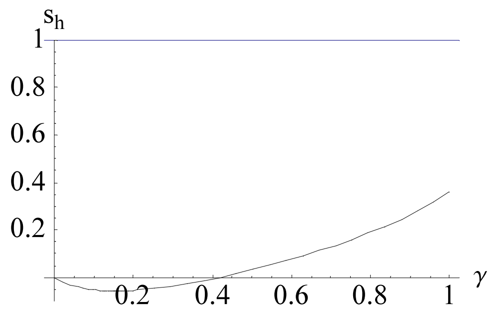

Figure d: $n_h = 2, n_f = 2$

Table A.2: Cournot: Optimal Bilateral Output Subsidies

Proposition 9 (Output subsidies with $(1,2)$ firms). *Restrict attention to values of γ for which an interior solution exists ($\gamma < 0.567835$). Then*

1. *Subsidizing output is a dominant strategy for the country with 1 firm (home).*
2. *The equilibrium in the choice of output subsidies when we have cournot competition is as follows:*

- *For $\gamma < 0.396448$ both countries engage in output promotion: the country with 1 firm (home) subsidies output, while the country with 2 firms (foreign) imposes a tax.*
- *For $0.396448 < \gamma < 0.552733$ the country with 1 firm (home) subsidizes output, while the country with 2 firms (foreign) remains inactive.*
- *For $0.552733 < \gamma < 0.567835$ both countries subsidize output.*

Proof. Figures b in tables 6 and 7 show that, for the relevant range ($\gamma < 0.567835$) the country with one firm (home in those figures), if engaged in active policy, wants to subsidize output. Figure b in table 8 shows that it prefers to engage in active policy if the other country (foreign in that figure) does not engage in active policy. Figure c in Table 10 shows that the country with 1 firm (foreign in that figure) prefers to remain active if the other country (home in that figure) has an active policy. This proves claim 1 in the proposition.

Since we know that the country with one firm has a dominant strategy, all we need to check is the best response of the country with two firms (foreign) to the other country being active. Figure b in table 10 shows that for $\gamma < 0.396448$ and $0.552733 < \gamma < 0.567835$ the foreign country wants to have an active policy, while for $0.396448 < \gamma < 0.552733$ it prefers to remain inactive. This completes the structure of the equilibrium in claim 2. To know the sign of the active policy for the foreign country, we need to look at figure c in table 7. There, for $\gamma < 0.396448$ the country with two firms (in that figure, the home country) wants to tax output, while for $0.552733 < \gamma < 0.567835$ it prefers to subsidize it. This completes the proof of claim 2 in the proposition. ■

Proposition 10 (Welfare under output policy in the $(1,2)$ case.). *Restricting attention to an interior solution ($\gamma < 0.567835$), then*

- *For $\gamma < 0.175777$ both countries are better off than under free trade.*
- *For $0.175777 < \gamma < 0.567835$ the country with one firm (home) is better off and the country with two firms (foreign) is worse off than under free trade.*

Proof. In equilibrium, both firms engage in active policy if $\gamma < 0.396448$ and $0.552733 < \gamma < 0.567835$. In figure b in table 9, the country with one firm (home) is better off under bilateral policy for all γ, whereas in figure c in that table, the country with 2 firms (home country in that picture) is better off under bilateral policy only if $\gamma < 0.175777$. If $0.396448 < \gamma < 0.552733$ then in equilibrium the country with one firm (home) engages in active policy, while the country with two firms remains inactive. In figure A.1 we show that welfare is lower for the country with two firms (foreign country in that picture) if it remains inactive while the other engages in active output policy. ■

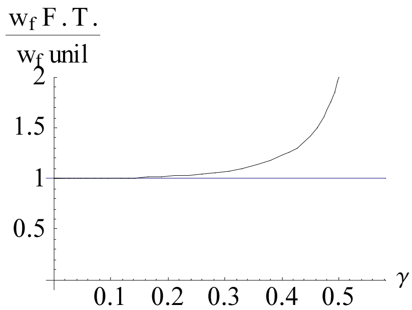

Figure A.1: Welfare comparison under Cournot Competition and output Subsidies: foreign unilaterally inactive vs. free trade ($n_h = 1, n_f = 2$)

A.3. Case $n_h = 2$, $n_f = 2$

For the unilateral choice of output subsidy, we need to restrict $\gamma < 0.603565$ to assure that $x_f, \Delta_f > 0$.and that $w_h > 0$.

For the bilateral choice of output subsidy, we need to restrict to $\gamma < 0.641866$ to assure $w_h > 0$.

Proposition 11 (Output subsidies with $(2, 2)$ firms). *If we restrict attention to values of γ for which an interior solution exists (i.e. $\gamma < 0.603565$) then*

1. *Engaging in active policy is a dominant strategy for both countries.*
2. *The sign of the (symmetric) bilateral policy depends on γ :*
   - *For $\gamma < 0.416944$ both firms impose a tax on output*
   - *For $0.416944 < \gamma < 0.603565$ both firms subsidize output.*

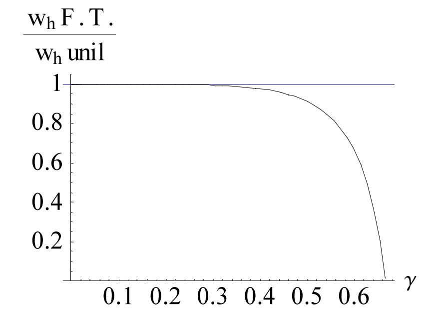

Figure a: $n_h = 1, n_f = 1$

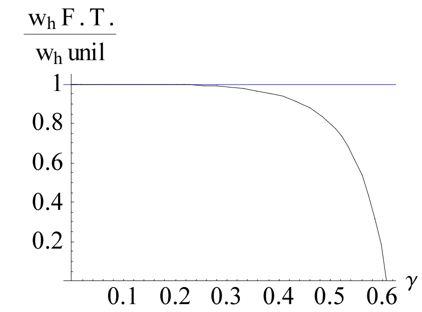

Figure b: $n_h = 1, n_f = 2$

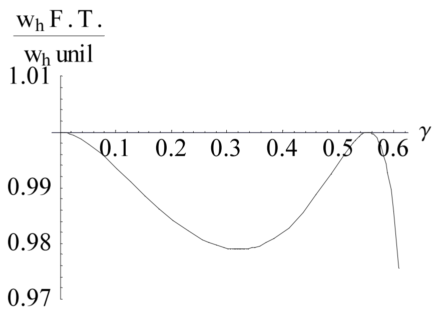

Figure c: $n_h = 2, n_f = 1$

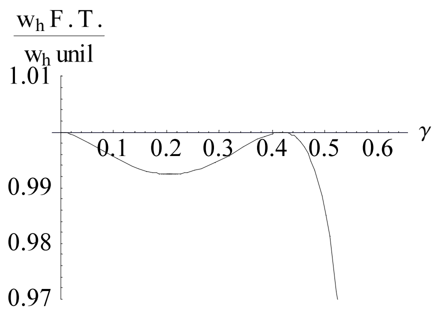

Figure d: $n_h = 2, n_f = 2$

Table A.3: Cournot: Free Trade vs. Unilateral ouput subsidies

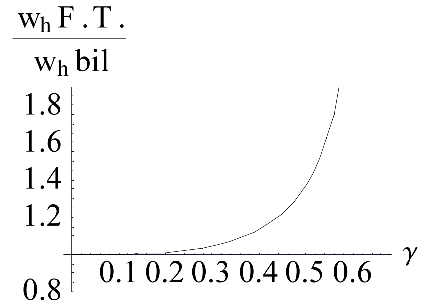

Figure a: $n_h = 1, n_f = 1$

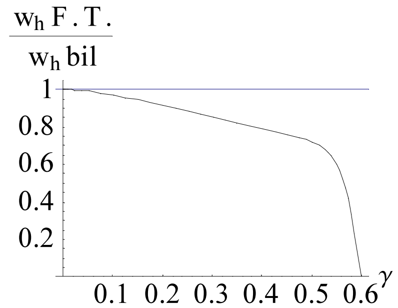

Figure b: $n_h = 1, n_f = 2$

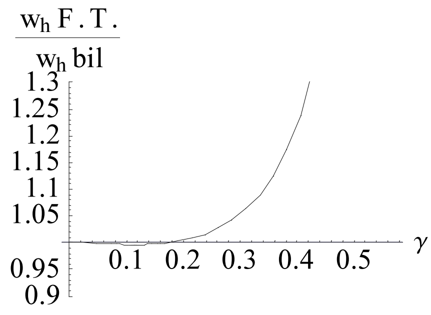

Figure c: $n_h = 2, n_f = 1$

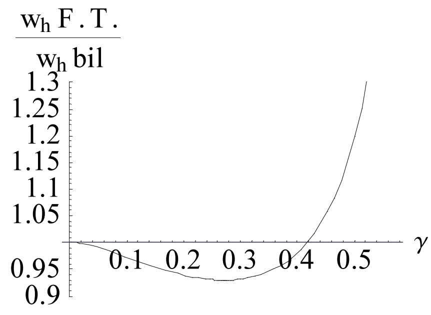

Figure d: $n_h = 2, n_f = 2$

Table A.4: Cournot: Free Trade vs. Bilateral output subsidies

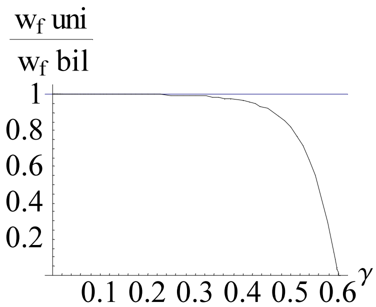

Figure a: $n_h = 1, n_f = 1$

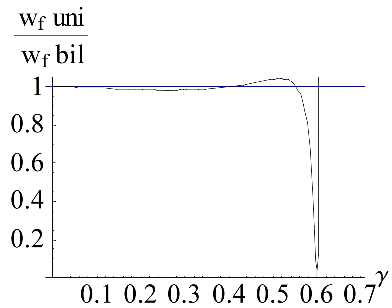

Figure b: $n_h = 1, n_f = 2$

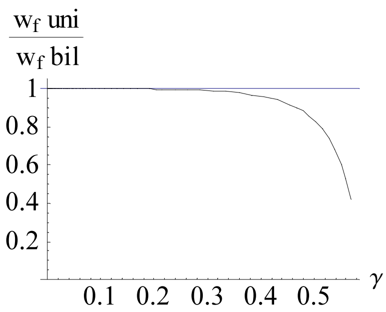

Figure c: $n_h = 2, n_f = 1$

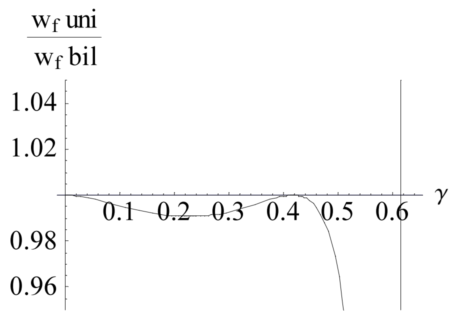

Figure d: $n_h = 2, n_f = 2$

Table A.5: Cournot: Unilaterally inactive vs Bilateral output subsidies

Proof. Figure d in table 8 shows that for the relevant range ($\gamma < 0.603565$) a country wants to engage in active policy if the other does not. Figure d in table 10 shows that for those values of γ, a country wants to be active if the other is also active. Therefore being active is a dominant strategy in this case (claim 1).

Given that we have a bilateral active policy in equilibrium, figure d in table 7 shows that each country wants to impose a negative subsidy on output (i.e. a tax) for $\gamma < 0.416944$ and an output subsidy for $0.416944 < \gamma < 0.603565$. This proves claim 2 in the proposition. ■

Proposition 12 (Welfare under output subsidies for $(2, 2)$ case). *Restricting attention to values of γ that generate an interior solution ($\gamma < 0.603565$), then*

- *For $\gamma < 0.416944$, both countries tax output and are better off than under free trade.*
- *For $0.416944 < \gamma < 0.603565$ both firms subsidize output and are worse off than under free trade.*

Proof. Immediate from figure d in table 9. ■

Remark Note that the standard prisoners' dilemma in international export promotion highlighted by Helpman and Krugman (1994) is now restricted to the range $0.416944 < \gamma < 0.603565$.

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