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THE ROLE OF COMMITMENT AND THE CHOICE OF TRADE POLICY INSTRUMENTS*

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Abstract

The incentives for governments to impose subsidies and tariffs on R&D and output is analyzed in a differentiated good industry where firms invest in a cost saving technology. When government commitment is credible, subsidies to R&D and output are positive both under Bertrand and Cournot competition. In the absence of government commitment the policy instrument is a tariff under Bertrand, and a subsidy under Cournot, competition. However, welfare under free trade is always greater than imposing a tariff unilaterally, or bilaterally, and hence non-committal under price competition is never an equilibrium. If a government has to choose either a subsidy on R&D (or on output) then, independent of price or quantity competition, it subsidies R&D for low levels of product substitutability and output for higher levels of substitutability.

Keywords: Product Differentiation, Trade Policies, Commitment, Tariffs, Subsidies.

JEL classification: F12, F13, L13.

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1. Introduction

In their (1983) paper Brander and Spencer study the effect of imposing a tariff, or subsidy, in a model where two domestic monopolies sell in a third market after having invested in a cost-saving technology in a previous stage. They show that for a homogenous goods industry, under free trade, firms overinvest in the cost saving technology. Further, if governments have the possibility of unilaterally (or bilaterally) subsidizing/taxing R&D, they choose to subsidize R&D. If, however, governments have the possibility of subsidizing/taxing both output and R&D, they tax R&D and subsidize output. An underlying assumption in their paper is that governments credibly commit to a policy action before firms choose their strategic variables[1].

The question of whether the choice of the optimal policy instrument is sensitive to the nature of market competition was addressed by Eaton and Grossman (1986). Using a model of conjectures they show that, under Bertrand competition, the optimal policy instrument is a tax on exports. However, under Cournot competition (as in Spencer and Brander (1993)) subsidies on exports are optimal. Eaton and Grossman (1986) do not explicitly model firm investment in R&D, or product differentiation, and assume that firms set output or prices taking subsidies and taxes as given.

The sensitivity of cost saving R&D to the choice of market competition and degree of product differentiation was shown by Bester and Petrakis (1993). In a differentiated goods industry firms invest in cost-reducing R&D before engaging in market competition. They show that investment in R&D not only depends on the degree of product substitutability, but also on the assumption on the nature of market competition (i.e., whether firms compete in prices or quantities). If the degree of product substitution is high, there are stronger incentives to invest in R&D under Bertrand competition than under Cournot competition. For low good substitutability, the result is reversed. They further show that, unlike the homogeneous good Spencer and Brander's (1993) results, underinvestment in R&D is obtained under both Cournot and Bertrand competition if the goods are poor substitutes. They do not, however, analyze incentives to invest in R&D under strategic trade policy instruments.

[1] Spencer and Brander (1983) further argue that it is reasonable to assume that governments commit and that the governments act in this leadership role (that is, moves first) is fairly natural, pp. 711,Section 4.

Besides Brander and Spencer the effect of trade policy instruments on R&D expenditure has been studied by Reitzes (1991) and Cabral, Kujal and Petrakis (1998). Reitzes (1991) used a Cournot duopoly model to study firm incentives to invest in cost-reducing technology under quantity restrictions. Firms invest in R&D initially and then compete in quantities. The introduction of a Voluntary Export Restraint (or a quota) at the free trade production level results in both the domestic and the foreign firms choosing lower levels of cost reducing R&D than they would under free trade.[2]

Following Reitzes (1991) Cabral et al. (1998) examine the effect of imposing a VER (or a quota) under Bertrand competition. They find that under Bertrand competition Reitzes's (1991) results are only *partially* reversed. Similar to the Cournot competition case, the domestic firm invests less in R&D relatively to the free trade case. The foreign firm, however, invests more in R&D than under free trade.[3]

Besides the sensitivity of R&D to the degree of product differentiation and the nature of product market competition, another related, and important, issue that has received some attention is the role of commitment in the choice of trade policy instruments[4]. Recent work by many[5] has shown that the ability of a government to

[2]In the presence of a quota, domestic investment in R&D declines because the strategic advantage of R&D vanishes for the domestic firm – with the quota, the domestic firm becomes a monopolist on the residual demand and chooses the cost minimizing level of R&D expenditures. The foreign firm, constrained by the quota, also has less incentives to invest in R&D. Reitzes (1991) also shows that a quota and a tariff may often produce opposite effects on domestic R&D since while a tariff preserves the strategic link between R&D and foreign output, a quota does not.

[3]This result is explained by the fact that under Bertrand competition foreign investment in R&D has a negative (indirect) strategic effect on foreign firms' profits: higher foreign investment in R&D makes the domestic firm lower its price which in turn results in lower prices and profits for the foreign firm. This makes the foreign firm "underinvest" in R&D (under Cournot competition this indirect strategic effect is of the opposite sign and consequently the firm overinvests in R&D). With the imposition of the quota the negative strategic effect disappears and investment in R&D necessarily increases for the constrained case. Contrarily, the domestic firm invests less in R&D as it faces lesser competition from the foreign firm (this effect is similar to the one present in Reitzes' (1991) model).

[4]As Brander (1995) notes, "An intriguing but under-appreciated aspect of trade policy analysis is the crucial importance of the timing of decisions." (p.1418).

[5]See Carmichael (1987), Leahy and Neary (1994, 1996, 1999) and Goldberg (1995) for horizontally differentiated markets, and Herguera, Kujal and Petrakis (1997) for vertically differentiated industries.

commit to a policy is relevant for the choice of trade policy outcomes. Carmichael (1987) and Herguera, Kujal and Petrakis (1997) show that if firms know that the subsidy level depends on their choice of price or quality, firms respond optimally and choose the maximum price, or quality. In this scenario, domestic welfare is lower than if the government moves first and commits to a given subsidy level. However, in the Herguera et al. (1997) framework, where the foreign firm sells in the domestic market, non-committal to a tariff results in higher domestic welfare than under free trade due to the possibility of quality switching between the high-, and low-, quality firms. Leahy and Neary (1996, 1997, 1999) show that domestic welfare under commitment is always higher if the government can commit to an R&D subsidy.[6] Besides the Herguera et al. result that welfare improves when the government does not commit to a tariff, a common theme in all of these papers is that government commitment to a subsidy is welfare improving.

The above results indicate that assumptions both on the nature of market competition, the degree of product differentiation, and the role of commitment are crucial in determining policy outcomes. Further, the policy instrument reversal suggested by Eaton and Grossman (1986) has put in doubt the robustness of the existing models.[7] It thus makes sense that extensions of the existing models are considered to see whether the policy reversal result in Eaton and Grossman is still observed.

In this paper, we study the choice of strategic trade policy instruments when firms invest in R&D and then compete in prices or in quantities. We use this model as it captures an important characteristic of oligopolistic markets. That is, in a stage prior to market competition firms invest in a strategic variable (the level of which cannot be altered in the market competition stage). In our case, firms first commit to a level of R&D expenditure before they compete in the market stage. Given that (i) firm incentives to invest in R&D depends on the nature of product market competition and on the degree of substitutability between the goods, (ii) quotas lead only to a partial reversal of results between Cournot and Bertrand competition when one considers a differentiated goods industry with firm investment in R&D, and that, (iii) the role of commitment is important in

[6]By committing to an R&D subsidy the government decreases the R&D expenditure of the foreign firm. Thus, it decreases the loss in the domestic firm's market share due to the foreign firm's overinvestment in R&D.

[7]In his critique of Strategic Trade Policy models Grossman (1988) questions the robustness of these models as the results are sensitive to the nature of product market competition.

determining policy outcomes, we use the Bester and Petrakis (1993) differentiated goods model, where firms invest in R&D before the market competition stage. We compare both Bertrand and Cournot market competition equilibria under the following policy instruments:

(i) Credible unilateral and bilateral subsidies to R&D.

(ii) Credible unilateral and bilateral subsidies to output.

(iii) Non-credilbe unilateral and bilateral subsidies to output.[8]

(iv) Credible unilateral and bilateral subsidies to both R&D and output.

We show that, if governments commit to a policy before the firms choose R&D, unilateral and bilateral subsidies to R&D are positive both under Cournot and Bertrand competition. Investment in innovation increases for the subsidized firm relative to free trade regardless of the nature of market competition. World output also increases both for unilateral and bilateral R&D subsidies. Further, when both governments subsidize output we find that they choose a positive subsidy on output both under both Bertrand and Cournot competition, unlike Eaton and Grossman's (1986) result[9]. However, under non-credibility, our results change: governments subsidize under Cournot competition and tax exports under Bertrand competition. The Eaton and Grossman's (1986) policy reversal result is obtained when the government does not commit to a trade policy. This highlights the role of the commitment in the choice of trade policy instruments. We further show that in a game where governments choose to, or not to, commit to a policy, unilaterally or bilaterally, the dominant strategy equilibria is that none chooses the non-commitment policy. Free trade is preferred over non-committal always. Thus, the policy reversal result, even though observed under price competition and non-committal, is never an equilibrium policy choice in our model.

Further, if the government has to choose between subsidizing R&D or output, it subsidizes R&D for low levels of product substitutability and output for higher levels of substitutability under Bertrand competition. If the governments choose to subsidize both R&D and output then under Bertrand competition governments will subsidize both, however, under Cournot competition R&D is taxed and output subsidized (as in Spencer and Brander (1983)).

The paper is structured as follows. In section 2 the model is laid out and the

[8]Given that R&D costs are sunk in our model and that firms invest in cost reducing innovation prior to the market competition stage, allowing for the government to move after the choice of R&D does not change any of the results.

[9]It should be noted that Eaton and Grossman (1986) assume government commitment.

free-trade results are derived. In Section 3 and 4 R&D and production subsidies are studied, respectively (both the unilateral and the bilateral subsidy cases are analyzed). In Section 5 the issue of non-credible policies are analyzed. Section 6 concludes.

2. The model under Free Trade

We use a third-country model to consider the case of two firms, located in two different countries, that produce a differentiated good which they sell in a third country. There is a competitive numeraire sector. The two 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 $\frac{\Delta^2}{2}$. Both firms face the following symmetric demand functions[10]:

$$x_i = \frac{1}{1-\gamma^2}\left[a(1-\gamma) - p_i + \gamma p_j\right], i, j = 1, 2. \tag{2.1}$$

γ measures the degree of product differentiation. As γ approaches zero each firm becomes a local monopolist and as γ approaches one, goods become almost perfect substitutes. To avoid corner solutions in the Bertrand game we limit our attention to the cases where $\gamma \leq 0.827891$.

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. The problem is solved using sub-game perfect equilibria.

We analyze both the quantity competition and the price competition cases.

[10]These are the demand functions of a consumer with utlity $u(x_i, x_j) = a(x_i + x_j) - \frac{(x_i^2+x_j^2+2\gamma x_i x_j)}{2} + m$ with m representing money, following Dixit (1979). Resulting inverse demand is $p_i = a - x_i - \gamma x_j$.

2.1. Cournot competition

2.1.1. The output choice stage

Firm i chooses x_i to maximize profits which, given inverse demand ($p_i = a - x_i - \gamma x_j$) and reduced unit cost ($c - \Delta$), are:

$$\max\left[(a - x_i - \gamma x_j - (c - \Delta_i))\right] x_i(p_i, p_j). \tag{2.2}$$

p_j and Δ_i are taken as given. Each firm's reaction function is thus derived:

$$x_i(x_j) = \frac{1}{2}(a - c + \Delta_i - \gamma x_j) \tag{2.3}$$

The intersection of the two reaction functions gives us the equilibrium quantities (q_1, q_2), each chosen given the output of the other firm. The equilibrium output and profits are respectively:

$$x_i^* = \frac{(2\Delta_i + (a-c)(2-\gamma) - \Delta_j\gamma)}{(4-\gamma^2)} \tag{2.4}$$

and

$$\pi_i^* = \left[\frac{(2\Delta_i + (a-c)(2-\gamma) - \Delta_j\gamma)}{(4-\gamma^2)}\right] - \frac{\Delta_i^2}{2}. \tag{2.5}$$

2.1.2. the R&D stage

Firm i, given Δ_j,chooses Δ_i to maximize its profits (defined above). First-order conditions and symmetry allow us to derive optimal R&D spending, output and price for each firm:

$$\Delta^* = \frac{4(a-c)}{(4 + 4\gamma - 2\gamma^2 - \gamma^3)}, \tag{2.6}$$

$$x^* = \frac{(a-c)(4-\gamma^2)}{(4 + 4\gamma - 2\gamma^2 - \gamma^3)}, \tag{2.7}$$

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

Firms' profits are then given by

$$\pi^* = (a-c)^2 \frac{(8-8\gamma^2+\gamma^4)}{(-4-4\gamma+2\gamma^2+\gamma^3)^2}. \tag{2.9}$$

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:

$$\max\left[p_i - (c-\Delta_i)\right] x_i(p_i, p_j). \tag{2.10}$$

p_j and Δ_i are taken as given. This defines each firm's reaction function:

$$p_i = b_i(p_j; \Delta_i) \equiv \frac{a(1-\gamma)+c-\Delta_i+\gamma p_j}{2} \tag{2.11}$$

Once more, the intersection of the two reaction functions determines the equilibrium prices (p_1, p_2), each chosen given the price of the other firm. The equilibrium prices and profits are:

$$p_i = \frac{1}{4-\gamma^2}\left\{\left[a(1-\gamma)+c\right](2+\gamma) - 2\Delta_i - \gamma\Delta_j\right\}, \tag{2.12}$$

and

$$\pi_i = \frac{(p_i - c + \Delta_i)^2}{1-\gamma^2} - \frac{\Delta_i^2}{2}. \tag{2.13}$$

The R&D stage Firm i, given Δ_j,chooses Δ_i to maximize its profits (defined above). From the first-order conditions and symmetry we obtain optimal R&D spending, output and price for each firm:

$$\Delta^* = \frac{2(2-\gamma^2)}{D_1(\gamma)}(a-c), \tag{2.14}$$

$$x^* = \frac{(4-\gamma^2)}{2(2-\gamma^2)}\Delta^*, \tag{2.15}$$

$$p^* = \frac{1}{2-\gamma}\left[a(1-\gamma)+c-\Delta^*\right]. \tag{2.16}$$

Firms' profits are then given by

$$\pi^* = \frac{8-16\gamma^2+7\gamma^4-\gamma^6}{D_1(\gamma)^2}(a-c)^2. \tag{2.17}$$

Where, $D_1(\gamma) = (1+\gamma)(2-\gamma)(4-\gamma^2) - 2(2-\gamma^2)$.

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 competition than under Bertrand competition. Further, due to the competitive nature of the Bertrand game, output under Bertrand competition is greater than under Cournot competition. Domestic welfare is higher under Bertrand competition for most values of γ. Only when γ is high enough ($\gamma > .78445$), i.e. the goods are close substitutes, is domestic welfare under Cournot competition higher. This is the Bester and Petrakis (1993) result that welfare does not only depend on the nature of competition but also of the degree of product differentiation.

3. Optimal R&D subsidies

In this section we analyze the effect of imposing optimal R&D subsidies upon the firms. Our motivations for the analysis of R&D subsidies is the same as in Spencer and Brander (1983). That is, R&D subsidies are permitted under the rulings of the WTO. We also thus view this as being the more relevant case in our model. We assume that the government can credibly commit to a policy action[11]. The game is modelled as follows: Governments first choose and announce their policy actions[12]. After this announcement, firms decide how much to invest in

[11] The possibility of non-credibility is analyzed in section 5.

[12] Some authors justify this modelling by arguing that governments are not playing strategies actively in the markets. They tend to commit to policy actions before the market participants.

cost reducing R&D. They then proceed to compete in prices or in quantities in the final stage of the game.

We consider unilateral subsidies and bilateral subsidies towards R&D. We analyze both the cases of Cournot competition and Bertrand competition.

3.1. Cournot competition

3.1.1. Unilateral R&D subsidies

We show that the incentive to unilaterally subsidize R&D in fact depends on the degree of product substitutability. Country 1 subsidizes R&D only if the degree of substitutability between the goods is low (i.e. low λ). For higher levels of product substitutability domestic welfare of the subsidizing country is negative and hence it never unilaterally subsidizes R&D. Further, investment in R&D is greater than free trade only when market competition is tougher (i.e low λ), however, the opposite is true for the non-subsidized firm. As in Spencer and Brander (1983) total domestic welfare for the subsidizing country is greater than under free trade while the contrary true for the non-subsidizing country.

Market competition stage We initially assume that only country 1 subsidizes R&D. A fraction z_1 of firm 1's expenditures on R&D is subsidized by the government. The problem is then no longer symmetric. Firm 1 and firm 2 again maximize profits:

$$\pi_1 = (a - x_1 - \gamma x_2 - c + \Delta_1)x_1 - (\frac{\Delta_1^2}{2})(1 - z_1) \tag{3.1}$$

$$\pi_2 = (a - x_2 - \gamma x_1 - c + \Delta_2)x_2 - (\frac{\Delta_2^2}{2}) \tag{3.2}$$

From the first order condition we get the reaction functions for firm $i, i, j = 1, 2$,

$$x_i = \frac{1}{2}(a - c + \Delta_i - \gamma x_j), i \neq j$$

that gives us the equilibrium outputs for firm $i, i, j = 1, 2$,

$$x_i^* = \frac{[2(a - c + \Delta_i) - (a - c)\gamma - \Delta_j\gamma]}{(4 - \gamma^2)}, i \neq j. \tag{3.3}$$

The R&D stage: Given the equilibrium outputs the firms maximize their profits with respect to Δ_i. From the first order conditions we get,

$$\Delta_1 = \frac{4[(a-c)(2-\gamma) - \Delta_2\gamma)]}{(-4+\gamma^2)^2(1-(\frac{8}{(-4+\gamma^2)^2}) - z_1)}$$

$$\Delta_2 = \frac{4(a(2-\gamma) - c(2-\gamma) - \Delta_1\gamma)}{(8 - 8\gamma^2 2 + \gamma^4)}$$

This gives us the equilibrium R&D investment for each firm,

$$\Delta_1^* = \frac{4(a-c)(4-4\gamma-2\gamma^2+\gamma^3)}{(16+12\gamma^4(1-z_1)-\gamma^6(1-z_1)-32z_1+8\gamma^2(5z_1-4))} \tag{3.4}$$

$$\Delta_2^* = \frac{(4(a-c)(4-4\gamma(1-z_1)-2\gamma^2(1-z_1)+\gamma^3(1-z_1)-8z_1))}{(16+12\gamma^4(1-z_1)-\gamma^6(1-z_1)-32z_1+8\gamma^2(5z_1-4))} \tag{3.5}$$

The two equations above can be solved for the optimal subsidy, z_1^*, and total welfare for both countries can be derived:

$$z_1^* = \frac{2\gamma^2}{(8-6\gamma^2+\gamma^4)} \tag{3.6}$$

$$TW_1^* = \frac{(4-4\gamma-2\gamma^2+\gamma^3)^2}{32-96\gamma^2+72\gamma^4-16\gamma^6+\gamma^8} \tag{3.7}$$

$$TW_2^* = \frac{(8-8\gamma^2+\gamma^4)(-8+8\gamma+12\gamma^2-8\gamma^3-2\gamma^4+\gamma^5)^2}{32-96\gamma^2+72\gamma^4-16\gamma^6+\gamma^8}. \tag{3.8}$$

It can be seen that the optimal subsidy is an increasing function of γ and reaches its maximum when $\gamma = 1$. The subsidy is zero when firm 1 has a monopoly on the production of the good ($\gamma = 0$) and reaches its maximum as the market becomes increasingly competitive. Welfare for country 1 is positive if γ is low, i.e., when goods are (high) imperfect substitutes. It becomes negative when goods are close substitutes. This is because the optimal subsidy is an increasing function of γ. Country 1 thus has no incentive to unilaterally subsidize R&D when market competition is high. For a high degree of product substitution, total welfare is greater than under free trade for country 1, while it is lower for country 2.

Innovation expenditures depend upon the degree of product differentiation and on whom receives the subsidy. Firm 1 (the subsidized firm) invests more in R&D relative to free trade when the degree of product differentiation is greater. The opposite applies for the other firm.

3.1.2. Bilateral R&D Subsidies

Market competition stage Suppose now that each country chooses to subsidize R&D, paying a fraction z_i of firm i's R&D expenditures. Profit functions change to include an extra term. $(1 - z_i)$ multiplies firm i's R&D expenditures. Once more, profit maximization yields the reaction functions:

$$x_i = \frac{1}{2}(a - c + \Delta_i - \gamma x_j), i \neq j.$$

Equilibrium output levels are then derived:

$$x_i = \frac{(2\Delta_i + a(2-\gamma) - c(2-\gamma) - \Delta_j \gamma)}{(4-\gamma^2)}. \tag{3.9}$$

The R&D stage Substituting the equilibrium outputs into profits, maximizing with respect to Δ_i and solving the first-order condition, we obtain:

$$\Delta_i = \frac{4(a(2-\gamma) - c(2-\gamma) - \Delta_j \gamma)}{((-4+\gamma^2)^2(1 - \frac{8}{(-4+\gamma^2)^2} - z_i))}.$$

The equilibrium level of innovation expenditures, Δ, for both the firms is then derived:

$$\Delta_i^* = \frac{(4(a-c)(4 - 4\gamma(1-z_j) - 2\gamma^2(1-z_j) + \gamma^3(1-z_j) - 8z_j))}{D_1(\gamma)}. \tag{3.10}$$

where, $D_1(\gamma) = (12\gamma^4(1-z_i)(1-z_j) - \gamma^6(1-z_i)(1-z_j) + 16(1-2z_i)(1-2z_j) - 8\gamma^2(4 - 5z_j - z_i(5 - 6z_j)))$.

Substituting the equilibrium cost reduction expenditures in profits and maximizing with respect to z_i we can next solve for the subsidies:

$$z_i = \frac{2\gamma^2}{(4-\gamma^2)(4z_i - 2 + \gamma^2(1-z_j))}.$$

The solution to the equilibrium subsidies is non-unique. Two values are obtained for both firm i and firm j. We choose the relevant subsidy as the one which results in a greater domestic welfare level[13].

Plotting the subsidy as a function of the degree of product differentiation it can be seen that both the countries subsidize the good only for low values of γ ($\leq .5878$). Looking at total welfare, it can be seen that if both the countries choose to subsidize they choose the following optimal subsidy:[14]

$$z_i = \frac{4\gamma^2}{(4-\gamma^2)(2-\gamma^2-\sqrt{4-12\gamma^2+\gamma^4}}$$

Plotting z_i and z_2 as a function of γ it is seen that the subsidies are positive only for gamma $\gamma \leq .5878$.

Discussion: As in Spencer and Brander (1983), we find that optimal R&D subsidies are positive when both the countries choose subsidies. Even though jointly suboptimal both the countries choose to subsidize due to the prisoners′ dilemma nature of the subsidy game. Total welfare under bilateral R&D subsidies is lower than under free trade for both the countries. However, given that under unilateral subsidies welfare is greater for the subsidizing country and lower for the other country, both the countries choose to subsidize R&D. This results in lower domestic welfare for both the countries. Both firms invest more in R&D under bilateral subsidies and world output increases relative to free trade.

3.2. Bertrand competition

As before the decision to unilaterally subsidize R&D depends on the degree of product substitutability. Contrary to Cournot competition unilateral subsidies are always positive for all degrees of product substitution. However, the subsidizing country only chooses to subsidize only for lower degrees of product substitution ($\lambda \leq .6739$). For higher degrees of λ domestic welfare is negative. As in Cournot competition domestic welfare of the subsidizing (non-subsidizing) country is higher (lower) than under free trade. In the case of price competition investment in R&D is only higher than free trade only the degree of product substitution is low.

[13]We assume that any rational government will choose a subsidy that maximizes total welfare.
[14]For the other root, total welfare is negative for both countries.

3.2.1. Unilateral R&D subsidies

As before, we assume that it is firm 1 that receives the subsidy. In this case, equilibrium prices for firm $i = 1, 2$ are:

$$p_i = \frac{2\Delta_i + \Delta_j\gamma - c(2+\gamma) - a(2-\gamma-\gamma^2)}{-4+\gamma^2} \tag{3.11}$$

Substituting equilibrium prices into profits and maximizing in order to Δ_i we obtain equilibrium investment levels in cost-saving innovation for both countries:

$$\Delta_1 = \frac{2(a-c)(-2+\gamma+\gamma^2)^2(-8-8\gamma+12\gamma^2+6\gamma^3-6\gamma^4-\gamma^5+\gamma^6)}{D_2(\gamma)} \tag{3.12}$$

$$\Delta_2 = \frac{\begin{array}{c}2(a-c)(-8+14\gamma^2-7\gamma^4+\gamma^6). \\ (-4+\gamma^2(4-6z_1)-(4\gamma-\gamma^3-\gamma^4)(-1+z_1)+8z_1)\end{array}}{D_2(\gamma)}. \tag{3.13}$$

Where, $D_2(\gamma) = \gamma^2(240-448z_1)+\gamma^6(236-336z_1)+\gamma^{10}(14-16z_1)+\gamma^{12}(-1+z_1)+64(-1+2z_1)+8\gamma^4(-44+71z_1)+\gamma^8(-81+103z_1)$. Finally, by substituting the equilibrium values of Δ_i we can solve for the equilibrium R&D subsidy, R&D spending, output, and welfare.

$$z_1^* = \frac{2\gamma^2}{-8+18\gamma^2-7\gamma^4+\gamma^6}.$$

$$\Delta_1^* = \frac{2(-2+\gamma+\gamma^2)^2(-8+18\gamma^2-7\gamma^4+\gamma^6)(-8-8\gamma+12\gamma^2+6\gamma^3-6\gamma^4-\gamma^5+\gamma^6)}{D_3(\gamma)}$$

$$\Delta_2^* = \frac{2(8-14\gamma^2+7\gamma^4-\gamma^6)N_1(\gamma)}{D_3(\gamma)}$$

$$x_1^* = \frac{\begin{array}{c}(-1+\gamma)^2(2+\gamma)^3. \\ (64+32\gamma-224\gamma^2-48\gamma^3+272\gamma^4-12\gamma^5-140\gamma^6+26\gamma^7+33\gamma^8-9\gamma^9-3\gamma^{10}+\gamma^{11})\end{array}}{D_3(\gamma)}$$

$$x_2^* = \frac{\gamma^2 N_2(\gamma)}{D_3(\gamma)}$$

$$TW_1 = \frac{(-2+\gamma+\gamma^2)^4(4+4\gamma-4\gamma^2-\gamma^3+\gamma^4)^2}{-D_3(\gamma)}$$

$$TW_2 = \frac{(128-448\gamma^2+552\gamma^4-280\gamma^6+33\gamma^8+23\gamma^{10}-9\gamma^{12}+\gamma^{14})N_2(\gamma)}{D_3(\gamma)}.$$

Where, $D_3(\gamma) = 512-2816\gamma^2+6688\gamma^4-8832\gamma^6+6928\gamma^8-3368\gamma^{10}+1031\gamma^{12}-195\gamma^{14}+21\gamma^{16}-\gamma^{18}$, $N_1(\gamma) = (-32+32\gamma+88\gamma^2-72\gamma^3-96\gamma^4+44\gamma^5+48\gamma^6-11\gamma^7-11\gamma^8+\gamma^9+\gamma^{10})$and $N_2(\gamma) = (-256+256\gamma+864\gamma^2-736\gamma^3-1240\gamma^4+744\gamma^5+952\gamma^6-380\gamma^7-424\gamma^8+107\gamma^9+111\gamma^{10}-16\gamma^{11}-16\gamma^{12}+\gamma^{13}+\gamma^{14})$.

Note that all the above expressions are a function of the degree of product differentiation γ. Comparing these results to the case of free trade it can be seen that the output of the firm that receives the subsidy is less (more) than the output under free trade when the degree of product differentiation is low (high). As markets get competitive a R&D subsidy in fact results in a lower level of output. However, the converse is true for firm 2 (the non subsidy-recipient).

Innovation expenditures for the subsidized firm are greater than under free trade when the goods are not close substitutes. Under uniltateral subsidies, firm-2 decreases its R&D expenditures relatively to free trade. Further, unilateral subsidies are positive for all γ. Domestic welfare is higher than under free trade when goods are imperfect substitutes (near monopolies at home). Welfare of the non-subsidizing country is always less than under free trade.

3.2.2. Bilateral R&D Subsidies

Price competition stage The problem of the firm is the same as in section 2.2 for the price selection stage. When both firms receive a subsidy of $z_i\frac{\Delta^2}{2}$, profit maximization with relation to R&D expenditures yields:

$$\Delta_i = \frac{2(-2+\gamma^2)(-4+\gamma^2(4-6z_j)-(4\gamma-\gamma^3-\gamma^4)(-1+z_j)+8z_j}{D_4(\gamma)}, i \neq j. \tag{3.14}$$

Where, $D_4(\gamma) = (\gamma^8(-1+z_i)(-1+z_j) + 16(-1+2z_i)(-1+2z_j) + \gamma^6(-9+z_i(11-13z_j)+11z_j) - 8\gamma^2(6-9z_j+z_i(-9+14z_j)) + \gamma^4(32-44z_j+z_i(-44+60z_j))$. Substituting Δ_i in total welfare we then solve for the equilibrium subsidy for each firm. This gives us the two roots (note we remove the subscripts as the roots are symmetric),

$$z_{ik}^* = \frac{2-3\gamma^2+\gamma^4 \pm S}{2(4-5\gamma^2+\gamma^4)}, i,k = 1,2. \tag{3.15}$$

where,

$$S = \sqrt{(4-20\gamma^2+21\gamma^4-6\gamma^6+\gamma^8}.$$

Given the two solutions, we assume that the government selects the dominating one, i.e. the one that yields a greater domestic welfare level. This then gives us the equilibrium expenditure on R&D, output and total welfare for firm $i, i, j = 1, 2 (i \neq j)$:

$$\Delta_i^* = (a-c)\frac{(2-\gamma^2)(2-3\gamma^2+\gamma^4+S)[-10\gamma^2-3\gamma^3+2\gamma^4+\gamma^5+\gamma(-2+S)+2(2+S)]}{D_5(\gamma)} \tag{3.16}$$

$$x_i^* = (a-c)\frac{N_3(\gamma)}{D_5(\gamma)}$$

$$W_i^* = (a-c)^2\frac{(1-\gamma^2)(-2+2\gamma+3\gamma^2+3\gamma^3)}{D_5(\gamma)}. \tag{3.17}$$

where $N_3(\gamma) = 22\gamma^8 + 10\gamma^9 - 2\gamma^{10} - \gamma^{11} + 16(2+S) - 40\gamma^2(4+S) - \gamma^7(41+S) - 2\gamma^6(50+S) + 8\gamma^4(27+2S) - 2\gamma^3(18+7S) + \gamma^5(76+7S)$ and, $D_5(\gamma) = (1+\gamma)(-12\gamma^{10}+\gamma^{12}+16(2+S)+\gamma^8(67+S)-3\gamma^6(68+3S)-8\gamma^2(24+7S)+\gamma^4(324+34S))$.

It can be seen that both governments choose to subsidize R&D and that investment in cost reducing innovation is greater than under free trade. The total output sold in the market increases relatively to the free trade case. Under price competition and when goods are imperfect substitutes, total welfare is lower relatively to free trade. However, under bilateral R&D subsidies, profits are higher for both firms.

3.2.3. Discussion:

Under Bertrand competition we also get the classic prisoners' dilemma. The unilaterally subsidizing country has a higher level of welfare than under free trade. Since the non-subsidizing country's welfare decreases, both the countries end up deciding to subsidize R&D. This occurs in spite of the fact that total welfare for both the countries is lower than under free trade. Comparing these results with the Cournot competition case, we see that in the Cournot case Δ is larger (smaller) for $\gamma < (>)\ 0.426$, output is lower and total welfare is higher (but still lower that in the free trade situation, as mentioned before). Further note that under Bertrand competition total output with bilateral subsidies is higher than under unilateral subsidies. Compared to Cournot competition total world output is higher under Bertrand competition.

Note, however, that the qualitative policy results do not change from Bertrand to Cournot competition. That is, the optimal subsidy to R&D is always positive. We do not obtain the reversal of policy instruments as do Eaton and Grossman (1986). In our model in the presence of government commitment R&D subsidy is always positive.

Further, in our model investment in R&D has a commitment value. Firms can strategically commit to a cost saving investment, thereby altering the best response of the other firm in the market competition stage. If a government commits to a policy before the firms invest in a cost saving technology, then the firm decision to invest in the cost saving decision enters the governments objective function.

Another interesting result coming out of our analysis is that total welfare is greater under R&D subsidies than under output subsidies for low levels of product substitution ($\lambda \in [0, .565]$) and the contrary is true for higher levels of product substitution ($\lambda \in [.565, .67]$). Thus, governments would choose to subsidize R&D over output for low levels of product substitution and output for higher levels of product substitution. This further emphasizes the result that the choice to subsidize R&D, or output, will also depend on the degree of product substitution and not only the nature of market competition.

4. Output subsidies under commitment

If the output subsidy is unilaterally chosen, the subsidizing country makes higher profits than if it does not subsidize output. Given the prisoners dilemma nature of the policy instrument choice, both the countries end up subsidizing output. The equilibrium outcome of the subsidy choice game is both countries choosing to subsidize. Thus, we only present the results for the bilateral subsidy case for both, Cournot and Bertrand competition.

4.1. Bilateral output subsidy

4.1.1. Cournot competition

Adding the subsidy term to the profit function from the first order conditions we can easily solve for output, x_i.

$$x_i^* = \frac{(2-\gamma)(a-c) + 2(\Delta_i + s_i) - \gamma(\Delta_j + s_j)}{4-\gamma^2}. \tag{4.1}$$

Substituting x_i into the profits the expenditure on R&D, Δ_i,is obtained,

$$\Delta_i = \frac{4[(a-c)(4-4\gamma-2\gamma^2+\gamma^3) + (4-2\gamma^2)s_i - \gamma(4-\gamma^2)s_j]}{16-32\gamma^2+12\gamma^4-\gamma^6}. \tag{4.2}$$

Substituting Δ_i into the profits and maximizing total welfare the equilibrium subsidy, s_i,is obtained,

$$s_i^* = (a-c)\frac{\gamma^2(48-40\gamma^2+2\gamma^4-\gamma^6)}{D_6(\gamma)}. \tag{4.3}$$

where, $D_6(\gamma) = 64 + 64\gamma - 128\gamma^2 - 64\gamma^3 + 72\gamma^4 + 20\gamma^5 - 16\gamma^6 - 2\gamma^7 + \gamma^8$
Equilibrium production, innovation and welfare levels are,

$$x_i^* = (a-c)\frac{2(4-\gamma^2)^2(2-\gamma^2)}{D_6(\gamma)} \tag{4.4}$$

$$\Delta_i^* = (a-c)\frac{8(8-6\gamma^2+\gamma^4)}{D_6(\gamma)} \tag{4.5}$$

$$W_i^* = (a-c)^2 \frac{(4-\gamma^2)^2(64 - 224\gamma^2 + 216\gamma^4 - 88\gamma^6 + 16\gamma^8 - \gamma^{10}}{D_6(\gamma)^2} \tag{4.6}$$

We set the equilibrium profits (π_i^*) equal to zero in order to obtain the value of γ below which the analysis of the profits and welfare is relevant. We restrict our attention to these γ values only. In this relevant range, we find that the equilibrium subsidy is always positive[15]. Total welfare is, however, maximized when $\gamma = 0$. Total world output increases due to the bilateral subsidy.

4.1.2. Bertrand competition

Adding the subsidy term to the profit function from the first order conditions we can easily solve for the price, p_i.

$$p_i = \frac{a(2-\gamma-\gamma^2) + c(2+\gamma) - 2(s_1 + \Delta_1) - \gamma(s_2 + \Delta_2)}{4-\gamma^2}.$$

Substituting p_i^* into the profits the expenditure on R&D , Δ_i,is obtained,

$$\Delta_i^* = \frac{2(2-\gamma)^2[(2-\gamma^2)^2 - \gamma(4-\gamma^2)](a-c) + s_1(2-\gamma^2)^2 - s_2\gamma(4-\gamma^2)}{16 - 48\gamma^2 + 32\gamma^4 - 9\gamma^6 + \gamma^8}.$$

Substituting Δ_i^* into the profits and writing the total welfare the subsidy, s_i^*, that maximizes total welfare is obtained,

$$s_i^* = (a-c)\,\frac{\gamma^2(16 + 24\gamma^2 - 28\gamma^4 + 9\gamma^6 - \gamma^8}{D_7(\gamma)}.$$

where $D_7(\gamma) = 64 + 64\gamma - 160\gamma^2 - 96\gamma^3 + 104\gamma^4 + 52\gamma^5 - 28\gamma^6 - 12\gamma^7 + 3\gamma^8 + \gamma^9$

Equilibrium output, innovation and welfare are respectively given by the following expressions:

$$x_i^* = (a-c)\frac{(8-6\gamma^2+\gamma^4)^2}{D_7(\gamma)}$$

$$\Delta_i^* = (a-c)\frac{2(4-\gamma^2)(2-\gamma^2)^3}{D_7(\gamma)}$$

[15]It should be noted that the government only chooses a tax instead of a subsidy for very high values of product substitution. However, since for these values firm profits are negative, firms do not enter the market.

$$W_i^* = (a-c)^2 \frac{2(8-6\gamma^2+\gamma^4)^2(16-56\gamma^2+38\gamma^4-10\gamma^6+\gamma^8}{D_7(\gamma)^2}$$

Once more, setting equilibrium profits, π_i^*, equal to zero (and plotting) we obtain the relevant γ for which the analysis of the profits and welfare is relevant. Profits, π_i, equal zero for $\gamma = .827891$. We restrict our attention to these values of γ only. It is easily seen that the equilibrium subsidy is always positive for all $\gamma(< .827891)$. However, note that total welfare becomes negative for $\gamma > 0.66659$. A welfare maximizing government would never choose to subsidize if welfare is negative[16]. The equilibrium subsidy is always positive in this range also. Firm innovation under bilateral output subsidies is greater than under free trade. Total world output increases due to the bilateral subsidy. The increase in output is greater than observed in the Cournot case.

5. Non-credible output subsidies

Under the scenario of non-committal several cases can arise. That is, a country can choose unilaterally not to commit, or both the countries can choose bilaterally not to commit[17]. Thus, the equilibrium of this commit/not-to-commit policy game will determine what policies will the governments actually adopt. In the first part of this section we first analyze the case of bilateral no-commitment.[18] Then finally we discuss the equilibria in the non-commitment game and show that in fact non-committal as a strategy is never an equilibrium strategy and if the policy choice is non-committal governments always prefer free trade to not committing (to a tariff) in our model.

In this section we assume that any policy announcement by the government is not credible. Hence, the firms will choose their policy actions as if the government chooses the policy variable after the firms move. First, the firm invests in R&D. After the firm has chosen its investment in cost reducing innovation the government chooses the optimal subsidy/tax announcement. Firms then play the

[16]Note that, again the values for which the government chooses a tax instead of a subsidy is for very high values of γ. However, as firm profits are negative in this range a firm would not enter the industry.

[17]Other cases, such as one country committing and the other not, or that the countries choosing policies sequentially, can arise. We do not consider all these cases and leave them for a future agenda for research.

[18]This enables us to compare our results with Eaton and Grossman (1986).

market competition game. This only requires us to change the sequence of the moves in the first two stages of the game. As we use the sub-game perfect equilibrium concept this implies that we first solve for the market competition stage, the government(s) then chooses its policy action and finally the firms choose their R&D expenditure.

5.1. Bilateral output subsidy

5.1.1. Cournot competition

Total welfare is a decreasing function of γ and is zero for $\gamma = 0.630804$. Total welfare is maximum for $\gamma = 0$. We focus on γ in the range where total welfare is non-negative. Firm incentive to invest in cost reduction is maximum under a monopoly and only slightly changes with the degree of product differentiation. Under non-credible policies innovation is higher than under credible subsidies and higher than under free trade.

Adding the subsidy term to the profit function, $\max\left[p_i - (c - \Delta_i - s_i)\right] x_i(p_i, p_j)$, from the first order conditions we solve for output, x_i.

$$x_i = \frac{(2-\gamma)(a-c) + 2(\Delta_i + s_i) - \gamma(\Delta_j + s_j)}{4-\gamma^2}. \tag{5.1}$$

Substituting x_i into the profits we get, $\pi_i(x_i, \Delta_i, s_i) = (x_i(\Delta_i, s_i))^2 - \frac{\Delta_i^2}{2}$,the policy announcement, s_i, by the government is obtained[19],

$$s_i^* = \frac{\gamma^2(16 - 12\gamma^2 + \gamma^4)}{32 + 32\gamma - 56\gamma^2 - 24\gamma^3 + 16\gamma^4 + 2\gamma^5 - \gamma^6}.$$

Further substituting s_i^* into the first order conditions the expenditure on R&D, Δ_i^*,is obtained,

$$\Delta_i^* = \frac{8(4-\gamma^2)}{32 + 32\gamma - 56\gamma^2 - 24\gamma^3 + 16\gamma^4 + 2\gamma^5 - \gamma^6}. \tag{5.2}$$

Given Δ_i^* and s_i^* , equilibrium output and welfare are then derived:

$$x_i^* = \frac{2(16 - 12\gamma^2 + \gamma^4)}{32 + 32\gamma - 56\gamma^2 - 24\gamma^3 + 16\gamma^4 + 2\gamma^5 - \gamma^6}. \tag{5.3}$$

[19]The government decision is independent of firm investment in R&D.

$$W_i^* = \frac{2(896\gamma^2 - 256 - 720\gamma^4 + 224\gamma^6 - 26\gamma^8 + \gamma^{10})}{(32 + 32\gamma - 56\gamma^2 - 24\gamma^3 + 16\gamma^4 + 2\gamma^5 - \gamma^6)^2}. \tag{5.4}$$

These results allow us to write the following propositions:

Proposition 5.1. *Government subsidy increases with the degree of product differentiation. The government does not subsidize a domestic monopolist.*

It is easy to see that s_i^* is zero for $\gamma = 0$. Further, plotting the optimal subsidy as a function of γ it is seen that it increases with γ.

Proposition 5.2. *Firm expenditure in R&D under Cournot competition is greater than under free trade. Total output increases and domestic welfare is lower than under free trade. Total domestic welfare*

5.1.2. Bertrand competition

Total welfare is a decreasing function of γ and is zero for $\gamma = .974307$. However, profits are non-negative only for $\gamma \leq 0.938$. Innovation is a decreasing function of product differentiation and is maximum under a domestic monopoly. Innovation expenditures under Bertrand competition are less than under Cournot competition under a duopoly. The government taxes exports for all degrees of product differentiation in the relevant range. This is the same result as in Eaton and Grossman (1986). This suggests that the policy reversal result is more likely to be observed when governments cannot commit to a policy.

Adding the subsidy term to the profit function from the first order conditions and after some manipulations we obtain the equilibrium price, subsidy, and total welfare.

$$p_i^* = \frac{a(6\gamma^4 - 4\gamma^6) - c(32 + 32\gamma + 40\gamma^2 + 40\gamma^3 - 14\gamma^4 - 14\gamma^5 + \gamma^6 - \gamma^7)}{-32 - 32\gamma - 40\gamma^2 - 40\gamma^3 + 14\gamma^4 + 14\gamma^5 - \gamma^6 + \gamma^7}.$$

$$\Delta_i^* = \frac{2(2-\gamma)^2(4 - 3\gamma^2)}{-32 - 32\gamma - 40\gamma^2 - 40\gamma^3 + 14\gamma^4 + 14\gamma^5 - \gamma^6 + \gamma^7}.$$

$$s_i^* = \frac{\gamma^2(-1 + \gamma^2)(16 - 12\gamma^2 + \gamma^4)}{-32 - 32\gamma - 40\gamma^2 - 40\gamma^3 + 14\gamma^4 + 14\gamma^5 - \gamma^6 + \gamma^7}.$$

$$W_i^* = \frac{640\gamma^2 - 256 + 640\gamma^2 - 464\gamma^4 - 32\gamma^6 + 174\gamma^8 - 69\gamma^{10} + 8\gamma^{12}}{-32 - 32\gamma - 40\gamma^2 - 40\gamma^3 + 14\gamma^4 + 14\gamma^5 - \gamma^6 + \gamma^7}.$$

Proposition 5.3. *Under time consistent subsidies and price competition the government taxes R&D. Innovation expenditures under Bertrand competition are less than under Cournot competition. Total welfare under time consistent tariffs is greater than under precommitment subsidies.*

Plotting the subsidy expression it is seen that it is negative for all values of product differentiation. Innovation expenditures under time consistent tariffs are smaller then under the precommitment (subsidy) equilibria. As firms do not overinvest in R&D in the presence of a tariff total welfare is greater under a time consistent tariff then under a precommitment subsidy.

6. Bilateral joint subsidies to R&D and production.

We only consider the case where the governments simultaneously subsidize R&D and output.[20] We choose to analyze the case where both the announcements are credible. If governments can subsidize both R&D and production, we find that they will choose to subsidize both R&D and output under Bertrand competition. The optimal subsidy on R&D is given by z_i^b, and the optimal subsidy on output is given by s_i^b:

$$z_i^b = \frac{\gamma^2}{4 - \gamma^2}$$

$$s_i^b = \frac{\gamma^4(a - c)}{1 + \gamma - 2\gamma^2 - \gamma^3}$$

However, under Cournot competition there is a partial reversal of results with both governments choosing to tax R&D while subsidizing output. This extends Spencer

[20] There are other alternatives to this scenario that can be considered, for example, R&D subsidies can be analyzed both in the presence, and absence, of government commitment for output subsidies. Further, it is not clear if the two governments would bilaterally choose trade policy instruments both for production and R&D.

and Brander's (1983) result to the case of product differentiation. Subsidies to R&D and output are given by z_i^c and s_i^c respectively:

$$z_i^c = -\frac{\gamma^2}{4-\gamma^2}$$

$$s_i^c = \frac{\gamma^2(a-c)}{1+\gamma-\gamma^2}$$

The reason why this happens is that, unlike the Bertrand case, overinvestment in R&D is observed under Cournot competition. As a result, both governments find it in their incentive to tax R&D under Cournot competition.

7. Conclusion

When firms in a differentiated industry invest in cost reducing R&D and governments can commit credibly to a policy, the Eaton-Grossman (1986) policy reversal result is not observed in our paper, independent of the nature of market competition and for all relevant degrees of product differentiation. That is, if we restrict out attention to the cases where both firm profits and country welfare are positive, it is optimal for the governments to subsidize firms. If the government does not commit to a policy instrument in the first stage then the Eaton-Grossman policy reversal is obtained for all degree of product differentiation. In a simple way, investment in cost reducing R&D captures firm investment in sunk costs (entry barriers) before it enters an industry (and helps us model firms commitment to a strategic variable prior to the market competition stage). Incorporating this feature in the model we see that the policy instrument reversal is no longer observed.

Our results also highlight the fact that market models that abstract from product differentiation may not be appropriate for the analysis of optimal trade policies when firms invest in cost reduction. We also show that the degree of product differentiation is an important determinant of the policy instrument choice. This is true for both Cournot and Bertrand competition[21]. We see that allowing for investment in cost reducing R&D has an important commitment value for both the firms. By committing to a level of cost reducing R&D firms are able to

[21] Allowing for no investment in cost reducing innovation, under bilateral output subsidies the optimal subsidy, or tax, is positive only if the domestic firm is not a monopoly.

affect the price/output choice in the market selection stage. The importance of government commitment is further highlighted in our framework. We show that policy reversals occur when government policy announcements are not credible. However, a credible government will never choose to tax the domestic firm regardless of the degree of product differentiation. In all the cases domestic welfare is always greater under free trade.

Further, modelling government no-commitment as a policy choice to be adopted unilaterally, or bilaterally, by governments, we show that in fact the dominant strategy equilibrium is that no governments adopts the no-commit policy and instead prefers free trade. If a government unilaterally chooses not to commit its welfare is lower than under free and decreases further if countries choose not to commit bilaterally. Thus, an interesting result coming out of our paper is that in horizontally differentiated industries lack of commitment as a policy action is never adopted by governments.

Results on innovation expenditures under Cournot and Bertrand competition are similar to Bester and Petrakis (1993), with firms investing more in cost-reducing innovation under Cournot than under Bertrand competition. Investment in R&D, however, depends on the degree of product differentiation. As the goods become closer substitutes, investment in R&D declines.

Our results further indicate that when both the countries subsidize R&D and output a partial policy reversal is obtained moving from Bertrand to Cournot competition. Unlike Eaton and Grossman, where countries tax output under Bertrand competition and subsidize output under Cournot, we show that under a system of dual instruments both governments subsidize output and R&D under Bertrand competition. However, under Cournot competition R&D is taxed and output is subsidized. However, it remains to be seen what multiple policy instruments are jointly adopted by the two countries as equilibrium strategies (in the same way that bilateral subsidies-even though jointly suboptimal-are adopted by both the countries).

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