International trade policy towards monopolies and oligopolies

Praveen Kujal and Juan Ruiz*
Universidad Carlos III de Madrid

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Abstract

We study the effect of market structure upon international trade policy when firms invest in process R&D before competing in a differentiated goods market. For a domestic monopoly, and increasing the number of foreign firms, the government either chooses a R&D (and output) subsidy, or remains inactive. For a domestic duopoly a government taxes, subsidizes, or does not promote R&D depending upon the number of domestic firms and the degree of product differentiation. R&D (and output) is taxed for high levels of product differentiation. For lower levels of product differentiation only one country may subsidize in equilibrium. Further, the results are robust to Cournot or Bertrand competition.

JEL Classification: F12, F13, L13.

Keywords: Product Differentiation, Strategic Trade Policy, Policy Reversals, R&D subsidies, monopoly, duopoly.

*Mailing Address: Universidad Carlos III de Madrid, Calle Madrid 126, 28903 Getafe, SPAIN. Fax: +(34) 91 624 9875. Kujal: Tel: +(34) 91 624 9651, e-mail: kujal@eco.uc3m.es. Ruiz: Tel: +(34) 91 624 9652, e-mail: jruiz@eco.uc3m.es Both authors aknowledge support from Comunidad de Madrid grant number 00/0064/2000.

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 in this framework the behavior of international oligopolies and the profit shifting argument can be easily studied. The main result from this model is that unilaterally active policy is beneficial. Extensions of this model have shown that it is sensitive to the nature of market competition[1] (Eaton and Grossman, 1986) and to the distribution of firms across exporting countries (Dixit,1984). Bagwell and Staiger (1994) show that R&D subsidy towards monopolies is robust to the nature of market competition. Others have meanwhile criticized the model for being mercantilist (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 faces the baffling question about the nature of market competition and what policy to choose[2]. We provide some answers to these questions.

In this paper we argue that optimal policy may vary depending upon the degree of product differentiation and whether the domestic market has a monopoly, or an oligopoly. Though, domestic monopolies competing in a third market reflect international oligopolistic competition, they do not capture export promotion policy towards domestic oligopolies competing in international markets. Given that most markets are characterized by oligopolies it is of interest to see how policy and welfare may change under such a scenario and how the results may differ from the special case of domestic monopolies. This is a reasonable question for many reasons. Though, the domestic monopolies model captures oligopolistic competition in the foreign market it ignores the effect of domestic oligopolies on policy choice[3]. If the choice of trade policy instruments is sensitive to market structure and the degree of product differentiation then policy makers should be aware of this aspect.

The issue of looking at domestic oligopolies is directly related to the numbers critique of the BS model[4]. It argues that trade policy instruments are sensitive to the *relative distribution* of firms in the foreign and home market. In this context we put the numbers critique in a different light. We frame it as policy choice towards a domestic monopoly, or oligopoly. We then show that trade policy instruments are sensitive to whether the domestic market structure is monopolistic, or duopolistic, and to the degree of product differentiation in a non-linear way. Across the various market structures that can emerge the monopoly case is shown to be a special case.

Moving from a domestic monopoly to a domestic oligopoly optimal trade policy changes in two ways. First, increasing the number of firms at home and abroad *alters* the sign of the optimal trade policy for both domestic and foreign governments in the same way. This is in contrast to the result where the sign *does not change* if the number of domestic and foreign firms increases proportionally across both exporting countries (Dixit, 1984). Second, in the standard numbers critique (Dixit, 1984), the sign of the policy depends on the relative difference in the number of firms at home and

[1] Strategic complementarity between prices and 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).

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

[3] Though, one can interpret the monopoly model as the government maximizing joint profits.

[4] The relative asymmetry in the number of firms across countries determine the choice of trade policy instruments (Dixit, 1984). 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.

in the foreign country[5]. We, however, show that the sign of the policy instrument depends only on whether the domestic market is monopolistic, or oligopolistic. Monopolies are subsidized[6], while oligopolies may be taxed, or subsidized, bilaterally, or unilaterally, depending upon the degree of product differentiation.

Regardless of the relative asymmetry in the distribution of firms oligopolies are always taxed for high levels of product differentiation. For oligopolistic market structures in both countries, the equilibrium policy is to subsidize R&D (or output) for low levels of product differentiation. For a domestic duopoly, engaging in active policy increases welfare over free trade for the active country. With only one active country in equilibrium, the inactive country may sometimes increase its welfare over free trade if the active country taxes R&D. However, depending on the degree of product differentiation, in most cases the inactive country obtains lower welfare than under free trade. Our results are robust to price or quantity competition[7].

The remainder of the paper is structured as follows. 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[8]. In Section-IV we briefly discuss the results for output subsidies. Section-V concludes. The appendix contains the results for the case of output subsidies.

2. Free Trade

We use a third-country model with 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 (spending $\frac{\Delta^2}{2}$). All firms face symmetric demand functions. If firm i is in the home country ($i \in H$), then,[9]

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

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

[5] 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 the sign of $n_f + 1 - n_h$. Also see Bhagwati et al.(1998 p. 397).

[6] This is true for R&D and output subsidies.

[7] 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 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.

[8] We have also analyzed results under output subsidies. The results are relegated to the appendix.

[9] 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 $p_i = a - x_i - \gamma(\sum_{h\neq i} x_h)$.

the vector of prices[10]. The parameter γ measures the degree of product differentiation, and we assume it between zero and one[11]. 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. Firms can use R&D strategically to improve their position in the subsequent market competition stage. In this context, investment in R&D has commitment value. 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[12]. 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, 2000 and 2002). 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.

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:

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

It is easy to see that the slope of each reaction function is negative and 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 is 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 $\mathbf{x} = \{x_{1h}, x_{2h}, \ldots, x_{n_h h}, x_{1f}, x_{2f}, \ldots, x_{n_f f}\}$, each chosen given the output of the other firm. Equilibrium output and profits (as a function of first-stage R&D expenditures) are, respectively:

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

[10] 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.

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

[12] 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).

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

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:

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

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

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

Firms' profits are then given by

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

Note that a firm has greater incentives to invest in cost-reducing R&D under Cournot competition than under a pure cost-minimizing strategy. This occurs due to the *positive* strategic effect of R&D on profits.

3. R&D subsidies

We look at government policy for R&D subsidies towards domestic monopolies and duopolies under output competition. A country engaging in active R&D policy will always tax a duopoly for higher degrees of product differentiation. If both countries have duopolies then, in equilibrium, they both tax R&D for high levels of product differentiation[13]. We show that changing the number of firms at home and abroad, symmetrically, or asymmetrically, changes the optimal trade policy instrument. Taxing and welfare improvement (over free trade) also occurs under Cournot competition and is not just an artifact of Bertrand competition. Even though a policy reversal is not to be observed, the prisoners' dilemma nature of policy choice is observed only in the case of domestic monopolies.

In this section we first present the results for R&D policy for domestic monopolies in each country under Cournot competition. Following this we present the case of domestic and foreign duopolies. We finish with the effects of introducing asymmetry in the model by looking at the case

[13]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.

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[14]

First, we briefly present the results for domestic monopolies. If firms invest in a strategic variable prior to the market competition stage then the Eaton and Grossman (1986) policy reversal is not observed. Under low degrees of product differentiation both governments subsidize R&D[15], while output is *always* subsidized. Following this we present results for a unilateral, or bilateral, R&D subsidy/tax for a country with a domestic monopoly, or duopoly. The model is then solved for the equilibrium in the R&D policy game played in the first stage[16]. We consider this to be the relevant case in our paper as under GATT ruling subsidies to R&D are allowed[17]. Firms in two countries sell a differentiated good in a third market. Governments first decide simultaneously whether, or not, to engage in active R&D policy. A government deciding to engage in an active policy commits 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 final stage firms compete in quantities, or prices[18].

3.2. Domestic and Foreign monopoly

Unlike Bagwell and Staiger (1994), governments do not always subsidize R&D. The incentives to subsidize depends upon the degree of product differentiation. Bilaterally active policy is observed for a smaller range of γ (compared to the case where only one firm is active). We present some new results for the well known monopoly case. If firms first invest in R&D and governments commit to a policy prior to this decision the policy reversal result due to Eaton and Grossman is not observed. We focus on the degree of product differentiation for which an interior solution is obtained under a R&D subsidy[19] $\gamma < 0.663916$ under unilateral, and $\gamma < 0.585998$ under bilateral policy[20]. Compared to a monopoly the permissible value of γ decreases under a duopoly. Active bilateral policy is observed only for the case when $\gamma < .427853$. This clearly indicates that governments will not subsidize regardless of the degree of product differentiation. For an increasing level of product differentiation both countries find it profitable to engage in export promoting policies (R&D subsidies). Further, for $\gamma \in (0.427853, 0.585998)$ there are two equilibria with *only one* country subsidizing R&D in each one of them.

Proposition 3.1 (Equilibrium for R&D subsidies- $(1,1)$ case). *Restricting attention to values of γ where an interior solution exists ($\gamma < 0.585998$) the equilibrium of the policy game is as follows:*

[14] Results for Bertrand competition are available at http://www.eco.uc3m.es/~jruiz/research.htm. As mentioned earlier the qualitative policy results do not change.

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

[16] 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.

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

[18] 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 available upon request.

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

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

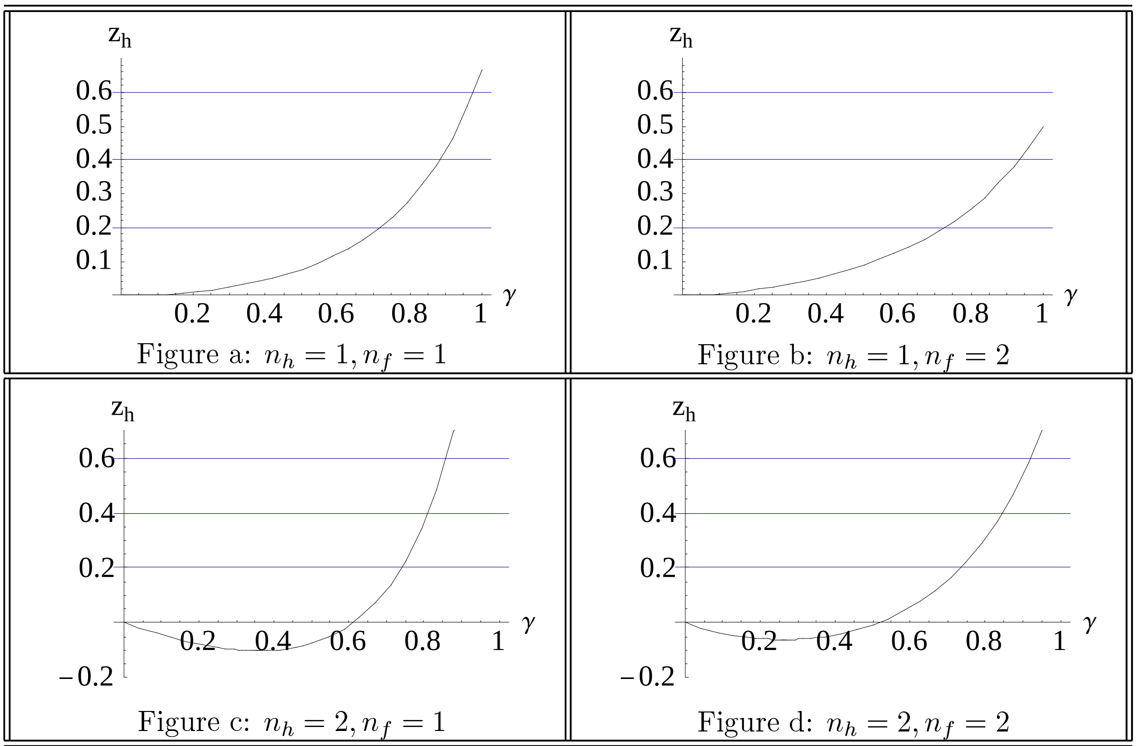

Figure a: $n_h = 1, n_f = 1$

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)

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

Proof. Figure (a) (table 3.1) shows that countries want to unilaterally subsidize R&D. Figure (a) (table 3.2) shows that if both countries engage in active policy, then both of them subsidize R&D. If country f is not subsidizing then country h prefers to (unilaterally) engage in active policy over free trade (see figure (a) (table 3.3)). On the other hand, for $\gamma < 0.427853$, if f subsidizes, then h prefers to subsidize as well (bilateral subsidies) otherwise, h prefers to remain inactive (see figure (a) (table 3.5)). ■

Proposition 3.2 (Welfare under R&D subsidies- $(1,1)$ case). *Restricting attention to values of γ for an interior solution and comparing the equilibrium of the policy game with the outcome under free trade we get,*

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 3.4)). However, for $\gamma \in (0.427853, 0.585998)$ we have an asymmetric equilibrium where only one country subsidizes. We can see that (figure (a), table 3.3) the country which subsidizes is better off relative to free trade, while (figure 3.1) the country that does not subsidize is worse off than under free trade. ■

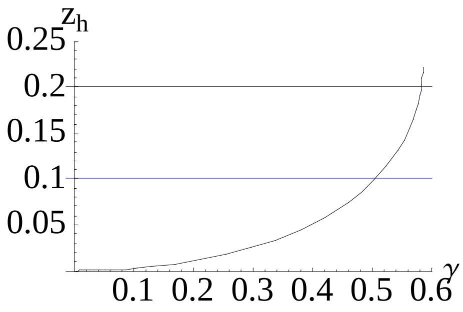

Figure a: $n_h = 1, n_f = 1$

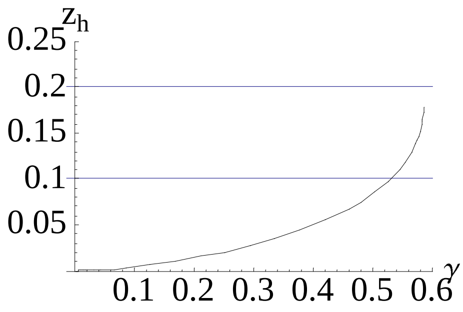

Figure b: $n_h = 1, n_f = 2$

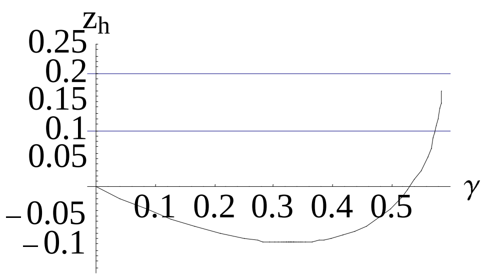

Figure c: $n_h = 2, n_f = 1$

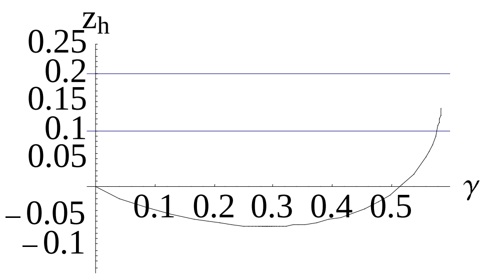

Figure d: $n_h = 2, n_f = 2$

Table 3.2: Cournot: Optimal Bilateral R&D Subsidies

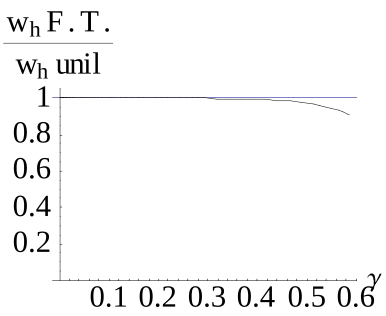

Figure a: $n_h = 1, n_f = 1$

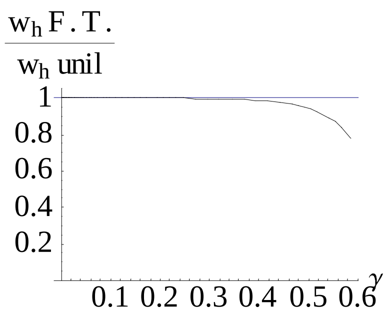

Figure b: $n_h = 1, n_f = 2$

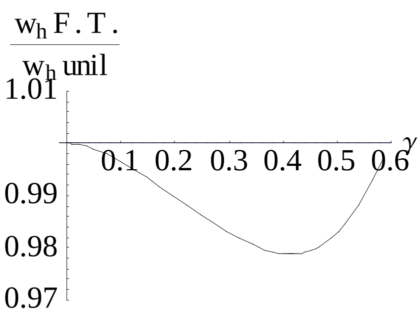

Figure c: $n_h = 2, n_f = 1$

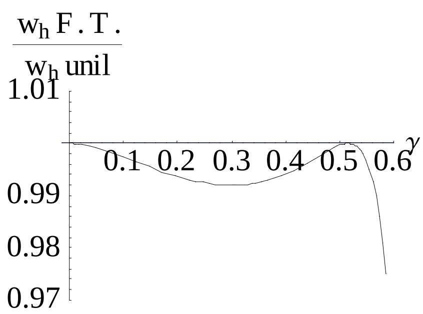

Figure d: $n_h = 2, n_f = 2$

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

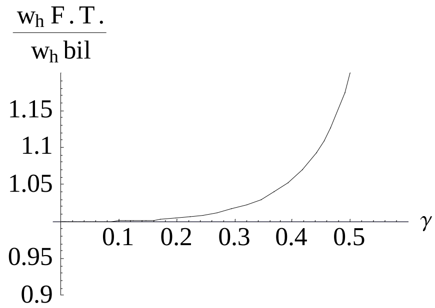

Figure a: $n_h = 1, n_f = 1$

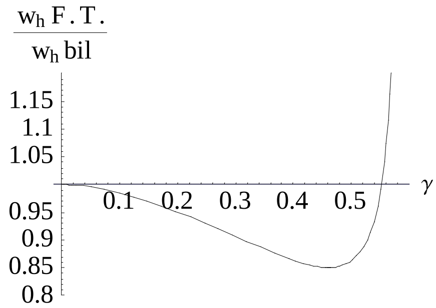

Figure b: $n_h = 1, n_f = 2$

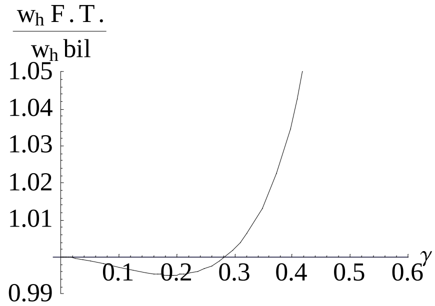

Figure c: $n_h = 2, n_f = 1$

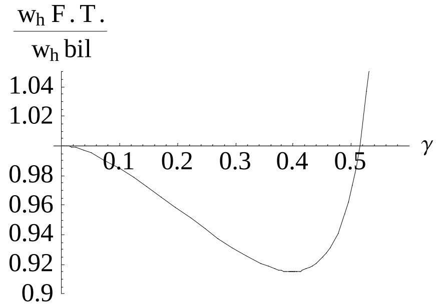

Figure d: $n_h = 2, n_f = 2$

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

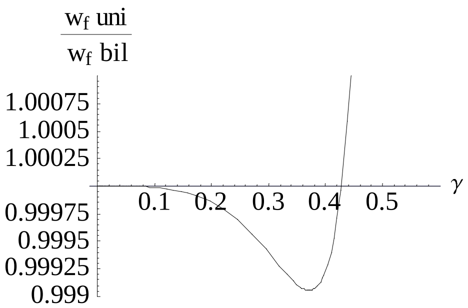

Figure a: $n_h = 1, n_f = 1$

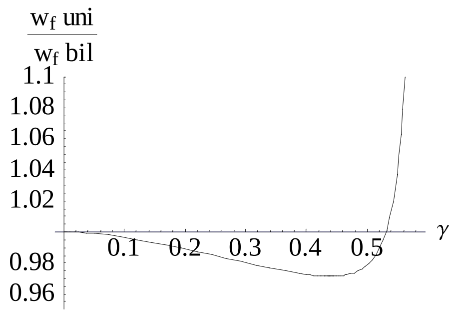

Figure b: $n_h = 1, n_f = 2$

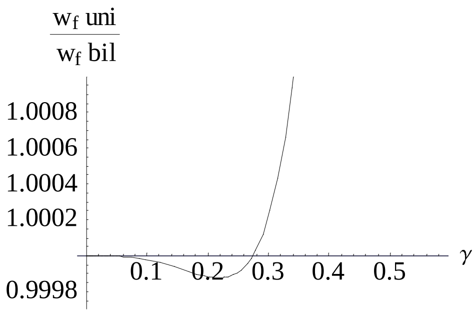

Figure c: $n_h = 2, n_f = 1$

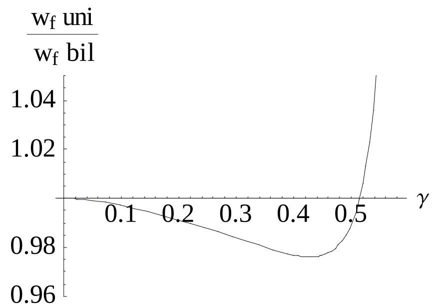

Figure d: $n_h = 2, n_f = 2$

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

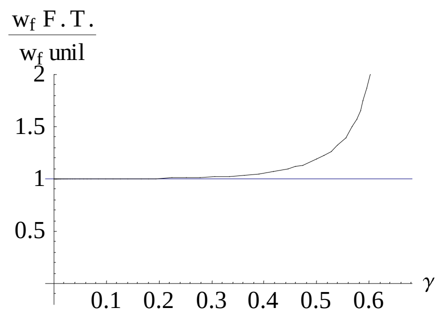

Figure 3.1: Welfare comparison for foreign country and R&D Subsidies: Free trade vs, inactive unilateral subsidies, case $n_h = 1, n_f = 1$.

Note that 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.

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

Welfare under bilateral export promotion is greater than under free trade. Welfare improvement is observed both under quantity and price competition. 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.

To understand why the policy instrument changes from the case of monopolies 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). 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 decreases output (and R&D expenditures). We show this to be the case under Cournot competition. 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. Our results go in the same direction under price competition. Welfare outcomes are also independent of market structure and the prisoners dilemma nature of policy choice is only restricted to the case of bilateral monopolies. In equilibrium, welfare is greater than free trade when both countries subsidize ($\gamma < 0.514708$). We only present the results for the case of bilateral R&D subsidies/taxes. First we present the results where only the home country subsidizes/taxes. Then we present results for bilateral R&D subsidy case. We focus only on the levels of product differentiation that provide interior solutions. Under unilateral R&D subsidy and bilateral duopolies we restrict[21] ourselves to $\gamma < 0.665703$. Meanwhile $\gamma < 0.586505$ for the case of bilateral policy[22].

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 (h) and the foreign (f) firm as,

[21] This range ensures that output, R&D and welfare are positive.
[22] This restriction prevents imaginary roots for the equilibrium bilateral subsidy.

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

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

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:

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

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.

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

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

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 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 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. It is clear that the optimal policy instrument depends upon the degree of competition in the market. Thus models that abstract from product differentiation only look at the special case of a (local) monopoly may not be a reasonable guide towards policy making.

R&D is taxed unilaterally if $\gamma < 0.514708$, and subsidized otherwise. Unilateral active R&D policy always increases welfare over free trade. Welfare of the non-active country increases if the unilateral policy is a tax but is reduced if the unilateral policy is a subsidy. The export tax lowers profits for the domestic firms while increasing it for the foreign 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 now analyze 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, $\hat{x}_i(\mathbf{\Delta};\gamma) = \frac{(a-c)(2-\gamma)+(2+\gamma(n_f+n_h-2))\Delta_i - \gamma\left(\sum_{j\in\{H\cup F-i\}}\Delta_j\right)}{(2-\gamma)(2+(n_f+n_h-1)\gamma)}$

R&D choice: Substituting the equilibrium quantities into the profit equation we get,

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

Maximizing $\hat{\pi}_i(\mathbf{\Delta};\gamma)$ by choice of $\mathbf{\Delta}_i$, we obtain the reaction functions for the domestic and foreign firms. These are exactly the same as equation 3.3 for the home firms and the analogously 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, government i maximizes total welfare (TW).

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

From the FOCs we obtain,

$$z_i = \frac{2+2\gamma-3\gamma^2-(1+\gamma)\sqrt{((2-(4-\gamma)\gamma)(2+3\gamma(4+3\gamma)))}}{((-2+\gamma)(2+\gamma)(2+3\gamma)} \tag{3.8}$$

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[23] range of $\gamma \in (0, .586505)$ (figure (d) in table 3.2).

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

$$TW_{RD} = (a-c^2)\frac{(-2+4\gamma-\gamma^2+((2+(4-3\gamma)\gamma)(2+(-4+\gamma)\gamma))}{\sqrt{((2-(4-\gamma)\gamma)(2+3\gamma(4+3\gamma)))}}. \tag{3.9}$$

Total welfare is positive for all $\gamma \leq 0.586505$ and bilateral policy choice increases welfare over free trade for $\gamma < 0.514708$. If only one country engages in active policy, then its welfare increases over free trade. The inactive country is worse off than under free trade. 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 market structure in a country the optimal policy (depending on the degree of product differentiation) may be a subsidy or tax, imposed unilaterally, or bilaterally. The results are summarized in the following proposition.

Proposition 3.3 (Equilibrium for R&D subsidies- $(2,2)$ case). *Restricting attention to interior solutions ($\gamma < 0.586505$) 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 equilibria, one country subsidizes R&D while the other does not engage in active trade policy.*

Proof. Figure (d) (table 3.3) shows that if the foreign country is not engaged in active policy, then a government always prefers to engage in trade policy unilaterally. We further need to show that this is the best response to the other country being active. Figure (d) (table 3.5) shows that if the other country is active, then 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.

Turning to the sign of the active policy we see that (figure (d), table 3.2)) 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), table 3.1) shows that for that range ($0.514708 < \gamma < 0.585998$) the active country imposes a subsidy. ■

Proposition 3.4 (Welfare under R&D subsidies-$(2,2)$ case). *Restricting attention to values of γ that generate an interior solution. Comparing the equilibrium of the policy game with the outcome under free trade,*

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

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 $\gamma < 0.514708$ (figure (d) in table 3.4). 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 3.3[24]). Looking at figure 3.2, for $0.514708 < \gamma < 0.585998$ a country is worse off when it remains unilaterally inactive (unil inac.). ■

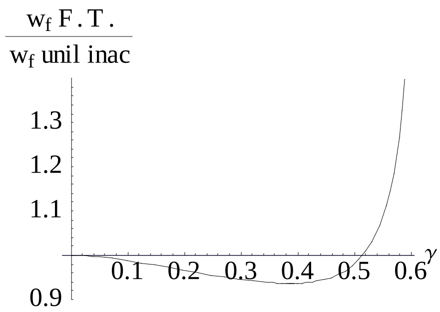

Figure 3.2: Welfare comparison for R&D Subsidies: Free trade vs, inactive unilateral subsidies, case $n_h = 2, n_f = 2$.

Under bilateral duopolies the prisoners' dilemma is no longer observed as both countries are better off. Unlike the results obtained for monopolistic market structures policy choice is always a tax for high degrees of product differentiation ($\gamma < 0.514708$). Further, the qualitative results are consistent under price or quantity competition.

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

We analyze the case when one country has a monopoly in its home market while the other has a duopoly.[25] The country with one firm subsidizes while the country with two firms taxes R&D. However, for some degrees of product differentiation both of them may not be active at the same time in equilibrium. As before, we focus on degrees of product differentiation for which we obtain an interior solution. In this case we need to restrict ourselves to $\gamma < 0.627557$ (if the country with one firm is unilaterally active), [26] to $\gamma < 0.679209$ (if the country with two firms imposes the unilateral policy), and to $\gamma < 0.587535$ (for the case of bilateral policy).[27]

A country duopoly unilaterally taxes (figure (c) in table 3.1) for high levels of product differentiation ($\gamma < 0.611472$) and subsidizes for all $\gamma \in (0.611472, 0.679209)$. A country with one firm has greater welfare than free trade for all γ and subsidizes R&D. Unilaterally active policy is always profitable. Under unilateral 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

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

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

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

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

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 3.5 (Equilibrium for R&D subsidies-$(1, 2)$ case). *Restricting attention to values of γ for which an interior solution exists ($\gamma < 0.587535$). 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.*
- *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. If the country with 2 firms does not engage in active policy then the country with one firm wants to unilaterally subsidize R&D for all γ (figure (b) in table 3.1). 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 $\gamma < 0.611472$ (figure (c) in table 3.1).[28] Figures (b) and (c) in table 3.3 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 3.5 shows that the country with 2 firms (in 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 3.5) 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) (table 3.2) 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 3.6 (Welfare under R&D subsidies-$(1, 2)$ case). *Restrict attention to 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).*

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

- *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. In equilibrium, both firms engage in active policy for $\gamma < 0.273545$. In figures (b) and (c) (table 3.4) we can see that in the relevant range bilateral policy is better for both countries than free trade. This 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 than under free trade. Figure (c) (table 3.3) shows that the country with 2 firms (home country 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) (table 3.3) 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 it remains unilaterally inactive. ■

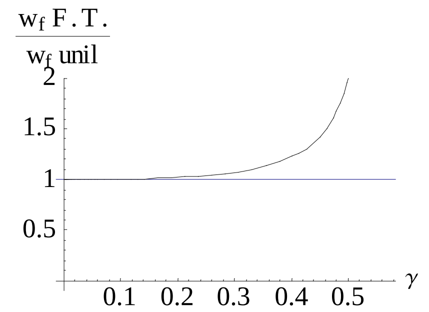

Figure 3.3: Welfare comparisons for foreign country (R&D Subsidies and Cournot compet.): Free trade vs. unilaterally inactive. $n_h = 1, n_f = 2$.

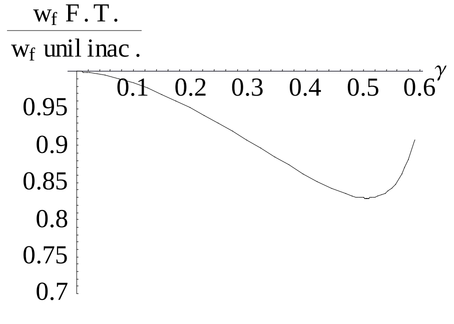

Figure 3.4: Welfare comparisons for foreign country with R&D Subsidies under Cournot competition: Free Trade vs. unilaterally inactive. $n_h = 2, n_f = 1$.

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 a monopolistic market structure. Welfare increases (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. This reaffirms that policy choice cannot be independent of the 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 outwards (while shifting the reaction function of the foreign firm inwards). 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. Due to the profit shifting argument the incentives to unilaterally subsidize a domestic monopoly thus exists.

However, this is not the case if there is more than one firm at home. A standard result from Cournot markets,with more than one firm at home, is that firms produce too much from the point of view of joint profits. Therefore, a government would want to tax a domestic oligopoly to solve the *negative domestic externality.* A government would want to subsidize 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. Imagine that we have a domestic firm on the x-axis and the aggregate output of all the others (including the other domestic firms) on the y-axis, 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 for high degrees of product differentiation. However, as the degree of product differentiation decreases the profit shifting effect dominates and governments have unilateral incentives to subsidize R&D.

4. Output subsidies

As mentioned before no policy reversal is observed under output subsidies. The only difference from R&D policy is that multiple equilibria do not exist with output subsidies. In the case where both countries have domestic monopolies the optimal policy (in the range where interior solutions exist) is always an output subsidy. As is well known, bilateral policy choice in this case is welfare decreasing for both countries. The results for the domestic monopolies case are summarized in figure-4.1. Note, however, that in our model we assume that R&D is fully effective at cost reduction and as such full cost effectiveness would be a special case of a more general model[29].

<figure-4.1 here>

For both domestic and foreign duopolies the optimal policy for both governments is a tax when the degree of product differentiation is high (figure-4.2). Welfare under a tax increases for both governments. For an intermediate range of γ both governments subsidize and welfare for both countries is lower. Note that in Dixit (1984) the optimal policy choice under this scenario would *always* be a subsidy, i.e. $n_f + 1 - n_h > 0$. Unlike Helpman and Krugman (1994) our results suggest that taxing may not always be an optimal policy. Depending upon the degree of product

[29] In a related paper (Kujal and Ruiz, 2003) we show that policy reversals may still be observed for low effectiveness of R&D at decreasing marginal costs. When R&D is fully effective, the special case in this paper, then no policy reversal is observed under Bertrand competition.

differentiation governments may also subsidize. Now, why should a duopoly be taxed for higher degrees of product differentiation? It seems that for high degrees of product differentiation the profit shifting effect is smaller[30] and the negative externality between the two domestic firms dominates, hence oligopolies are taxed. However, for an intermediate range of product differentiation the profit shifting effect dominates the negative (output) externality and hence firms are subsidized[31].

<figure-4.2 here>

For the case of a domestic oligopoly and a foreign monopoly we show, as in the R&D case, that a domestic duopoly is taxed when the degree of product differentiation is low, while the government is *inactive* for an intermediate range of γ (an inactive government is always the optimal policy in Dixit, i.e. $n_f + 1 - n_h = 0$) (see figure-4.3). Independent of the number of foreign firms a domestic monopoly is always subsidized (this is also the case in Dixit (1984) when $n_h = 1$ and $n_f > 1$, i.e. $n_f + 1 - n_h > 0$). Welfare outcomes in this case depend upon the degree of product differentiation. If the domestic market is oligopolistic, then welfare increases under a tax for higher degree of product differentiation. For an intermediate range of γ welfare declines under a tax. However, for the subsidizing country welfare always increases. Our results make a clear and easily interpretable policy prediction. The only distinction domestic governments have to worry about is whether the domestic market is oligopolistic, or monopolistic, and the degree of substitutability between products.

<figure-4.3 here>

5. Conclusion

This paper presents some new results in strategic trade policy. It shows that the sign optimal policy is not only sensitive to firm distribution in the two exporting countries but also to the market structure and the degree of product differentiation. Moving from domestic monopolies to domestic duopolies countries tax R&D (and output) for high degrees of product differentiation. This is the scenario in which the optimal policy does not change in Dixit (1984). Second, unlike Dixit (1984), increasing the numbers of firms at home and abroad, symmetrically or asymmetrically, changes the policy instrument in a non-linear manner. Countries may tax, subsidize, or be inactive depending upon the degree of product differentiation. Countries with duopolies usually tax R&D[32] and this result is robust to both Cournot and Bertrand competition. Finally, the degree of product differentiation matters in policy choice.

We further show that the prisoners dilemma does not exist for domestic oligopolies under R&D subsidies. The prisoners dilemma, however, reappears in the case of output subsidy for domestic monopolies. The policy reversal, however, is never observed. We further show that when governments decide on policy they 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 matters as the presence of a duopoly engenders a negative externality on domestic firms. This externality is smaller, or greater, depending upon the degree of product differentiation. If the domestic market is monopolistic then the domestic government always subsidizes both under price and quantity competition. Governments subsidize as they can shift the reaction function of the monopolist to the Stackelberg point. In this scenario depending on the degree of product

[30] Note, the profit shifting effect would be zero for a monopoly, i.e. $\gamma = 0$.

[31] It would be interesting to see how the range for which firms are taxed changes with γ. Due to computational difficulties we could not solve the model for a large number of firms.

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

differentiation several equilibria may occur where bilateral, or unilateral, R&D promotion may be undertaken. For higher degrees of product differentiation both governments subsidize for high levels of product differentiation while, only one government subsidizes for an intermediate range. The welfare for the active government in this case increases.

As in the numbers critique, policy depends on the number of firms that are present inside and outside a country. Unlike Dixit (1984) we show that optimal policy does not depend only upon the relative asymmetry in the distribution of firms. Taxing R&D and output dominates for high degrees of product differentiation for symmetric oligopolies and welfare under such a tax is always greater than under free trade. Duopolies are taxed if the degree of product differentiation is in the intermediate range. In some cases the equilibrium involves a government remaining inactive, even though its welfare is reduced with respect to free trade. Thus, retaliation may not be observed by the competing government. There are several limitations of our analysis. We do not allow for domestic consumers, country asymmetries, or a large numbers of firms in both countries. Some of the issues are left for future research.

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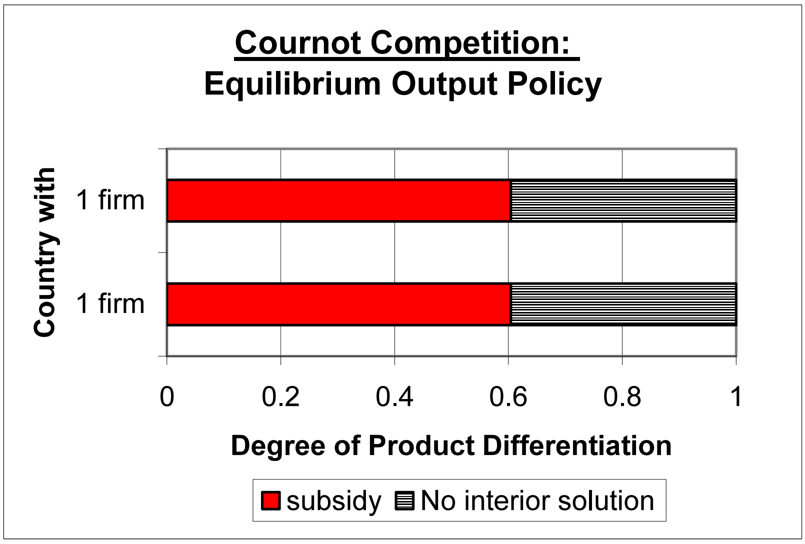

Figure 4.1

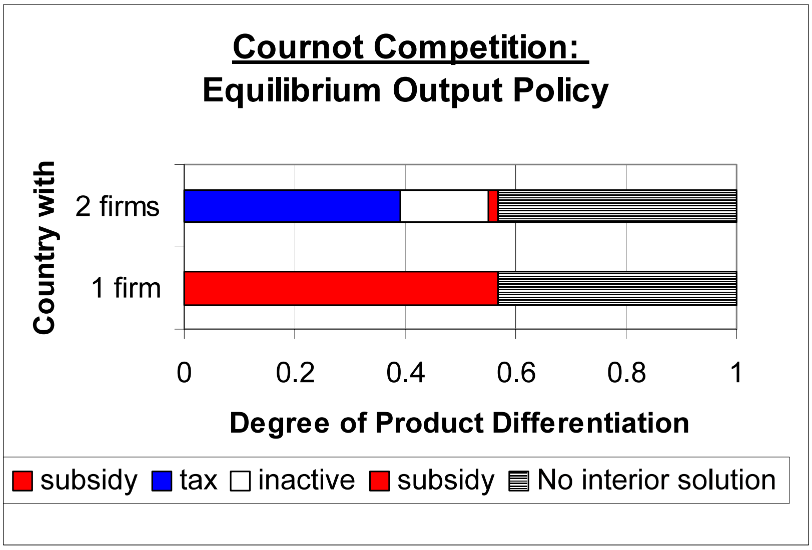

Figure 4.2

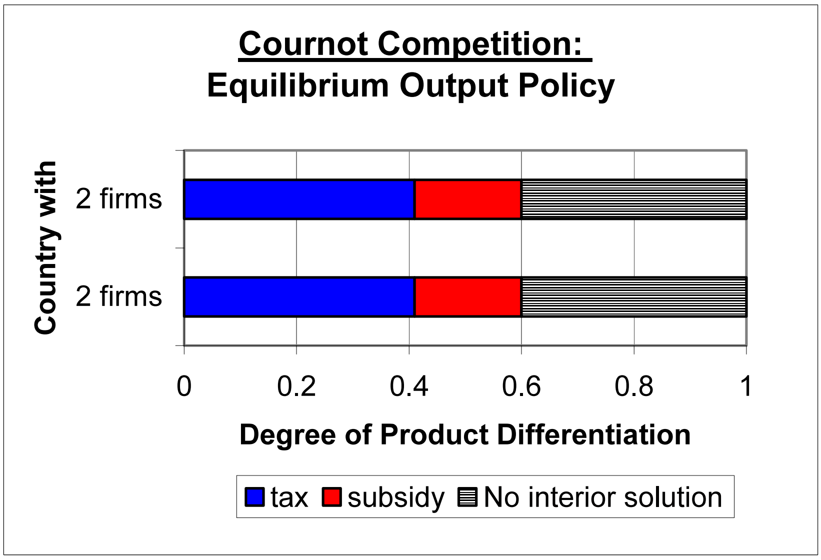

Figure 4.3