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INTERNATIONAL TRADE POLICY AND THE *NATIONAL COOPERATIVE RESEARCH ACT*

By

Julie Anne DeCourcy

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ABSTRACT

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In the United States firms engaged in cooperative research and development (R&D) are accorded more lenient antitrust treatment of their cooperative research activities. This more lenient treatment was granted by the *National Cooperative Research Act of 1984* (NCRA). One of the intended goals of the NCRA was to give American firms a competitive advantage over foreign firms. This dissertation seeks to determine whether we should expect the NCRA to have the effect of improving competitiveness and what has been the actual effect of the NCRA on the competitiveness of American firms.

In chapters 1 and 2 a theoretical model is developed that combines a traditional strategic trade policy model with a closed economy cooperative R&D model. In chapter 1 it is assumed that firms are Cournot competitors in the product market. Under this assumption, domestic firms are always better off when they cooperate in R&D and foreign firms are frequently worse off. In chapter 2 it is assumed that firms are Bertrand competitors in the product market. Under this assumption, all firms are better off when domestic firms cooperate in R&D. In contrast with Cournot competition, however, foreign firms benefit more than do

domestic firms. While domestic firms are better off regardless of which assumption is made, the optimal policy depends on whether firms are Cournot or Bertrand competitors. In the case of Cournot competition, a domestic government will want to actively pursue cooperative R&D as a strategic trade policy. In the case of Bertrand competition, a domestic government will want to encourage other countries to pursue cooperative R&D.

In chapter 3, an empirical study is undertaken to determine what effect the NCRA has had on the competitiveness of American firms. This study takes advantage of the fact that firms wishing to receive the more lenient treatment under the NCRA must register their cooperative venture with the U.S. Department of Justice. Data on American firms engaged in cooperative R&D is combined with data on the price and quantity of American exports for the years 1985 – 1997 for 11 2-digit SIC industries. The net effect on American competitiveness appears to differ across industries. In two industries, the net effect of the NCRA is increased market power with an average reduction in export quantity of 65.2% and an average increase in export price of 15.7%. In another industry the net effect is increased competitiveness with an increase in export quantity of 16.9% and a reduction in export price of 0.4%. A pooling of the data suggests that the net effect of the NCRA as been to enhance the ability of American firms to act anti-competitively.

To my mom who encouraged me follow my dreams, to my dad who has always been willing to help, and to my husband whose support has meant everything.

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CHAPTER 1
COOPERATIVE R&D AND STRATEGIC TRADE POLICY WITH COURNOT COMPETITION

1.1 Introduction

A movement began in the 1980s, in both the United States and Europe, to change the way that cooperative research and development (R&D) is evaluated under antitrust laws. The U.S. Congress, in 1984, passed the *National Cooperative Research Act* (NCRA). This act changed the way cooperative R&D is evaluated in two ways. The first is cases brought against firms engaged in cooperative R&D are evaluated using the rule of reason. The second is those firms certified by the U.S. Department of Justice would only be subject to single damages, as opposed to treble damages, if found to be in violation of antitrust laws. Around this same time the European Commission (EC) began to modify its competition policy in regard to cooperative research ventures. Article 85 of the Treaty of Rome puts forth a broad prohibition of collusion between firms where that collusion affects trade between member states of the European Union and has as its purpose a restriction or distortion of competition (Jacquemin, 1988). If, however, sufficient social benefit is perceived to accrue from a particular collusive activity, the EC will grant an exception to that activity. For some aspects of industrial activity the EC has granted block exemptions from the Article 85 prohibition. In particular, the EC has granted an exemption for cooperative R&D and the joint exploitation of cooperative research. In both the United States and in Europe these exemptions were later extended to include joint production ventures as well.

Firms in the United States argued, prior to the passage of the NCRA, that the fear of antitrust prosecution prevented them from entering into joint ventures that would increase their competitiveness. In Europe, at the time the block exemptions were being considered, the EC commented that cooperative R&D "stimulates competition within the common market, and helps to strengthen the ability of European industry to compete internationally" (Fourteenth Report on Competition Policy, par. 28). The era in which these changes were made to antitrust policy was one of high trade deficits, conflicts over foreign market access, and concern about shrinking domestic market share. It was thought that by allowing firms to work cooperatively on R&D the result would be increased competitiveness of domestic firms relative to foreign rivals.

Beginning with d'Aspremont and Jacquemin (1988), there have been numerous papers examining the effects of cooperation in R&D. Many of these papers have been inspired by the changes to American and European antitrust law regarding cooperative R&D. For the most part, these papers seek to determine the effects of cooperation on the amount of research conducted as well as the effects on product market variables. Until recently, the literature on cooperative R&D has only been concerned with the domestic effects of cooperation and has ignored the effects of cooperation on competition with foreign firms. The few papers that have examined cooperative R&D in an open economy setting include, Motta (1996), Leahy and Neary (1999), and Neary and O'Sullivan (1999).

Motta examines the implications for both domestic and foreign welfare when only domestic firms cooperate in R&D, when domestic firms cooperate while simultaneously foreign firms cooperate, and when domestic firms cooperate with foreign firms. The framework he uses is similar to the strategic trade policy model of Spencer and Brander (1983) in which firms are Cournot competitors in the product market. He assumes there are spillovers from R&D and that these spillovers are the same within a country and between countries. In addition he assumes that production costs are declining in own and in rival R&D. In his model, cooperation in R&D means that firms fully share the results of their research. He finds that domestic firms are better off when they are allowed to cooperate in R&D. In addition, he finds that both domestic and foreign governments should allow their firms to cooperate in R&D domestically and welfare can be improved further if firms are allowed to cooperate internationally.

Leahy and Neary examine R&D subsidies, export subsidies and cooperative R&D in the presence of local and international spillovers, where these spillovers differ, using the Spencer and Brander framework. They assume production costs decline in own and rival R&D and that there are spillovers from both intra-industry rival R&D (international spillovers) and inter-industry rival R&D (local spillovers). That is, there are two types of spillovers – those between domestic firms and those between domestic firms and foreign firms. In their model, they assume cooperative R&D means choosing R&D in order to maximize joint profits. They find that when domestic firms are allowed to cooperate in R&D that these firms over-internalize the externality and over-invest in R&D. They conclude that in addition to allowing cooperation that R&D should be taxed.

Neary and O'Sullivan examine the question of whether it is better for a government to allow its firms to cooperate in R&D with foreign firms or whether direct subsidization of exports is better in terms of improving national welfare. Neary and O'Sullivan also use the strategic trade policy framework of Spencer and Brander. They assume there are only between country spillovers from R&D and that production cost is declining in both own and rival R&D. As in Leahy and Neary, they assume cooperation in R&D means choosing R&D to maximize joint profits. Neary and O'Sullivan find that cooperative R&D raises welfare when spillovers are relatively low, since it reduces the incentive to strategically over-invest in R&D, and when spillovers are relatively high, since it reduces the incentive to strategically under-invest in R&D. They also find that subsidization with commitment is better than cooperation except when R&D is highly effective and spillovers are near complete. In addition, when spillovers are low it is welfare maximizing to choose a level of subsidies that prevents entry of the foreign firm altogether.

A common approach among these open economy models of cooperative R&D is to use a strategic trade policy framework in which firms engage in Cournot competition in the product market. Where they differ, apart from the policy question they seek to answer, is in their treatment of cooperation in R&D. Kamien et al. (1992) have identified three possibilities for cooperative R&D. The first possibility is an R&D cartel (RDC) in which cooperating firms choose R&D to maximize joint profits. This is the approach taken by Leahy and Neary and by Neary and O'Sullivan. The second possibility is a research joint venture (RJV) in which R&D is chosen to maximize individual firm profits but the results of the research are fully shared. This is the approach taken by Motta. The third possibility is a research joint venture cartel (RJVC) in which the levels of R&D are chosen to maximize joint profits and the results of the research are fully shared. This chapter adds to the emerging literature on open economy cooperative R&D by examining all three of these cooperative arrangements in a strategic trade policy model where firms engage in Cournot competition in the product market. This chapter is primarily concerned with three questions. The first question is whether or not we should expect cooperation in R&D to improve domestic welfare. The preliminary evidence from the three papers mentioned previously suggests that we should expect improved welfare. The second question is, given that cooperation in R&D is beneficial, which cooperative arrangement yields the highest welfare improvement. The third question is whether or not a domestic government could achieve a higher welfare improvement through the use of R&D subsidies instead of allowing cooperative R&D.

The model analyzed here is most similar to the model analyzed by Motta. The strategic trade policy framework of Spencer and Brander is used, including the assumption that firms are Cournot competitors in the product market. It is assumed that there are spillovers from R&D and these spillovers are the same within a country and between countries. Also, production costs are declining in own and in rival R&D. Under these assumptions, domestic firms are always better off when they cooperate in R&D regardless of the form of cooperation. It is the research joint venture cartel, however, that yields the largest welfare improvement. In contrast, Foreign firms are usually worse off when domestic firms cooperate in R&D. These results diverge from those found by Salant et al. (1983) for mergers in a quantity setting game. In that paper, when a subset of the industry's firms merge, those firms inside the merger are usually worse off, while those firms outside the merger are better off. Even when the insiders do benefit from a merger, the outsiders benefit more. In this chapter, we can view the domestic firms, which cooperate in R&D, as the insiders and the foreign firms, which are not cooperating, as the outsiders. Unlike the analysis of mergers, the insiders do benefit from cooperative R&D while the outsiders are usually worse off. R&D subsidies are also effective in improving welfare, however, allowing cooperative R&D yields a larger welfare improvement. Consumers are also likely to benefit from cooperation in R&D since price is lower and output is higher in the research joint venture cartel.

The plan for the remainder of the chapter is as follows. Section 1.2 gives a description of the model and the outcomes for the non-cooperative equilibrium. Next, in section 1.3, there is an analysis of the cooperative regimes that includes a comparison with the non-cooperative equilibrium. Section 1.4 gives an analysis of R&D subsidies that includes a comparison with both the non-cooperative and the cooperative equilibria. Finally, section 1.5 gives some concluding remarks and some possible extensions.

1.2 Non-cooperative Equilibrium

It is assumed that there are only four firms, with two located in the Home country and with the remaining two located in the Foreign country. These firms are identical in every respect with the exception of national origin. As is standard in strategic trade policy models, it is assumed that all output is sold in a third country. This allows us to only examine firm profits when analyzing welfare. The model to be analyzed is a three-stage game where, in the first stage, the Home government decides whether to allow cooperative R&D. In the second stage, firms make their R&D choices given the government's move and the R&D choices of their rivals. In the third stage, firms choose output given all of the R&D choices of the previous stage and the output choices of their rivals.

It is assumed that firms produce only one homogenous good with inverse demand,

$P(Q) = a - Q,$

where $Q = \sum_{i=1}^{4} q_i$ and q_i is the output of firm i. The total cost function is,

$$TC_i\,(q_i,\mathbf{x}) = \left(c - x_i - \gamma\sum_{j\neq i} x_j\right)q_i + \frac{1}{2}vx_i^2,$$

where $\mathbf{x}$ is the vector of R&D choices of all firms; x_i is a unit of R&D undertaken by firm i and x_j is a unit of R&D undertaken by a firm other than firm i; c is the positive constant marginal cost of production with $c < a$; v is a positive constant marginal cost of R&D parameter; γ indicates the degree of spillovers from R&D done by rivals with $0 < \gamma < 1$ ($\gamma = 0$ is no spillovers, $\gamma = 1$ is complete spillovers).

The total cost of R&D, $\frac{1}{2}vx_i^2$, is quadratic to reflect the diminishing returns that are thought to exist in R&D.[1] It is necessary to constrain the marginal cost of R&D such that,

$$v \geq \frac{1}{5}\left(\left(201\gamma^4 - 598\gamma^3 + 513\gamma^2 - 144\gamma + 64\right)^{1/2} - 3\gamma^2 - 7\gamma + 16\right).$$

This restriction ensures that all of the necessary conditions of both the non-cooperative and cooperative regimes are satisfied. It provides a lower bound on the marginal cost of R&D so firms do not undertake an inefficiently large amount of R&D. The existence of diminishing returns

[1] See Dasgupta (1986) for a discussion of the returns to R&D.

to R&D makes undertaking an infinite amount of R&D sub-optimal. This lower bound, however, is decreasing in the spillover parameter γ. As spillovers increase a single unit of R&D becomes more productive than it would be otherwise. For this reason a higher level of R&D is desired and therefore a larger marginal cost of R&D is not required. The production costs of firm i are a function of its own output, its own R&D and the R&D of its rivals. It is assumed that R&D is of the process innovation variety and that unit production cost is decreasing in own and rival R&D. For a particular firm i, a unit increase in own R&D reduces its own production cost by that unit, while a unit increase in R&D by firm j ($j \neq i$) only reduces the production cost of firm i by a fraction, γ, of that unit.

The assumptions about demand and costs yield the following profit function for firm i,

$$\Pi_i(\mathbf{q}, \mathbf{x}) = \left(a - Q - c + x_i + \gamma \sum_{j \neq i} x_j \right) q_i - \frac{1}{2} v x_i^2,$$

where $\mathbf{q}$ is the vector of output choices of all firms. As is standard for this type of model the equilibrium solutions are found by backward induction. The above profit function is maximized with respect to firm i's output, holding fixed R&D and rival output. The maximization problem yields the following output reaction function for firm i,

$$q_i(\mathbf{q}_{-i}, \mathbf{x}) = \frac{1}{2} \left(1 - \sum_{j \neq i} q_j + x_i + \gamma \sum_{j \neq i} x_j \right),$$

where $\mathbf{q}_{-i}$ is the vector of output choices of all firms excluding the choice of firm i and the expression a – c has been normalized to 1. The output reaction function is downward sloping. This means firms have a strategic incentive to increase R&D in the first stage as a means of committing to higher output in the second stage. Noting that the firms are symmetric yields the following solutions for the output sub-game,

$$q_i(\mathbf{x}) = \frac{1}{5}\left(1 + (4 - 3\gamma)x_i - (1 - 2\gamma)\sum_{j \neq i} x_j\right),$$

$$\Pi_i(\mathbf{x}) = \frac{1}{25}\left(1 + (4 - 3\gamma)x_i - (1 - 2\gamma)\sum_{j \neq i} x_j\right)^2 - \frac{1}{2}vx_i^2.$$

Maximizing the above profit function with respect to the R&D of firm i, holding fixed rival R&D, yields the following R&D reaction function for firm i,

$$x_i(\mathbf{x}_{-i}) = \frac{2(4 - 3\gamma)\left(1 - (1 - 2\gamma)\sum_{j \neq i} x_j\right)}{25v - 2(4 - 3\gamma)^2},$$

where $\mathbf{x}_{-i}$ is the vector of R&D choices of all firms excluding the choice of firm i. The slope of this reaction function changes from negative to positive as γ changes from $\gamma < 0.5$ to $\gamma > 0.5$. In order to understand why this change in slope occurs, consider the following. Suppose that, *ceteris paribus*, firm i increases its R&D by one unit. This causes the marginal production cost of firm i to fall by one. The marginal revenue of firm i,

$$MR_i = a - 2q_i - \sum_{j \neq i} q_j,$$

is now greater than the marginal cost of firm i. As a result, firm i increases its output by 0.5. The marginal revenue of firm j, due to symmetry, falls by 0.5. The initial increase in R&D by firm i, however, causes the marginal cost of firm j to fall by γ. If γ is less than 0.5, then the marginal cost of firm j is higher than its marginal revenue. As a result, firm j will decrease its R&D in order to produce less output. If γ is greater than 0.5, then the marginal cost of firm j is less than its marginal revenue. In this case, firm j will increase its R&D in order to produce more output. The implication for the R&D reaction function is that it is downward sloping for $\gamma < 0.5$ and upward sloping for $\gamma > 0.5$. The second order condition for profit maximization is,

$$v > \frac{2}{25}(4 - 3\gamma)^2.$$

The stability condition, which guarantees that the R&D reaction curves intersect, is

$$v > \frac{2}{5}(1 - \gamma)(4 - 3\gamma).$$

Both of these conditions are satisfied for the range of v under consideration.

Solving the R&D reaction functions for x_i, again noting that the firms are symmetric, yields the following solution for R&D,

$$x_i = \frac{2(4 - 3\gamma)}{25v - 2(1 + 3\gamma)(4 - 3\gamma)}.$$

This solution for R&D is decreasing in the spillover parameter, γ. An increase in spillovers leads firms to undertake less R&D since more of their R&D spills over to rivals. Substituting the equilibrium solution for R&D into the output sub-game solutions yields the following results for output, profits and price,

$$q_i = \frac{5v}{25v - 2(1+3\gamma)(4-3\gamma)},$$

$$\Pi_i = \frac{\left(25v - 2(4-3\gamma)^2\right)v}{\left(25v - 2(1+3\gamma)(4-3\gamma)\right)^2},$$

$$P = \frac{5v - 2(1+3\gamma)(4-3\gamma)}{25v - 2(1+3\gamma)(4-3\gamma)}.$$

1.3 Cooperative Equilibria

There is a positive externality caused by spillovers that is socially beneficial but privately harmful. A unit of R&D done by firm i lowers firm i's marginal cost by that unit but also lowers its rival's marginal cost by a fraction of that unit. Therefore, in a decentralized equilibrium, we would expect firms to undertake too little R&D relative to the social optimum. While the fraction of R&D that spills over is constant across firms, the externality can be divided into two components. The first is spillovers between firms in the same country and the second is spillovers between firms in different countries. One of the purported goals of allowing cooperative R&D is to have firms internalize the positive spillover externality by centralizing decision-making. Whether or not the centralization of decision-making occurs depends on the particulars of the cooperative arrangement. In an R&D cartel and a research joint venture cartel, R&D decisions are centralized, while in a research joint venture they are not. The way in which cooperative R&D is organized may lead to additional under-provision problems that are not present in the non-cooperative equilibrium. In the research joint venture and research joint venture cartel firms completely share their R&D. As a result, we might expect under-provision of R&D due to a free rider problem. The centralized decision-making of the R&D cartel and the research joint venture cartel serve to combat under-provision problems, but in the research joint venture regime, with decentralized decision-making, we would expect under-provision problems to persist. In all cases, however, the positive spillover externality between Home and Foreign firms is unaffected. Therefore, even with centralized decision-making, we would never expect to see the spillover externality fully internalized. There is also a drawback to encouraging centralized decision-making and that is it tends to lead to an increase in market power for the cooperating firms. Therefore, these firms have an incentive to restrict their R&D as a means of decreasing output and raising price. Potentially combating this incentive, however, is the fact that Home firms continue to compete with Foreign firms for market share. As a result, there is an incentive to increase R&D in order to increase output and market share at the expense of Foreign firms. The direction of the different effects on Home R&D,

and the cooperative arrangements in which we expect them to occur, are summarized in Figure 1.1.

Type of effect (Direction of effect)	RDC	RJV	RJVC
Centralized Decision-making (+)	✓		✓
Free Rider Problem (-)		✓	✓
Between Country Spillovers (-)	✓	✓	✓
Market Power (-)	✓		✓
Foreign Competition (+)	✓	✓	✓

Figure 1.1 – Expected effects on Home firm R&D

1.31 R&D Cartel Equilibrium

In this cooperative arrangement, Home firms choose their levels of R&D to maximize joint profits. Since there is no cooperation in output and the underlying parameters of the model remain unchanged, the output sub-game solutions for this arrangement are the same as in the non-cooperative equilibrium. In the R&D sub-game, Home firms maximize joint profits with respect to both firms' R&D, holding fixed the R&D of Foreign firms. The Foreign firms continue to maximize their individual profit functions with respect to own R&D, holding fixed rival R&D. Noting that firms from the same country are symmetric yields the following R&D reaction functions,

$$x_{Hi}(x_{Fi}) = \frac{2(3-\gamma)(1-2(1-2\gamma)x_{Fi})}{25v-2(3-\gamma)^2},$$

$$x_{Fi}(x_{Hi}) = \frac{2(4-3\gamma)(1-2(1-2\gamma)x_{Hi})}{25v-2(3-\gamma)(4-3\gamma)},$$

where the H and F subscripts refer to Home and Foreign respectively. As in the non-cooperative equilibrium, these reaction functions are downward sloping for $\gamma < 0.5$ and upward sloping for $\gamma > 0.5$. The second order condition for Home firm profit maximization is,

$$v > \frac{2}{25}\left(13\gamma^2 - 28\gamma + 17\right),$$

while the stability condition is,

$$v > \frac{2}{5}(1-\gamma)(3-\gamma).$$

The second order condition for Foreign firm profit maximization and the stability condition for Foreign firms remain unchanged from the non-cooperative equilibrium. Both of the above conditions are satisfied for the range of v under consideration. Solving the system of R&D reaction functions yields the following solutions for R&D,

$$x_{Hi} = \frac{2(3-\gamma)(5v-2(1-\gamma)(4-3\gamma))}{g_1(\gamma,v)},$$

$$x_{Fi} = \frac{2(4-3\gamma)(5v-2(1-\gamma)(3-\gamma))}{g_1(\gamma,v)},$$

where $g_1(\gamma,v) = 125v^2 - 10(3-\gamma)(7-4\gamma)v + 4(1-\gamma)(1+3\gamma)(3-\gamma)(4-3\gamma)$.

These solutions are decreasing in the spillover parameter, γ, as in the non-cooperative equilibrium. Substituting the solutions into the output sub-game solutions from the non-cooperative equilibrium yields the following results for output, profits and price,

$$q_{Hi} = \frac{5(5v - 2(1-\gamma)(4-3\gamma))v}{g_1(\gamma, v)},$$

$$q_{Fi} = \frac{5(5v - 2(1-\gamma)(3-\gamma))v}{g_1(\gamma, v)},$$

$$\Pi_{Hi} = \frac{\left(25v - 2(3-\gamma)^2\right)(5v - 2(1-\gamma)(4-3\gamma))^2 v}{(g_1(\gamma, v))^2},$$

$$\Pi_{Fi} = \frac{\left(25v - 2(4-3\gamma)^2\right)(5v - 2(1-\gamma)(3-\gamma))^2 v}{(g_1(\gamma, v))^2},$$

$$P = \frac{25v^2 - 10(1+\gamma)(7-4\gamma)v + 4(1-\gamma)(1+3\gamma)(3-\gamma)(4-3\gamma)}{g_1(\gamma, v)}.$$

A comparison of these results with the non-cooperative equilibrium is summarized in Table 1.1. The R&D cartel solutions are denoted by a RDC superscript and the non-cooperative solutions are denoted by a NC superscript.

Table 1.1 – R&D Cartel and Non-cooperative Solution Comparison

	$\gamma \le 0.5$	$\gamma > 0.5$
R&D	$x_{Fi}^{RDC} > x_i^{NC} > x_{Hi}^{RDC}$	$x_{Hi}^{RDC} > x_{Fi}^{RDC} > x_i^{NC}$
Firm Output	$q_{Fi}^{RDC} > q_i^{NC} > q_{Hi}^{RDC}$	$q_{Hi}^{RDC} > q_{Fi}^{RDC} > q_i^{NC}$
Profit	$\Pi_{Hi}^{RDC} > \Pi_{Fi}^{RDC} > \Pi_i^{NC}$	$\Pi_{Fi}^{RDC} > \Pi_{Hi}^{RDC} > \Pi_i^{NC}$
Market Output	$Q^{RDC} < Q^{NC}$	$Q^{RDC} > Q^{NC}$
Price	$P^{RDC} > P^{NC}$	$P^{RDC} < P^{NC}$

In the case where spillovers are low ($\gamma \leq 0.5$), we have that cooperation leads Home firms to undertake less R&D relative to the non-cooperative equilibrium. When spillovers are high ($\gamma > 0.5$) cooperation has the opposite effect and Home firms undertake more R&D. In the first instance the effects of increased market power and between country spillovers dominate, and in the second instance the effects of centralized decision-making and competition with Foreign firms dominate. One method of isolating these different effects is to restrict the spillover parameter, γ, to be zero and then examine the resulting equilibrium levels of R&D. This exercise allows us to examine the effects of increased market power and of Foreign competition simultaneously without the effects from centralized decision-making and between country spillovers. We find that in the case of no spillovers Home R&D is lower relative to the non-cooperative equilibrium. This result indicates that the effect of increased market power outweighs the effect of Foreign competition. Therefore, when spillovers are low, it must be the case that raising price is more important to increasing profits than is increasing market share. Restricting R&D in order to raise price is not as costly when spillovers are low since the harm from not internalizing the externality is lower. When spillovers are high, however, we must have that the effect of Foreign competition and the effect of centralized decision-making combined are larger than the effect of increased market power. That is, the benefit from internalizing the externality combined with the effect of

Foreign competition, exceeds the benefit from restricting output. Again, this is expected because when spillovers are high the harm from not internalizing the externality is greater.

Home firms are always better off when they participate in an R&D cartel. When spillovers are low ($\gamma \leq 0.5$), Home firms have lower R&D, lower output and higher profits in the face of a higher price. Home firms' profits are higher primarily because they have lower total cost. Total cost is lower first, because the total cost of R&D is lower, and second, because Foreign firms undertake more R&D which spills over to Home firms. The increase in price also helps to raise profits. The increase in price alone, however, is not sufficient to raise Home profits without requiring a higher restriction on the lower bound of the marginal cost of R&D. When spillovers are high ($\gamma > 0.5$), Home firms have higher R&D, higher output and higher profits in the face of a lower price. Total cost in this case is lower for Home firms because both Home and Foreign undertake more R&D. Even if Home firms did not benefit from the additional R&D done by Foreign firms, the decrease in total cost from their own increased R&D is sufficiently large to compensate for a lower price.

Not only do Home firms benefit from their participation in an R&D cartel but Foreign firms benefit as well. Which firms benefit more is dependent on the degree of spillovers. When spillovers are low ($\gamma \leq 0.5$), Foreign firms have lower profits than Home firms. Since Foreign firms undertake more R&D than Home firms when spillovers are low, the cost of R&D is higher for Foreign firms. In addition, since spillovers are low and Home firms are undertaking less R&D, Foreign firms do not receive much benefit from Home firms. These factors taken together lead Foreign firms to have lower profits than Home firms. When spillovers are high ($\gamma > 0.5$), Foreign firms have higher profits than Home firms. Since Home firms undertake more R&D than Foreign firms when spillovers are high, the cost of R&D is higher for Home firms. In addition, since spillovers are high, Foreign firms receive more benefit from Home R&D at no added cost. The Foreign firms receive the benefit of a public good while the Home firms incur the cost of providing that good. As a result, Foreign firms have higher profits than Home firms.

1.32 Research Joint Venture Equilibrium

In this cooperative arrangement, Home firms choose R&D to maximize individual firm profits but fully share the results of their R&D. Since spillovers are complete we have $\gamma = 1$ and the following expression for the profit of Home firm i,

$$\Pi_{Hi}(\mathbf{q},\mathbf{x}) = \left(a - Q - c + \sum_{i=1}^{2} x_{Hi} + \gamma \sum_{i=1}^{2} x_{Fi}\right) q_{Hi} - \frac{1}{2} v x_{Hi}^{2}.$$

The problem for Foreign firms remains unchanged from the non-cooperative equilibrium and therefore their profit function is also unchanged. Maximizing each firm's profit function with respect to its own output, holding fixed R&D and rival output, yields the following output reaction functions.

$$q_{Hi}(q_{Fi},\mathbf{x})=\frac{1}{3}\left(1-2q_{Fi}+\sum_{i=1}^{2}x_{Hi}+\gamma\sum_{i=1}^{2}x_{Fi}\right),$$

$$q_{Fi}(q_{Hi},\mathbf{x})=\frac{1}{3}\left(1-2q_{Hi}+x_{Fi}+\gamma\left(x_{Fj}+\sum_{i=1}^{2}x_{Hi}\right)\right),$$

where again, a – c has been normalized to one. As in the non-cooperative equilibrium and the R&D cartel equilibrium, these reaction functions are downward sloping. Noting that firms from the same country are symmetric yields the following solutions for the output sub-game,

$$q_{Hi}(\mathbf{x})=\frac{1}{5}\left(1+(3-2\gamma)\sum_{i=1}^{2}x_{Hi}-(1-2\gamma)\sum_{i=1}^{2}x_{Fi}\right),$$

$$q_{Fi}(\mathbf{x})=\frac{1}{5}\left(1-(2-3\gamma)\sum_{i=1}^{2}x_{Hi}+(4-3\gamma)x_{Fi}-(1-2\gamma)x_{Fj}\right),$$

$$\Pi_{Hi}(\mathbf{x})=\frac{1}{25}\left(1+(3-2\gamma)\sum_{i=1}^{2}x_{Hi}-(1-2\gamma)\sum_{i=1}^{2}x_{Fi}\right)^2-\frac{1}{2}vx_{Hi}^2,$$

$$\Pi_{Fi}(\mathbf{x})=\frac{1}{25}\left(1-(2-3\gamma)\sum_{i=1}^{2}x_{Hi}+(4-3\gamma)x_{Fi}-(1-2\gamma)x_{Fj}\right)^2-\frac{1}{2}vx_{Fi}^2.$$

In the R&D sub-game, each firm maximizes its own profit function from above with respect to its own R&D, holding fixed rival R&D. Noting again that firms from the same country are symmetric yields the following R&D reaction functions,

$$x_{Hi}(x_{Fi})=\frac{2(3-2\gamma)(1-2(1-2\gamma)x_{Fi})}{25v-4(3-2\gamma)^2},$$

$$x_{Fi}(x_{Hi})=\frac{2(4-3\gamma)(1-2(2-3\gamma)x_{Hi})}{25v-2(3-\gamma)(4-3\gamma)}.$$

As in the non-cooperative equilibrium and the R&D cartel equilibrium, the slope of the reaction function for Home firms changes from negative to positive as γ changes from $\gamma < 0.5$ to $\gamma > 0.5$. The slope of the reaction function for Foreign firms, however, changes from negative to positive as γ changes from $\gamma < 0.67$ to $\gamma > 0.67$. This results in a third possibility for the combination of these curves that is not present in the non-cooperative equilibrium and the R&D cartel equilibrium. For values of the spillover parameter in the range $0.5 < \gamma < 0.67$, we have that the reaction curve for Home firms is upward sloping, while simultaneously the reaction curve for Foreign firms is downward sloping. Home firms have a strategic incentive to increase R&D in order to raise their profits at the expense of Foreign firms. An increase in R&D by Foreign firms, however, raises the profits of all firms. These possibilities are demonstrated in Figure 1.2.

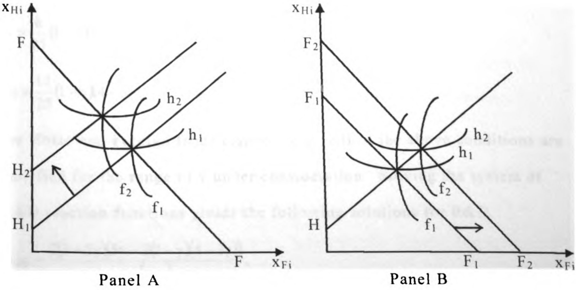

Figure 1.2 – Possible R&D reaction functions and iso-profit curves in a research joint venture

In Panel A, an increase in Home R&D shifts the reaction curve of Home firms from H_1 to H_2. This causes the iso-profit curve of Home firms to shift from h_1 to the higher curve h_2. The iso-profit curve of Foreign firms shifts from f_1 to the lower curve f_2. In Panel B, an increase in Foreign R&D shifts the reaction curve of Foreign firms from F_1 to F_2. This causes the iso-profit curve of Foreign firms to shift from f_1 to the higher curve f_2. The iso-profit curve of Home firms shifts from h_1 to the higher curve h_2.

Given these R&D reaction functions, the second order condition for Home profit maximization is,

$$v > \frac{2}{25}(3-2\gamma)^2,$$

while the second order condition for Foreign firms remains unchanged from the non-cooperative equilibrium. The stability conditions are,

$$v > \frac{8}{25}(1-\gamma)(3-2\gamma),$$

$$v > \frac{14}{25}(1-\gamma)(4-3\gamma),$$

for Home and Foreign firms respectively. All of the above conditions are satisfied for the range of v under consideration. Solving the system of R&D reaction functions yields the following solutions for R&D,

$$x_{Hi} = \frac{2(3-2\gamma)(5v-2(1-\gamma)(4-3\gamma))}{g_2(\gamma, v)},$$

$$x_{Fi} = \frac{2(4-3\gamma)(5v-4(1-\gamma)(3-2\gamma))}{g_2(\gamma, v)},$$

where $g_2(\gamma, v) = 125v^2 - 10(2-\gamma)(15-11\gamma)v + 8(1-\gamma)(1+2\gamma)(3-2\gamma)(4-3\gamma)$.

As in the non-cooperative equilibrium and the R&D cartel equilibrium, these solutions are decreasing in the spillover parameter, γ. Substituting the solutions for R&D into the output sub-game solutions given above yields the following results for output, profits and price,

$$q_{Hi} = \frac{5(5v - 2(1-\gamma)(4-3\gamma))v}{g_2(\gamma, v)},$$

$$q_{Fi} = \frac{5(5v - 4(1-\gamma)(3-2\gamma))v}{g_2(\gamma, v)},$$

$$\Pi_{Hi} = \frac{\left(25v - 2(3-2\gamma)^2\right)(5v - 2(1-\gamma)(4-3\gamma))^2 v}{(g_2(\gamma, v))^2},$$

$$\Pi_{Fi} = \frac{\left(25v - 2(4-3\gamma)^2\right)(5v - 4(1-\gamma)(3-2\gamma))^2 v}{(g_2(\gamma, v))^2},$$

$$P = \frac{25v^2 + 10\left(3\gamma^2 + 3\gamma - 10\right)v + 8(1-\gamma)(1+2\gamma)(3-2\gamma)(4-3\gamma)}{g_2(\gamma, v)}.$$

A comparison of these results with the non-cooperative equilibrium is summarized in Table 1.2 where the research joint venture solutions are denoted by a RJV superscript.

In a research joint venture, cooperating Home firms undertake less R&D relative to the non-cooperative equilibrium for all values of the spillover parameter. This means the incentive for Home firms to free ride and the effect of between country spillovers exceeds the incentive to gain market share at the expense of Foreign firms. Home firms are always better off when they participate in a research joint venture. Home firms have higher output and profits regardless of the level of spillovers.

Table 1.2 – Research Joint Venture and Non-cooperative Solution Comparison

	$\gamma \le 0.5$	$\gamma > 0.5$
R&D	$x_i^{NC} > x_{Fi}^{RJV} > x_{Hi}^{RJV}$	$x_i^{NC} > x_{Fi}^{RJV} > x_{Hi}^{RJV}$
Firm Output	$q_{Hi}^{RJV} > q_i^{NC} > q_{Fi}^{RJV}$	$q_{Hi}^{RJV} > q_i^{NC} > q_{Fi}^{RJV}$
Profit	$\Pi_{Hi}^{RJV} > \Pi_i^{NC} > \Pi_{Fi}^{RJV}$	$\Pi_{Hi}^{RJV} > \Pi_i^{NC} > \Pi_{Fi}^{RJV}$
Market Output	$Q^{RJV} > Q^{NC}$	$Q^{RJV} < Q^{NC}$
Price	$P^{RJV} < P^{NC}$	$P^{RJV} > P^{NC}$

Lower R&D on the part of both Home and Foreign firms would seem to suggest that all firms should have lower output. While less R&D would normally raise marginal production cost, we have that the marginal production cost of Home firms is actually lower. This is due to the fact that a unit of R&D done by a Home firm in a research joint venture is twice as effective in lowering marginal production cost for Home firms, whereas in the non-cooperative equilibrium a unit of R&D done by a Home firm is only $(1 + \gamma)$-times as effective in lowering marginal production cost. Therefore, the negative effect of decreased R&D on marginal production cost is outweighed by the increase in the effectiveness of R&D.[2] As a result, Home firms have higher output

[2] For $\gamma \ge 0.67$ we also require $v < \frac{4-3\gamma}{25(2-3\gamma)}\left(11\gamma^2 + 25\gamma - 54 - \left(121\gamma^4 + 1990\gamma^3 - 3203\gamma^2 - 2300\gamma + 3396\right)^{1/2}\right)$ in order for marginal production cost to be lower. If the marginal cost of R&D becomes too high,

relative to the non-cooperative equilibrium. A lower marginal cost of production and a lower total cost of R&D lead Home firms to have a lower total cost for most parameter values. While in some instances total cost is not lower, higher total revenue for all parameter values leads Home firms to have higher profits relative to the non-cooperative equilibrium.

A precise derivation of the effect of between country spillovers is somewhat difficult, but we can get a sense of the effect by looking at the changes in price and total output. Home firms always have higher output and Foreign firms always have lower output regardless of the level of spillovers. Price, however, is lower when spillovers are low ($\gamma \leq 0.5$), and it is higher when spillovers are high ($\gamma > 0.5$). Therefore, when spillovers are low, the increase in Home output exceeds the decrease in Foreign output, causing total output to be higher. As spillovers increase, however, the effect of the externality becomes more important. Higher spillovers imply, all else equal, less R&D and therefore less output. For the reasons mentioned above, Home firms continue to increase their output, but when spillovers are high they do so by a smaller amount. As a result, the increase in Home output is no longer sufficient to lead to an increase in total output.

It should be noted that when Home firms participate in a research joint venture, Foreign firms always have lower profits. For this reason, a strategic trade policy that encourages Home firms to participate in a

then the benefit of increased spillovers is outweighed by the fact that too little R&D is being undertaken.

research joint venture may invite retaliation on the part of the Foreign government.

1.33 Research Joint Venture Cartel Equilibrium

In the case of a research joint venture cartel, Home firms choose R&D to maximize joint profits and share the results of their R&D. Since $\gamma = 1$, as in the research joint venture equilibrium, the solutions for the output sub-game from that cooperative arrangement are applicable here as well. In the R&D sub-game, Home firms choose their levels of R&D to maximize joint profits, holding fixed the R&D of Foreign firms. Foreign firms maximize their individual profits with respect to their own R&D, holding fixed rival R&D. Noting that firms from the same country are symmetric yields the following R&D reaction functions,

$$x_{Hi}(x_{Fi}) = \frac{4(3-2\gamma)(1-2(1-2\gamma)x_{Fi})}{25v - 8(3-2\gamma)^2},$$

$$x_{Fi}(x_{Hi}) = \frac{2(4-3\gamma)(1-2(2-3\gamma)x_{Hi})}{25v - 2(3-\gamma)(4-3\gamma)}.$$

As in the research joint venture equilibrium, the slope of the Home reaction function changes from negative to positive as the spillover parameter changes from $\gamma < 0.5$ to $\gamma > 0.5$, while the slope of the Foreign reaction function changes from negative to positive as γ changes from $\gamma < 0.67$ to $\gamma > 0.67$. The second order condition for Home firm profit maximization is,

$$v > \frac{4}{25}(3-2\gamma)^2,$$

while the stability condition for Home firms is,

$$v > \frac{32}{25}(1-\gamma)(3-2\gamma).$$

The second order condition for Foreign firms remains unchanged from the non-cooperative equilibrium, while the stability condition for Foreign firms is the same as in the research joint venture equilibrium. The above conditions are satisfied for the range of v under consideration. Solving the system of R&D reaction functions yields the following solutions for R&D,

$$x_{Hi} = \frac{4(3-2\gamma)(5v-2(1-\gamma)(4-3\gamma))}{g_3(\gamma,v)},$$

$$x_{Fi} = \frac{2(4-3\gamma)(5v-8(1-\gamma)(3-2\gamma))}{g_3(\gamma,v)},$$

where $g_3(\gamma,v) = 125v^2 - 10(19\gamma^2 - 61\gamma + 48)v + 16(1-\gamma)(1+2\gamma)(3-2\gamma)(4-3\gamma)$.

A sufficient condition for these solutions to be decreasing in the spillover parameter, as in the other equilibria, is,

$$v > \frac{8}{15}(18\gamma^2 - 46\gamma + 29).$$

Substituting these solutions into the output sub-game solutions from the research joint venture equilibrium yields the following results for output, profits and price,

$$q_{Hi} = \frac{5(5v-2(1-\gamma)(4-3\gamma))v}{g_3(\gamma,v)},$$

$$q_{Fi} = \frac{5(5v-8(1-\gamma)(3-2\gamma))v}{g_3(\gamma,v)},$$

$$\Pi_{Hi} = \frac{\left(25v - 8(3-2\gamma)^2\right)\left(5v - 2(1-\gamma)(4-3\gamma)\right)^2 v}{\left(g_3(\gamma, v)\right)^2},$$

$$\Pi_{Fi} = \frac{\left(25v - 2(4-3\gamma)^2\right)\left(5v - 8(1-\gamma)(3-2\gamma)\right)^2 v}{\left(g_3(\gamma, v)\right)^2},$$

$$P = \frac{25v^2 + 10\left(3\gamma^2 + 7\gamma - 16\right)v + 16(1-\gamma)(1+2\gamma)(3-2\gamma)(4-3\gamma)}{g_3(\gamma, v)}.$$

A comparison of these results with the non-cooperative equilibrium is summarized in Table 1.3. The research joint venture cartel solutions are denoted by a RJVC superscript.

Table 1.3 – Research Joint Venture Cartel and Non-cooperative Solution Comparison

	$\gamma \leq 0.77$	$\gamma > 0.77$
R&D	$x_{Hi}^{RJVC} > x_i^{NC} > x_{Fi}^{RJVC}$	$x_{Hi}^{RJVC} > x_{Fi}^{RJVC} > x_i^{NC}$
Firm Output	$q_{Hi}^{RJVC} > q_i^{NC} > q_{Fi}^{RJVC}$	$q_{Hi}^{RJVC} > q_{Fi}^{RJVC} > q_i^{NC}$
Profit	$\Pi_{Hi}^{RJVC} > \Pi_i^{NC} > \Pi_{Fi}^{RJVC}$	$\Pi_{Hi}^{RJVC} > \Pi_{Fi}^{RJVC} > \Pi_i^{NC}$
Market Output	$Q^{RJVC} > Q^{NC}$	$Q^{RJVC} > Q^{NC}$
Price	$P^{RJVC} < P^{NC}$	$P^{RJVC} < P^{NC}$

In a research joint venture cartel, Home firms undertake more R&D relative to the non-cooperative equilibrium. The effect of centralized decision-making and the effect of Foreign competition dominate the effect of increased market power and the free rider problem. An examination of the resulting solutions when Foreign firms are excluded allows us to examine the effect of centralized decision-making, the effect of increased market power and the free rider problem simultaneously without the effect of Foreign competition. This exercise reveals that Home firms continue to undertake more R&D relative to the non-cooperative equilibrium. This implies that the effect of centralized decision-making is larger than the effects of increased market power and the free rider problem. Coordinating R&D decisions not only eliminates the free rider problem but it also dominates the benefits of increased market power.

Home firms are always better off when they participate in a research joint venture cartel. They undertake more R&D, have a higher output and higher profits in the face of a lower price. For Home firms, the decrease in price is offset by a decrease in marginal production cost. The decrease in marginal production cost is sufficient to lead Home firms to have higher profits. Unless spillovers are relatively high ($\gamma > 0.77$), Foreign firms will have lower profits when Home firms participate in a research joint venture cartel. Therefore, as in the research joint venture equilibrium, a strategic trade policy that encourages Home firms to participate in this type of cooperative venture may invite retaliation on the part of the Foreign government.

1.34 Comparison of the Cooperative Equilibria

While consumers have not been considered explicitly in this model we can make some comments on their welfare by looking at the implications for market output and price in each cooperative arrangement. Market output is higher and price is lower relative to the non-cooperative equilibrium in a research joint venture cartel, in a research joint venture when spillovers are low ($\gamma \leq 0.5$), and in an R&D cartel when spillovers are high ($\gamma > 0.5$). It is, therefore, these instances in which we would expect consumers to be better off as a result of cooperation by Home firms. Market output is the highest and price is the lowest, however, when Home firms participate in a research joint venture cartel. A research joint venture cartel is best for consumers and it is the cooperative arrangement that Home firms would prefer. Among the different cooperative arrangements, Home profits, output, and R&D are all higher in the research joint venture cartel than in either of the other two cooperative arrangements.

There are primarily two reasons why the research joint venture cartel appears as the preferable cooperative arrangement. The first is it enhances the positive spillover externality. In the R&D cartel, only a fraction of each firm's R&D spills over to the other firm. In a research joint venture cartel, however, spillovers are complete. All else equal, this makes a research joint venture cartel a preferable cooperative arrangement. In a research joint venture spillovers are complete as well. The research joint venture, however, has the concomitant free rider problem. The second reason the research joint venture cartel is the preferred cooperative arrangement is because the existence of centralized decision-making eliminates this problem. Therefore, the research joint venture cartel is the only arrangement in which the positive spillover externality can be improved and internalized simultaneously.

Other comparisons between cooperative solutions that might be of interest are less straightforward. While Home firms always prefer the research joint venture cartel, Foreign firms only prefer this cooperative arrangement when spillovers are very high ($\gamma > 0.9$). Home firms prefer a research joint venture to an R&D cartel provided spillovers are not very high ($\gamma < 0.86$), while Home R&D is usually higher in an R&D cartel than in a research joint venture. Finally, Foreign firms have the lowest profits when Home firms participate in a research joint venture. From the above comparisons we can conclude that Foreign firms will most likely be harmed when Home firms cooperate in R&D. The cooperative arrangements that bring the highest profits for Home firms generally bring lower profits for Foreign firms. As mentioned previously, such a result suggests that the Foreign government may have an incentive to retaliate against the use of cooperative R&D as a strategic trade policy.

1.4 Analysis of R&D Subsidies

Another solution to the under provision problem caused by the positive spillover externality may be the use of R&D subsidies. The subsidization of R&D is an alternate strategic trade policy tool the government could use in its attempt to increase welfare. Spencer and Brander analyze the use of this tool and find the use of positive R&D subsidies allows domestic firms to gain at the expense of foreign firms.

Their model differs from the one presented here, however, in that they do not consider the existence of spillovers. The traditional analysis of positive externalities suggests that the use of subsidies will force firms to internalize the externality they are creating. In the traditional analysis, however, firms are perfectly competitive and price is fixed to the firm. In the present analysis, price is not fixed and firms have a strategic incentive to vary their R&D in order to affect price. A government considering a subsidy cannot be ignorant of this incentive and must take this into consideration when determining the optimal policy. The government must consider the trade off between imposing a subsidy, which puts the importance of internalizing the externality above strategic considerations, and imposing a tax, which puts strategic considerations first. Since the under-provision problem caused by the externality becomes more severe as the level of spillovers increase, we would expect strategic considerations to be more important when spillovers are low and internalizing the externality to become more important as spillovers increase.

It is assumed the Home government can credibly commit to an R&D subsidy before firms choose their levels of R&D. In this way firms cannot affect the level of the subsidy through their R&D choices. The entire game continues to be solved by backward induction as before, with the final stage in the solution process being the determination of the optimal subsidy. The profit function for Home firm i is as follows,

$$\Pi_{Hi}(\mathbf{q},\mathbf{x}) = \left(a - Q - c + x_{Hi} + \gamma\left(x_{Hj} + \sum_{i=1}^{2} x_{Fi} \right) \right) q_{Hi} - \frac{1}{2} v x_{Hi}^2 + s_R x_{Hi},$$

where s_R in the final component of this function is the R&D subsidy. The profit function for Foreign firms remains unchanged from the non-cooperative equilibrium. Since the existence of R&D subsidies does not directly affect the output sub-game, the reaction functions and solutions for that sub-game are the same as in the non-cooperative with the exception that the solution for Home profits has the additional subsidy component.

In the R&D sub-game, each firm maximizes its own profit function from the output sub-game with respect to its own R&D, holding fixed rival R&D. Noting that firms from the same country are symmetric yields the following R&D reaction functions,

$$x_{Hi}(x_{Fi}) = \frac{25 s_R + 2(4 - 3\gamma)(1 - 2(1 - 2\gamma))x_{Fi}}{25v - 2(3 - \gamma)(4 - 3\gamma)},$$

$$x_{Fi}(x_{Hi}) = \frac{2(4 - 3\gamma)(1 - 2(1 - 2\gamma))x_{Hi}}{25v - 2(3 - \gamma)(4 - 3\gamma)},$$

where, again, the expression $a - c$ has been normalized to 1. As in the non-cooperative equilibrium, the slope of these reaction functions changes from negative to positive as γ changes from $\gamma < 0.5$ to $\gamma > 0.5$. The second order condition for profit maximization is the same as in the non-cooperative equilibrium. The stability condition is,

$$v > \frac{2}{25}(4 - 3\gamma)(6 - 5\gamma),$$

and is satisfied for the range of v under consideration. Solving the system of R&D reaction functions yields the following solutions for R&D as a function of the subsidy level,

$$x_{Hi} = \frac{1}{2}\left(\frac{5s_R}{5v - 2(1-\gamma)(4-3\gamma)} + \frac{25s_R + 4(4-3\gamma)}{25v - 2(1+3\gamma)(4-3\gamma)}\right),$$

$$x_{Fi} = \frac{1}{2}\left(\frac{-5s_R}{5v - 2(1-\gamma)(4-3\gamma)} + \frac{25s_R + 4(4-3\gamma)}{25v - 2(1+3\gamma)(4-3\gamma)}\right).$$

The R&D of Home firms is increasing in the subsidy and, as we would expect given the R&D reaction curves, the R&D of Foreign firms is decreasing in the subsidy for $\gamma < 0.5$ and is increasing in the subsidy for $\gamma > 0.5$.

The Home government chooses the subsidy level that maximizes the following expression for Home welfare,

$$W(s_R) = 2(\Pi_{Hi}(s_R) - s_R x_{Hi}(s_R)),$$

which is the sum of Home firm profits less the cost of providing the subsidy. The resulting optimal subsidy is,

$$s_R = \frac{-2(1-2\gamma)(25v - 2(4-3\gamma)(7-9\gamma))(5v - 2(1-\gamma)(4-3\gamma))v}{5g_4(\gamma, v)},$$

where $g_4(\gamma, v) = 625v^3 - 50(3-\gamma)(11-7\gamma)v^2 - 4(3-\gamma)(4-3\gamma)(27\gamma^2 - 7\gamma - 22)v$
$$- 8((1-\gamma)(1+3\gamma)(4-3\gamma))^2 .$$

The optimal subsidy is negative for $\gamma \leq 0.5$ and is positive for $\gamma > 0.5$. That is, R&D is only truly subsidized when spillovers are high ($\gamma > 0.5$). When spillovers are low ($\gamma \leq 0.5$) the optimal policy is to impose an R&D tax. The optimal subsidy is increasing in the level of spillovers as we would expect. When spillovers are low, however, strategic considerations are more important to raising profits than is internalizing the externality. Substituting the above value of the subsidy into the expressions for R&D yields the following solutions,

$$x_{Hi} = \frac{2(5v - 2(1-\gamma)(4-3\gamma))(5(3-\gamma)v - 2(1-\gamma)(1+3\gamma)(4-3\gamma))}{g_4(\gamma, v)},$$

$$x_{Fi} = \frac{2(4-3\gamma)\left(25v^2 - 2(3-\gamma)(9-8\gamma)v + 4(1-\gamma)^2(1+3\gamma)(4-3\gamma)\right)}{g_4(\gamma, v)}.$$

For a given value of the subsidy, these solutions are decreasing in the spillover parameter, as in the non-cooperative equilibrium. The corresponding solutions for output, profits, and price are as follows,

$$q_{Hi} = \frac{(5v - 2(1-\gamma)(4-3\gamma))(25v - 2(3-\gamma)(4-3\gamma))v}{g_4(\gamma, v)},$$

$$q_{Fi} = \frac{5\left(25v^2 - 2(3-\gamma)(9-8\gamma)v + 4(1-\gamma)^2(1+3\gamma)(4-3\gamma)\right)v}{g_4(\gamma, v)},$$

$$\Pi_{Hi} = \frac{g_5(\gamma, v)(5v - 2(1-\gamma)(4-3\gamma))^2 v}{5(g_4(\gamma, v))^2},$$

$$\Pi_{Fi} = \frac{\left(25v - 2(4-3\gamma)^2\right)\left(25v^2 - 2(3-\gamma)(9-8\gamma)v + 4(1-\gamma)^2(1+3\gamma)(4-3\gamma)\right)^2 v}{(g_4(\gamma, v))^2},$$

$$P = \frac{\begin{pmatrix} 125v^3 + 10\left(17\gamma^2 - 2\gamma - 47\right)v^2 + 4(4-3\gamma)\left(3\gamma^3 - 70\gamma^2 + 39\gamma + 32\right)v \\ - 8((1-\gamma)(1+3\gamma)(4-3\gamma))^2 \end{pmatrix}}{g_4(\gamma, v)},$$

where $g_5(\gamma, v) = 3125v^3 - 250(3-\gamma)(13-11\gamma)v^2 + 20(2+\gamma)(4-3\gamma)\left(51\gamma^2 - 106\gamma + 59\right)v$
$- 8(1-\gamma)(1+3\gamma)(4-3\gamma)^2\left(21\gamma^2 - 36\gamma + 19\right).$

Our ultimate interest is whether the use of R&D subsidies is superior to allowing cooperative R&D for improving welfare. It is worthwhile, however, to first assess the merits of R&D subsidies relative to the non-cooperative equilibrium. A comparison of the R&D subsidy results with the results from the non-cooperative equilibrium is made in Table 1.4. The R&D subsidy solutions are denoted by a SR superscript.

Table 1.4 – R&D Subsidy and Non-cooperative Solution Comparison

	$\gamma \leq 0.5$	$\gamma > 0.5$
R&D	$x_{Fi}^{SR} > x_i^{NC} > x_{Hi}^{SR}$	$x_{Hi}^{SR} > x_{Fi}^{NC} > x_i^{SQ}$
Firm Output	$q_{Fi}^{SR} > q_i^{NC} > q_{Hi}^{SR}$	$q_{Hi}^{SR} > q_{Fi}^{NC} > q_i^{SQ}$
Profit	$\Pi_{Fi}^{SR} > \Pi_i^{NC} > \Pi_{Hi}^{SR}$	$\Pi_{Fi}^{SR} > \Pi_{Hi}^{NC} > \Pi_i^{SQ}$
Market Output	$Q^{SR} < Q^{NC}$	$Q^{SR} > Q^{NC}$
Price	$P^{SR} > P^{NC}$	$P^{SR} < P^{NC}$
Home Welfare	$W^{SR} > W^{NC}$	$W^{SR} > W^{NC}$

Recall that welfare in the non-cooperative equilibrium is simply the sum of firm profits, while in the presence of R&D subsidies welfare is the sum of firm profits less the cost of providing the subsidy.

Relative to the non-cooperative equilibrium, Home firms undertake less R&D when spillovers are low ($\gamma \leq 0.5$) and more R&D when spillovers are high ($\gamma > 0.5$). This result is straightforward considering how the sign of the optimal subsidy changes from negative to positive as the value of the spillover parameter changes from $\gamma < 0.5$ to $\gamma > 0.5$. The R&D reaction curves indicate that this leads Foreign firms to always undertake more R&D relative to the non-cooperative equilibrium. The contrast between the use of R&D subsidies and cooperative R&D is Home firms need not be better off. The use of an R&D tax when spillovers are low allows Home firms to credibly commit to a lower level of R&D in order to raise price. The problem for Home firms, however, is they bear the cost of raising the price while Foreign firms benefit as well. The Home firms bear the explicit cost of the R&D tax and the implicit cost of higher marginal production costs. On the positive side, they do have a lower total cost of R&D and the benefit of higher Foreign R&D. The benefit of higher Foreign R&D is small, however, since spillovers are low. Unfortunately for Home firms, a higher price, a lower total cost of R&D, and higher Foreign R&D are not sufficient to outweigh the increases in their costs. Since Home welfare is higher, however, Home firms can be made better off if the government returns the tax proceeds to firms in a lump sum manner. In contrast to the case of low spillovers, Home firms are always better off when spillovers are high. Home firms have higher R&D, higher output and higher profits in the face of a lower price. Total cost is lower for Home firms because both Home and Foreign firms undertake more R&D. Unlike the R&D cartel equilibrium, the increase in R&D by Home firms is not sufficient to compensate for a lower price without the help of the additional Foreign R&D. The use of R&D subsidies differs from cooperative R&D in that Foreign firms are always better off. Foreign firms have higher profits regardless of the level of spillovers. For this reason we would not expect the Foreign government to undertake retaliatory measures as we might with cooperative R&D.

It is clear R&D subsidies will also achieve the objective of raising Home welfare. It remains to be determined, however, which policy, allowing cooperative R&D or subsidization of R&D, leads to the largest increase in welfare. Among the different cooperative arrangements considered, the research joint venture cartel is most preferred by Home firms. If we assume firms can choose the type of cooperative arrangement, we should expect the research joint venture cartel to prevail. Therefore, in order to assess these competing policies, the results for R&D subsidies should be compared with the results for the research joint venture cartel. This comparison is made in Table 1.5. The comparison can only be made for $\gamma \leq 0.9$ without requiring any additional restrictions on the marginal cost of R&D. The conclusions concerning Home profit and welfare, however, continue to hold for $\gamma > 0.9$.

Again, while not considering consumers explicitly, we can make some comments about their welfare. Market output is higher and price is lower in the research joint venture cartel equilibrium relative to the R&D subsidy equilibrium. Therefore, we would expect consumers to be better off under the research joint venture cartel than under the R&D subsidies. This expectation may not be reasonable, however, if the Home government were to redistribute the tax revenue to consumers. A more complete analysis of these different policies would certainly need to include consumers explicitly in order to come to any reasonable conclusions about their welfare.

Table 1.5 – R&D Subsidy and Research Joint Venture Cartel Solution Comparison

	Home	Foreign
R&D	$x_{Hi}^{RJVC} > x_{Hi}^{SR}$	$x_{Fi}^{SR} > x_{Fi}^{RJVC}$
Firm Output	$q_{Hi}^{RJVC} > q_{Hi}^{SR}$	$q_{Fi}^{SR} > q_{Fi}^{RJVC}$
Profit	$\Pi_{Hi}^{RJVC} > \Pi_{Hi}^{SR}$ for $\gamma < 0.81$ $\Pi_{Hi}^{SR} > \Pi_{Hi}^{RJVC}$ for $\gamma \geq 0.81$	$\Pi_{Fi}^{SR} > \Pi_{Fi}^{RJVC}$
Market Output	$Q^{RJVC} > Q^{SR}$	
Price	$P^{SR} > P^{RJVC}$	
Home Welfare	$W^{RJVC} > W^{SR}$	

The conclusions for Home profits are somewhat mixed as well. For most values of the spillover parameter ($\gamma < 0.81$), Home profits are higher in the research joint venture cartel equilibrium. For very high spillovers ($\gamma \geq 0.81$), Home profits are higher in the R&D subsidy equilibrium. Home welfare, however, is highest in the research joint venture cartel equilibrium regardless of the level of spillovers. In order to understand why welfare is highest under the research joint venture cartel equilibrium it is necessary to examine the cases of low spillovers ($\gamma \leq 0.5$) and high spillovers ($\gamma > 0.5$) separately. When spillovers are low, profits are increased in the R&D subsidy equilibrium by raising price. In the research joint venture cartel equilibrium, profits are increased by lowering total cost. The increase in profits in the R&D subsidy equilibrium, inclusive of the tax revenue, do not outweigh the decrease in total cost in the research joint venture cartel equilibrium that is afforded by complete spillovers. All else equal, total cost is higher in the R&D subsidy equilibrium, inclusive of the tax revenue, than in the research joint venture cartel equilibrium. That is, enhancing the positive spillover externality is more important to raising profits than are strategic considerations. When spillovers are high, both cooperation and subsidies lead firms to internalize the positive spillover externality. For most values of the spillover parameter, total cost is lower in the research joint venture cartel equilibrium than in the R&D subsidy equilibrium. It is for this reason that profits are higher in the research joint venture cartel even though price is lower. As γ approaches one, however, total cost is lower in the R&D subsidy equilibrium. This lower total cost, combined with a higher price, leads firms to have higher profits when spillovers are very high. Once the cost of providing the subsidy is included, however, total welfare remains highest in the research joint venture cartel.

1.5 Conclusion

The changes to antitrust policy in regard to cooperative research ventures in the United States and Europe can be viewed as a form of strategic trade policy. In the framework established, allowing domestic firms to work cooperatively on R&D raises their profits relative to, and often at the expense of, the profits of foreign rivals. Domestic firms achieve the highest level of profits when they participate in a research joint venture cartel. While consumers are not considered explicitly here, we would expect the benefit to consumers of higher output and lower prices in the research joint venture cartel would increase national welfare beyond the increase in profits. There are potentially negative consequences of allowing cooperative R&D as a strategic trade policy. The fact that foreign firms are usually worse off in the cooperative regimes that domestic firms prefer could lead to retaliatory policies by foreign governments. In contrast, when the domestic government uses R&D subsidies both domestic and foreign welfare improves. While not the preferred policy, the use of R&D subsidies may be better since it is less likely to invite retaliation. Given these conclusions it is important to examine the effects of both countries allowing cooperative R&D.

There are other important extensions of the present model that should be considered as well. One might be how the results of the present model compare with the use of export subsidies in place of, or in addition to, R&D subsidies. Others might be how changing the number of firms or how changing the strategic variable in the second stage of competition affects the foregoing results. To the extent that the present model conforms to reality, however, there exists a strategic trade policy motivation for allowing cooperative R&D.

CHAPTER 2
COOPERATIVE R&D AND STRATEGIC TRADE POLICY WITH BERTRAND COMPETITION

2.1 Introduction

Beginning with d'Aspremont and Jacquemin (1988), there have been numerous papers examining the effects of cooperation in research and development (R&D). Many of these papers have been inspired by changes to American and European antitrust law in the 1980s that granted a more favorable antitrust environment to cooperative R&D. For the most part, these papers seek to determine the effects of cooperation on the amount of research conducted as well as the effects on product market variables. One frequently stated objective of the legislative changes regarding cooperative R&D was to improve the competitive position of domestic firms relative to foreign firms.[3] Until recently, the literature on cooperative R&D has only been concerned with the domestic effects of cooperation and has ignored the effects of cooperation on competition with foreign firms. The few models that examine cooperative R&D in an open economy setting include, Motta (1996), Leahy and Neary (1999), Neary and O'Sullivan (1999) as well as the model in Chapter 1 of this work.

All of these models use a framework similar to the strategic trade model of Spencer and Brander (1983) in which firms are Cournot competitors in the product market. They assume that R&D reduces

[3] See Jacquemin (1988) and Hamphill (1997).

production costs and that there are spillovers from R&D. This means that production costs are decreasing in own and rival R&D. Where these papers differ, apart from the policy questions they address, is in the assumptions that are made about cooperation in R&D. Kamien et al. (1992) have identified three possibilities for cooperative R&D. The first possibility is an R&D cartel in which cooperating firms choose R&D to maximize joint profits. This is the assumption made by Leahy and Neary and by Neary and O'Sullivan. The second possibility is a research joint venture in which R&D is chosen to maximize individual firm profits but the results of the research are fully shared. This is the assumption made by Motta. The third possibility is a research joint venture cartel in which the levels of R&D are chosen to maximize joint profits and the results of the research are fully shared. Chapter 1 examines the implications of all three of these possibilities for cooperation in R&D.

Motta examines the implications for both domestic and foreign welfare when only domestic firms cooperate in R&D, when domestic firms cooperate while simultaneously foreign firms cooperate, and when domestic firms cooperate with foreign firms. He assumes that the spillovers from R&D are the same within a country and between countries. He finds that domestic firms are better off when they are allowed to cooperate in R&D. In addition, he finds that both domestic and foreign governments should allow their firms to cooperate in R&D domestically and welfare can be improved further if firms are allowed to cooperate internationally.

Leahy and Neary examine R&D subsidies, export subsidies and cooperative R&D in the presence of local and international spillovers where these spillovers differ. They assume that there are spillovers from both intra-industry rival R&D (international spillovers) and inter-industry rival R&D (local spillovers). That is, there are two types of spillovers – those between firms in the same country and those between domestic firms and foreign firms. They find that when domestic firms are allowed to cooperate in R&D that these firms over-internalize the externality and over-invest in R&D. They conclude that in addition to allowing cooperation that R&D should be taxed.

Neary and O'Sullivan examine the question of whether it is better for a government to allow its firms to cooperate in R&D with foreign firms or whether direct subsidization of exports is better in terms of improving national welfare. They assume that there are only between country spillovers from R&D. Neary and O'Sullivan find that cooperative R&D raises welfare when spillovers are relatively low, since it reduces the incentive to strategically over-invest in R&D, and when spillovers are relatively high, since it reduces the incentive to strategically under-invest in R&D. They also find that subsidization with commitment is better than cooperation except when R&D is highly effective and spillovers are near complete. In addition, when spillovers are low it is welfare maximizing to choose a level of subsidies that prevents entry of the foreign firm altogether.

Chapter 1 examines the implications for domestic and foreign welfare when only domestic firms cooperate in R&D. It is assumed that the spillovers from R&D are the same within and between countries. In that chapter it is shown that domestic welfare is always higher when domestic firms cooperate in R&D and that foreign welfare is frequently lower. The research joint venture cartel yields the largest welfare improvement among the three possibilities for cooperative R&D. Chapter 1 also examines the use of R&D subsidies and shows that while R&D subsidies are beneficial, they are not as effective in improving domestic welfare.

Strategic trade policy models are frequently criticized because the results that were obtained under the assumption of Cournot competition are often overturned when the same problem is examined under the assumption of Bertrand competition.[4] This chapter adds to the emerging literature on open economy cooperative R&D by examining the effects of cooperation in R&D among domestic firms in a strategic trade policy model where firms engage in Bertrand competition in the product market. While similar to the other models of open economy cooperative R&D in the use of a strategic trade policy framework, the assumption of Bertrand competition allows us to evaluate whether the usual criticism of this type

[4] See Eaton and Grossman (1986).

of model is valid when the policy instrument is cooperative R&D. The goal of the chapter is to determine whether a domestic government would want to allow cooperative R&D as a strategic trade policy when firms are Bertrand competitors in the product market.

The model analyzed here is most similar to the model analyzed in Chapter 1. The strategic trade policy framework of Spencer and Brander is used, however, it is assumed that firms compete in price in the product market. There are spillovers from R&D and these spillovers are the same within a country and between countries. Also, production costs are declining in own and in rival R&D. Of the different possibilities for cooperative R&D, it is assumed that cooperating domestic firms participate in an R&D cartel, which means that R&D is chosen to maximize joint profits. Under these assumptions, both domestic and foreign firms benefit when the domestic government allows its firms to cooperate in R&D. Not only do the firms of both countries benefit, but foreign firms benefit more than do domestic firms. This is due to the fact that the domestic firms do all the work to raise profits, either through raising price or increasing R&D, while foreign firms free ride on those efforts. These results are analogous to those found by Deneckere and Davidson (1985) for mergers in a price-setting game. In their paper, when a subset of the industry's firms merge, all firms benefit but those firms outside the merger benefit more than those inside the merger. In this chapter, we can view the domestic firms, which cooperate in R&D, as the insiders and the foreign firms, which are not cooperating, as the outsiders. Just as in the analysis of mergers, all firms benefit but the outsiders benefit more than the insiders. Consumers may also benefit from cooperation in R&D through lower prices and higher output, but only when R&D spillovers are high.

The plan for the remainder of the chapter is as follows. Section 2.2 describes the model and gives the outcomes for the non-cooperative game. Following the discussion of the non-cooperative solutions, in section 2.3, is an analysis of the cooperative solutions. Section 2.4 compares the cooperative solutions of this chapter with those from Chapter 1. Finally, section 2.5 gives some concluding remarks.

2.2 Non-cooperative Equilibrium

It is assumed that there are only four firms, with two located in the Home country and with the remaining two located in the Foreign country. These firms are identical in every respect with the exception of national origin. As is standard in strategic trade policy models, it is assumed that all output is sold in a third country. This allows us to only examine firm profits when analyzing welfare. The model to be analyzed is a three-stage game where in the first stage the Home government decides whether to allow cooperative R&D. In the second stage, firms make their R&D choices given the government's move and the R&D choices of their rivals. In the third stage firms choose prices given all of the choices in the previous stages and the price choices of their rivals.

It is assumed that each firm produces one variety of a differentiated good, where the demand for firm i's variety is,

$$q_i(\mathbf{p}) = 1 - p_i - 5(p_i - \bar{p}_{-i}),$$

and q_i is the output of firm i; **p** is the vector of prices charged by all firms; p_i is the price charged for firm i's variety; $\bar{p}_{-i}$ is the mean of the prices charged by all firms other than firm i. This demand function is a variation of the one found in Deneckere and Davidson where the substitutability parameter has been set equal to 5. Since the effects of the substitutability of the firms' products is not of primary interest, a specific value for the substitutability parameter was chosen in order to simplify the solutions that follow. The value chosen is sufficient, in addition to other parameter restrictions, for all of the non-cooperative and cooperative solutions to be non-negative. While the choice of a particular value affects the final form of the solutions, it does not affect the results of the model in a meaningful way.

The total cost function is,

$$TC_i\ (q_i,\mathbf{x}) = \left(c - x_i - \gamma \sum_{j \neq i} x_j\right) q_i + \frac{1}{2} v x_i^2,$$

where **x** is the vector of R&D choices for all firms; x_i is a unit of R&D undertaken by firm i and x_j is a unit of R&D undertaken by a firm other than firm i; c is the constant marginal cost of production, $0 < c < 1$; v is a positive constant marginal cost of R&D parameter; γ indicates the degree of spillovers from R&D done by rivals, $0 < \gamma < 1$ ($\gamma = 0$ is no spillovers, γ

= 1 is complete spillovers). The production costs of firm i are a function of its own output, its own R&D and the R&D of its rivals. It is assumed that R&D is of the process innovation variety and that unit production cost is decreasing in own and rival R&D. For a particular firm i, a unit increase in its own R&D reduces its own production cost by that unit, while a unit increase in R&D by firm j ($j \neq i$) only reduces the production cost of firm i by a fraction, γ, of that unit. The total cost of R&D, $\frac{1}{2}vx_i^2$, is quadratic to reflect the diminishing returns that are thought to exist in R&D.[5]

The assumptions about demand and costs yield the following profit function for firm i,

$$\Pi_i(\mathbf{p},\mathbf{x}) = \left(1 - 6p_i + \frac{5}{3}\sum_{j\neq i} p_j\right)\left(p_i - c + x_i + \gamma\sum_{j\neq i} x_j\right) - \frac{1}{2}vx_i^2 .$$

The above function is maximized with respect to firm i's price, holding fixed R&D and rival prices. The maximization problem yields the following price reaction function for firm i,

$$p_i(\mathbf{p}_{-i},\mathbf{x}) = \frac{1}{12}\left(2 - 6\left(x_i - \gamma\sum_{j\neq i} x_j\right) + \frac{5}{3}\sum_{j\neq i} p_j\right),$$

where $\mathbf{p}_{-i}$ is the vector of price choices excluding the choice of firm i and c has been set equal to 1/6 in order to simplify the solutions that follow. The price reaction function is upward sloping. This means that each firm

[5] See Dasgupta (1986) for a discussion of the returns to R&D.

has a strategic incentive to increase R&D in the first stage as a means of committing to a lower price and thereby undercutting its rivals in the second stage. If firms could collude, however, they would prefer to restrict R&D as a means of committing to higher prices. Solving the system of price reaction functions, noting that the firms are symmetric, yields the following solutions for the price sub-game,

$$p_i(\mathbf{x}) = \frac{2}{287}\left(41 - 3(26 + 15\gamma)x_i - 3(5 + 36\gamma)\sum_{j \neq i} x_j\right),$$

$$q_i(\mathbf{x}) = \frac{1}{287}\left(205 + 6(131 - 90\gamma)x_i - 6(30 - 71\gamma)\sum_{j \neq i} x_j\right),$$

$$\Pi_i(\mathbf{x}) = \frac{1}{494214}\left(205 + 6(131 - 90\gamma)x_i - 6(30 - 71\gamma)\sum_{j \neq i} x_j\right)^2 - \frac{1}{2}vx_i^2.$$

Maximizing the above profit expression with respect to the R&D of firm i, holding fixed rival R&D, yields the following R&D reaction function for firm i,

$$x_i(\mathbf{x}_{-i}) = \frac{2(131 - 90\gamma)\left(205 - 6(30 - 71\gamma)\sum_{j \neq i} x_j\right)}{82369v - 12(131 - 90\gamma)^2},$$

where $\mathbf{x}_{-i}$ is the vector of R&D choices excluding the choice of firm i. The slope of this reaction function changes from negative to positive as γ changes from $\gamma < 30/71$ to $\gamma > 30/71$. The turning point for the slope of the reaction function is directly related to the value chosen for the substitutability parameter in the demand function. As the substitutability of the goods increases, the range of γ for which the reaction function is positively sloped decreases. When the substitutability of the goods is low the range of γ for which the reaction function is positively sloped is relatively large. When the substitutability of the goods is high the range of γ for which the reaction function is positively sloped is relatively small. When the goods are unrelated the reaction function is always positively sloped and when the goods are perfect substitutes the slope of the reaction function is always negative. Therefore, choosing a particular value for the substitutability parameter in the demand function only affects where the change in slope of the reaction function occurs and not whether it occurs. The second order condition for profit maximization is,

$$v > \frac{12}{82369}(131 - 90\gamma)^2.$$

The stability condition, which guarantees that the R&D reaction curves intersect, is,

$$v > \frac{1932}{82369}(1-\gamma)(131 - 90\gamma).$$

Solving the system of R&D reaction functions, noting again that the firms are symmetric, yields the following solution for R&D,

$$x_i = \frac{10(131 - 90\gamma)}{2009v - 12(1+3\gamma)(131 - 90\gamma)}.$$

The equilibrium level of R&D is decreasing in the spillover parameter γ. An increase in the rate of spillovers leads firms to undertake less R&D since more of their R&D spills over to rivals. Substituting the equilibrium solution for R&D into the price sub-game solutions yields the following results for price, output, and profits,

$$p_i = \frac{574v - 12(1+3\gamma)(131-90\gamma)}{2009v - 12(1+3\gamma)(131-90\gamma)},$$

$$q_i = \frac{1435v}{2009v - 12(1+3\gamma)(131-90\gamma)},$$

$$\Pi_i = \frac{25\left(82369v - 12(131-90\gamma)^2\right)v}{6(2009v - 12(1+3\gamma)(131-90\gamma))^2}.$$

The non-negativity constraints for the final solutions require,

$$v > \frac{12}{574}(1+3\gamma)(131-90\gamma),$$

for $\gamma > 0.03$ in addition to the second order and stability conditions. This non-negativity constraint is binding.

2.3 Cooperative Equilibrium

There is a positive externality caused by R&D spillovers that is socially beneficial but privately harmful. A unit of R&D done by firm i lowers firm i's marginal production cost by that unit but also lowers its rival's marginal production cost by a fraction of that unit. Therefore, in a decentralized equilibrium we would expect firms to undertake too little R&D relative to the social optimum. While the fraction of R&D that spills over is constant across firms, the externality can be divided into two components. The first is spillovers between firms in the same country and the second is spillovers between firms in different countries. One of the purported goals of allowing cooperative R&D is to have firms internalize the positive spillover externality by centralizing decision-making. We would expect the effect of such centralization to be an increase in the level of R&D. Even with centralized decision-making, however, we would never expect to see the spillover externality fully internalized. This is due to the fact that the spillover externality between Home and Foreign firms remains unaffected when Home firms cooperate in R&D. There is also a drawback to encouraging centralized decision-making and that is it tends to lead to an increase in market power for the cooperating firms. Therefore, these firms have an incentive to restrict their R&D as a means of raising price. Potentially combating this incentive, however, is the fact that Home firms continue to compete with Foreign firms for market share. As a result, there is an incentive to increase R&D in order to lower price and gain market share at the expense of Foreign firms. The direction of the different effects on Home R&D discussed above is summarized in Figure 2.

Effect	Direction of Effect on R&D
Centralized Decision-making	Increase
Between Country Spillovers	Decrease
Market Power	Decrease
Foreign Competition	Increase

Figure 2 – Expected effects on Home firm R&D

Cooperation in R&D by Home firms means that these firms choose their levels of R&D to maximize joint profit. Since there is no cooperation in the product market, the price sub-game solutions are the same as in the non-cooperative equilibrium. In the R&D sub-game, Home firms maximize joint profits with respect to both firms' R&D, holding fixed the R&D of Foreign firms. The Foreign firms continue to maximize their individual profit functions with respect to own R&D, holding fixed rival R&D. Noting that firms from the same country are symmetric yields the following R&D reaction functions,

$$x_{Hi}(x_{Fi}) = \frac{2(5(4141-779\gamma)-12(30-71\gamma)(101-19\gamma)x_{Fi})}{82369v-12(101-19\gamma)^2},$$

$$x_{Fi}(x_{Hi}) = \frac{2(131-90\gamma)(205-12(30-71\gamma)x_{Hi})}{82369v-12(131-90\gamma)(101-19\gamma)}.$$

The H and the F subscripts refer to Home and Foreign respectively. As in the non-cooperative equilibrium, these reaction functions are downward sloping for $\gamma < 30/71$ and upward sloping for $\gamma > 30/71$. The second order condition for Home profit maximization is,

$$v > \frac{12}{82369}\left(13141\gamma^2 - 27840\gamma + 18061\right),$$

while the Home stability condition is,

$$v > \frac{12}{82369}(1-\gamma)(101-19\gamma).$$

The second order condition for Foreign profit maximization and the Foreign stability condition are unchanged from the non-cooperative equilibrium. Solving the system of R&D reaction functions yields the following solutions for R&D,

$$x_{Hi} = \frac{10(101-19\gamma)(11767v-276(1-\gamma)(131-90\gamma))}{f_1(\gamma,v)},$$

$$x_{Fi} = \frac{10(131-90\gamma)(11767v-276(1-\gamma)(101-19\gamma))}{f_1(\gamma,v)},$$

$$\text{where } f_1(\gamma,v) = 23639903v^2 - 3444(101-19\gamma)(232-109\gamma)v \\ +3312(1-\gamma)(1+3\gamma)(101-19\gamma)(131-90\gamma).$$

These solutions are decreasing in the spillover parameter γ, as in the non-cooperative equilibrium. Substituting the solutions for R&D into the price sub-game solutions yields the following results for price, output and profits,

$$p_{Hi} = \frac{\begin{pmatrix} 6754258v^2 + 3444(4729\gamma^2 - 4948\gamma - 9867)v \\ +3312(1-\gamma)(1+3\gamma)(101-19\gamma)(131-90\gamma) \end{pmatrix}}{f_1(\gamma,v)},$$

$$p_{Fi} = \frac{\begin{pmatrix} 6754258v^2 + 3444(3664\gamma^2 - 3433\gamma - 10317)v \\ +3312(1-\gamma)(1+3\gamma)(101-19\gamma)(131-90\gamma) \end{pmatrix}}{f_1(\gamma,v)},$$

$$q_{Hi} = \frac{1435(11767v-276(1-\gamma)(131-90\gamma))v}{f_1(\gamma,v)},$$

$$q_{Fi} = \frac{1435(11767v-276(1-\gamma)(101-19\gamma))v}{f_1(\gamma,v)},$$

$$\Pi_{Hi} = \frac{25(82369v-12(101-19\gamma)^2)(11767v-276(1-\gamma)(131-90\gamma))^2 v}{6(f_1(\gamma,v))^2},$$

$$\Pi_{Fi} = \frac{25(82369v-12(131-90\gamma)^2)(11767v-276(1-\gamma)(101-19\gamma))^2 v}{6(f_1(\gamma,v))^2}.$$

The non-negativity constraints for these solutions require,

$$v > \frac{3}{11767}\left(\begin{array}{l} 10317 + 3433\gamma - 3664\gamma^2 \\ + \left(52125616\gamma^4 - 313013432\gamma^3 + 397430217\gamma^2 - 41440830\gamma + 6625825\right)^{1/2} \end{array} \right),$$

for $\gamma \le 30/71$ and

$$v > \frac{3}{11767}\left(\begin{array}{l} 9867 + 4948\gamma - 4729\gamma^2 \\ + \left(61064161\gamma^4 - 334654592\gamma^3 + 392408322\gamma^2 - 14633520\gamma - 2456975\right)^{1/2} \end{array} \right),$$

for $\gamma > 30/71$ in addition to the second order and stability conditions. These non-negativity constraints are binding. A comparison of the cooperative equilibrium with the non-cooperative equilibrium is summarized in Table 2. The cooperative solutions are denoted by a C superscript and the non-cooperative solutions are denoted by a NC superscript.

Table 2 – Cooperative and Non-cooperative Solution Comparison

	$\gamma \le 30/71$	$\gamma > 30/71$
R&D	$x_{Fi}{}^C > x_i{}^{NC} > x_{Hi}{}^C$	$x_{Hi}{}^C > x_{Fi}{}^C > x_i{}^{NC}$
Price	$p_{Hi}{}^C > p_{Fi}{}^C > p_i{}^{NC}$	$p_i{}^{NC} > p_{Fi}{}^C > p_{Hi}{}^C$
Output	$q_{Fi}{}^C > q_i{}^{NC} > q_{Hi}{}^C$	$q_{Hi}{}^C > q_{Fi}{}^C > q_i{}^{NC}$
Profit	$\Pi_{Fi}{}^C > \Pi_{Hi}{}^C > \Pi_i{}^{NC}$	$\Pi_{Fi}{}^C > \Pi_{Hi}{}^C > \Pi_i{}^{NC}$

In the case where spillovers are low ($\gamma \le 30/71$), we have that cooperation leads Home firms to undertake less R&D relative to the non-cooperative equilibrium. When spillovers are high ($\gamma > 30/71$), cooperation has the opposite effect and Home firms undertake more R&D.

In the first instance, the effect of increased market power and the continued existence of between country spillovers dominate, and in the second instance the effect of centralized decision-making and the continued existence of competition with Foreign firms dominate. One method of isolating these different effects is to restrict the spillover parameter, γ, to be zero and then examine the resulting equilibrium levels of R&D. This exercise allows us to examine the effect of increased market power and the effect of Foreign competition simultaneously without the effects from centralized decision-making and between country spillovers. We find that in the case of no spillovers Home R&D is always lower relative to the non-cooperative equilibrium. This result indicates that the effect of increased market power outweighs the effect of Foreign competition. Therefore, when spillovers are low it must be the case that raising price is more important to increasing profits than is increasing market share. Restricting R&D in order to raise price is not as costly when spillovers are low since the harm from not internalizing the externality is lower. When spillovers are high, however, we must have that the effect of Foreign competition and the effect of centralized decision-making combined are larger than the effect of increased market power. That is, the benefit from internalizing the externality combined with the effect of Foreign competition, exceeds the benefit from restricting output. Again, this is expected because when spillovers are high the harm from not internalizing the externality is greater. These results are similar to the R&D cartel results from Chapter 1 where cooperative R&D is analyzed in a quantity-setting game.

Home firms are always better off when they cooperate in R&D. When spillovers are low ($\gamma \leq 30/71$), Home firms have lower R&D, a higher price, lower output and higher profits. It is not obvious that Home firms should have higher profits when spillovers are low. The fact that Home firms undertake less R&D has two competing effects on their total costs. One component of total cost, the cost of R&D, is now lower, however, the second component of total cost, the cost of production, is now higher.[6] Only for low values of γ in this range does the decrease in the cost of R&D outweigh the increase in the cost of production. The fact that R&D is decreasing in γ means that the cost of R&D falls at a decreasing rate, while the cost of production rises at an increasing rate. Therefore for low values of γ total cost is lower, but for higher values of γ total cost is higher. In those instances where total cost is higher, total revenue is also higher to compensate for an increased total cost. This leads profits to be higher for all values of γ in this range. When spillovers are high ($\gamma > 30/71$), Home firms have higher R&D, a lower price, higher output, and higher profits. The profits of Home firms are higher relative to the non-cooperative equilibrium because their total cost is lower. Total cost in this case is lower for Home firms because both

[6] In regard to production costs, Home firms do benefit from additional R&D done by Foreign firms through spillovers, however, the increase in Foreign R&D is not sufficient to outweigh the decrease in R&D by Home firms. As a result the production costs of Home firms increase.

Home and Foreign firms undertake more R&D. The additional R&D undertaken by Home firms, in the absence of any additional Foreign R&D, however, does not lower total cost sufficiently to compensate for a lower price.

While we are not explicitly interested in the outcomes for Foreign firms, a few of the results merit some explanation. When spillovers are low ($\gamma \leq 30/71$), Foreign firms have higher R&D, a higher price, higher output, and higher profits. These results for Foreign firms are interesting because we normally think of R&D and output as moving in the opposite direction of price. While the total R&D undertaken by Foreign firms is higher, the net R&D -- the R&D of Foreign firms plus the R&D that spills over from Home firms -- is lower as a result of the reduction in R&D by Home firms. Therefore, Foreign firms have a higher cost of production and, as a result, higher prices. This would seem to imply that Foreign firms should have lower output. Total output in the market is lower relative to the non-cooperative equilibrium due to the higher prices charged by all firms. Since the price charged by Home firms is higher than that charged by Foreign firms, Foreign firms have a larger share of a smaller market. The output of Foreign firms is increased relative to the non-cooperative equilibrium because these firms now charge a lower price relative to Home firms even though the Foreign price has risen relative to the non-cooperative equilibrium.

Another interesting result relating to Foreign firms is that they are always better off as a result of Home firms' cooperation in R&D. Not only are Foreign firms better off, but they benefit more than do Home firms. Essentially, Home firms do all of the work to raise profits while Foreign firms reap the benefits. When spillovers are low ($\gamma \leq 30/71$) Home firms restrict R&D in order to raise price. Foreign firms are then able to take advantage of higher Home prices by raising price themselves. When spillovers are high ($\gamma > 30/71$), Home firms undertake more R&D than Foreign firms causing Home firms have a higher cost of R&D. Since spillovers are higher, Foreign firms receive more benefit from Home firm R&D at no added cost. In both cases, Foreign firms receive the benefit of a public good while Home firms incur the cost of providing that good. As a result, Foreign firms have higher profits than Home firms.

While consumers have not been considered explicitly in this model we can make some comments on their welfare by looking at the implications for output and price in the cooperative equilibrium. When spillovers are low ($\gamma \leq 30/71$) firms from both countries charge higher prices and Foreign firms produce more output while Home firms produce less. The welfare of consumers is not clear in this situation. The prices of all varieties are higher but now more of the Foreign variety is being produced. Depending on consumers' preferences over varieties they may be better off but are not necessarily better off. When spillovers are high ($\gamma > 30/71$) firms from both countries charge lower prices and produce more output. Since all firms have lower prices and produce more output, we would expect consumers to be better off.

2.4 Comparison with a Quantity-Setting Game

The main criticism of strategic trade policy models, that the policy implications are reversed when price-setting games are considered, is not entirely valid in regard to cooperative R&D. The similarities between the model analyzed here, and that analyzed in Chapter 1, allow for some general comparisons between quantity-setting and price-setting games. While Home welfare is improved in both settings, the policy implications of these models are somewhat different. In the quantity-setting game, Foreign welfare is usually lower. In those instances where Foreign welfare is higher, the Home country usually benefits more than does the Foreign country. In the price-setting game Foreign welfare is higher and the Foreign country benefits more than does the Home country. These results imply different roles for policy-makers depending on the type of competition in the product market. In a quantity-setting game there is an active role for the Home government since allowing cooperation in R&D increases Home firm profit often at the expense of Foreign firm profit. The results from the price-setting game suggest a passive role for the Home government. Since Foreign firms benefit more when Home firms cooperate in R&D, the Home government should encourage cooperation among Foreign firms while discouraging cooperation among Home firms.

These implications for policy are interesting given the environment in which the antitrust exemptions to cooperative R&D were first formulated. American firms, in the early 1980s, were losing both international and domestic market share to Japanese firms. Policy-makers in the United States viewed lax antitrust enforcement in Japan as one of the factors contributing to the success of Japanese firms.[7] This was one of the motivating factors for allowing more lenient antitrust treatment for cooperative R&D in the United States. This action on the part of the United States seems justified given the policy implications of allowing cooperative R&D in a quantity-setting game. The policy implications of the price-setting game, however, suggest that policy-makers in the United States should not have been concerned about lax antitrust enforcement in Japan. Policy-makers in the United States should have welcomed this lax enforcement as it would be expected to benefit American firms more than Japanese firms. It appears that part of the traditional criticism of strategic trade policy models remains. While domestic firms benefit in both quantity-setting and price-setting games, the policy implications of these models are still different.

2.5 Conclusion

The purpose of this chapter is two-fold. First, it seeks to contribute to a somewhat overlooked aspect of cooperative R&D. Only a few papers have begun to examine the effects of cooperative R&D on international

[7] Baranson (1981), which was funded by the U.S. Office of Technology Assessment, is typical of the rhetoric during this period.

competition and one goal of this chapter is to contribute to this emerging dialogue. Second, it seeks to address a longstanding criticism of strategic trade policy models. It is well known that the policy predictions of strategic trade policy models depend in an important way on the choice of strategic variable in the product market. For this reason, strategic trade policy models have become somewhat out of vogue. This chapter demonstrates that under the assumption of price competition in the product market that a domestic government may still want to allow its firms to cooperate in R&D.

This chapter also demonstrates, however, that the optimal policy may be to do nothing. If foreign firms gain more than domestic firms when domestic firms cooperate in R&D, then the domestic government could obtain a larger welfare improvement by simply encouraging the foreign government to allow cooperative R&D. There are a couple of possible explanations for this result. The first explanation is that it may be an inherent feature of price games. Supporting this idea are Deneckere and Davidson's results for mergers in price-setting games. The second, and more likely, explanation is that it is a function of the way in which R&D and cooperation in R&D have been treated. It was assumed that R&D directly resulted in a reduction in unit cost. It may be possible that by modeling R&D in another way, such as a patent race, that firms' behavior would be different. In addition, there are other possible cooperative arrangements besides an R&D cartel. While the optimal policy may be to do nothing, a country would not be made worse off by allowing cooperative R&D. This conclusion liberates strategic trade policy models somewhat from their usual criticism. Whether firms compete in quantity or in price these firms cannot be made worse off by allowing them to cooperate in R&D.

CHAPTER 3
RESEARCH JOINT VENTURES AND INTERNATIONAL COMPETITIVENESS: EVIDENCE FROM THE *NATIONAL COOPERATIVE RESEARCH ACT*

3.1 Introduction

In both the United States and the European Union, firms engaged in cooperative research and development (R&D) are accorded more lenient antitrust treatment of their cooperative research activities. In the United States, this more lenient treatment was granted by the *National Cooperative Research Act of 1984* (NCRA). Under the NCRA, firms that register their cooperative venture with the U.S. Department of Justice are only subject to single, instead of treble, damages if they are found to be in violation of antitrust laws. While improving the competitiveness of American firms relative to foreign firms was an intended goal of the more lenient antitrust treatment, most research on cooperative R&D has focused on the domestic effects of cooperative ventures. This chapter examines the effect of the NCRA on the international competitiveness of the United States, where competitiveness is measured in terms of changes in the price and quantity of American exports.

Data on NCRA registered research joint ventures (NCRA-RJVs) in 11 2-digit SIC industries are combined with data on the price and quantity of American exports in those same industries for the years 1985 – 1997 in order to estimate the net effect of cooperative R&D on American exports. The goal is to determine whether, on balance, the NCRA had the intended effect of improving the international competitiveness of American firms.

Cooperation in R&D, however, is likely to have two opposing effects on firm behavior and the competitiveness of American firms. First, we might expect cooperation in R&D to resolve the appropriability problem thought to be inherent with most R&D. To the extent that firms cannot prevent the results of their research from spilling over to their rivals, they have an incentive to restrict their research output. Cooperation in R&D allows firms to internalize the positive externality created by R&D spillovers and therefore firms might engage in more R&D. If we think of R&D as lowering the cost of production, then cooperation in R&D should lead to lower costs and increased competitiveness. Second, we might expect cooperation in R&D to enhance the ability of firms to behave anti-competitively. If R&D serves to lower production cost, then firms may have an incentive to restrict their R&D for strategic reasons. Restricting R&D serves as a credible commitment to higher future costs and higher future prices. Therefore, we might expect cooperation in R&D to lead to decreased competitiveness. The results for competitiveness depend on which of these effects dominates.[8] The empirical analysis conducted in this paper does not attempt to distinguish between these two opposing effects of cooperative R&D on competitiveness. The main goal is to determine the net effect of cooperation on the international competitiveness of American firms.

[8] See Chapter 1 for a discussion of the different effects of cooperation in R&D.

The theoretical literature on cooperative R&D, until recently, has only been concerned with the domestic effects of cooperation and has ignored the effects of cooperation on competition with foreign firms. The few models that examine cooperative R&D in an open economy setting include, Motta (1996), Leahy and Neary (1999), Neary and O'Sullivan (1999), as well as the model in Chapter 1 of this work. All of these models use a framework similar to the strategic trade policy model of Spencer and Brander (1983) in which firms are Cournot competitors in the product market. They assume that R&D reduces production costs and that there are spillovers from R&D. Motta examines the implications for welfare when only domestic firms cooperate in R&D, when domestic firms cooperate while simultaneously foreign firms cooperate, and when domestic firms cooperate with foreign firms. He finds that welfare is highest when international cooperation in R&D is allowed. Leahy and Neary examine cooperative R&D in the presence of local and international spillovers. They find that when domestic firms are allowed to cooperate in R&D these firms over-invest in R&D. Neary and O'Sullivan examine the question of whether it is better for a government to allow its firms to cooperate in R&D with foreign firms or whether direct subsidization of exports is better in terms of improving national welfare. They find that if the domestic government can credibly commit to the subsidy that subsidization is better than allowing cooperation in R&D. In Chapter 1 the implications for domestic and foreign welfare is examined when only domestic firms cooperate in R&D. In addition, Chapter 1 examines whether R&D subsidies would be better in terms of improving domestic welfare. It is shown that both cooperation in R&D and R&D subsidies improve domestic welfare but that allowing cooperation in R&D is superior to subsidization. While the results from these theoretical studies are mixed, there is some evidence that allowing cooperative R&D as trade policy is welfare improving.

The requirement that cooperating firms register their research joint venture (RJV) with the U.S. Department of Justice has provided a unique opportunity for empirical analyses of the effects of cooperative R&D. Of the studies that make use of the information from the NCRA, two are primarily of a descriptive nature, while the remaining three address empirical questions regarding NCRA-RJV participation. The two descriptive papers, Link (1996) and Vonortas (1997a), examine various features of NCRA-RJVs between 1985 and 1995. Some of these features include, the number and size of NCRA-RJVs, the main area of research, the composition of membership, and the research goals of the venture.

Scott (1988) examines whether cooperative R&D undertaken by NCRA-RJVs solves the appropriability problem and what effect cooperation has on the level of innovative activity. In addition, he examines whether diversifying R&D investments is a better solution to the appropriability problem. He finds that cooperative R&D is occurring in concentrated industries with higher productivity growth relative to industries without cooperation. In addition, he finds that cooperative R&D is not found in those industries where appropriability is considered to be more difficult and cooperating firms are those that had previously diversified their R&D investments. Vonortas (1997b) examines firm incentives to participate in NCRA-RJVs and the impact of participation on overall R&D expenditures and profits. He finds that two important explanations for firm participation in NCRA-RJVs include previous participation in cooperative R&D and large R&D expenditures. In addition, Vonortas concludes that participation in an NCRA-RJV appears to have a negative effect on profitability and R&D intensity. Leyden and Link (1999) seek to explain why federal laboratories are invited to participate in NCRA-RJVs more frequently the larger the size of the venture. The authors find that whether a federal laboratory is invited to participate in an NCRA-RJV depends on the way in which the laboratory affects economies of scope, appropriability, and costs – all of which are a function of the number of firms. They conclude that when a federal laboratory lowers costs and reduces appropriability only large NCRA-RJVs will invite the federal laboratory to participate.

This chapter examines the effect of NCRA-RJVs on the international competitiveness of the United States and finds that the net effect of participation in NCRA-RJVs differs across industries. In two of the 11 industries in the sample, the net effect of the NCRA appears to be increased market power, with an average reduction in export quantity of

65.2% and an average increase in export price of 15.7%. In another industry, the net effect appears to be increased competitiveness with an increase in export quantity of 16.9% and a reduction in export price of 0.4%. A pooling of the industries in the sample suggests the net effect is increased market power with a reduction in export quantity of 16.2% and an increase in export price of 27.1%. To the extent that the NCRA has had any effect on the price and quantity of American exports, these findings suggest that the net effect has not been an improvement in the competitiveness of American firms, but instead has been an enhancement of the ability of firms to act anti-competitively.

The plan for the remainder of the chapter is as follows. Section 3.2 describes the characteristics of NCRA-RJVs. Following this, in section 3.3, is a description of the econometric model. Section 3.4 describes the data sources used in this study and section 3.5 discusses the estimation results. Finally, section 3.6 gives some concluding remarks.

3.2 NCRA-RJV Characteristics

There have been 797 RJVs that have registered under the NCRA through the end of 1999. Table 3.1 summarizes the number of NCRA-RJVs in a particular technical area where technical area is defined by a 2-digit SIC code. The four technical areas with the largest number of NCRA-RJVs are Electronic and Other Electric Equipment (SIC 36) with 125 NCRA-RJVs, Communications (SIC 48) with 117 NCRA-RJVs, Transportation Equipment (SIC 37) with 104 NCRA-RJVs and Industrial Machinery and Equipment (SIC 35) with 66 NCRA-RJVs.

Table 3.1 – Number of NCRA-RJVs by Technical Area

Technical Area (2-digit SIC)	NCRA-RJVs
Agricultural Production – Crops (01)	1
Agricultural Production – Livestock (02)	1
Agricultural Services (07)	1
Oil and Gas Extraction (13)	53
Nonmetallic Minerals, Except Fuels (14)	1
General Building Contractors (15)	1
Heavy Construction, Except Building (16)	1
Food and Kindred Products (20)	3
Tobacco Products (21)	2
Apparel and Other Textile Products (23)	1
Lumber and Wood Products (24)	3
Printing and Publishing (27)	1
Chemicals and Allied Products (28)	70
Petroleum and Coal Products (29)	44
Rubber and Misc. Plastics Products (30)	6
Stone, Clay, and Glass Products (32)	10
Primary Metal Industries (33)	26
Fabricated Metal Products (34)	5
Industrial Machinery and Equipment (35)	66
Electronic and Other Electronic Equipment (36)	125
Transportation Equipment (37)	104
Instruments and Related Products (38)	37
Misc. Manufacturing Industries (39)	3
Railroad Transportation (40)	1
Water Transportation (44)	2
Pipelines, Except Natural Gas (46)	1
Communications (48)	117
Electric, Gas, and Sanitary Services (49)	11
Depository Institutions (60)	5
Nondepository Institutions (61)	1
Business Services (73)	64
Motion Pictures (78)	3
Amusement and Recreation Services (79)	2
Health Services (80)	17
Engineering and Management Services (87)	5
Environmental Quality and Housing (95)	2
Nonclassifiable Establishments (99)	1

Participants in the NCRA-RJVs include firms, government laboratories, universities, and non-profit organizations. There have been 6,517 unique participants in NCRA-RJVs. Table 3.2 summarizes the number of new participants in NCRA-RJVs by year. The year that saw the most participants register was 1995 with 1,373, while the year that saw the fewest was 1986 with 232.

Table 3.2 – New NCRA-RJV Participants by Year

Year	New Participants in NCRA-RJVs
1985	445
1986	232
1987	240
1988	457
1989	743
1990	760
1991	1100
1992	921
1993	1164
1994	960
1995	1373
1996	1288
1997	1131
1998	668
1999	1309

The typical NCRA-RJV participant is usually involved in only one NCRA-RJV, however, some participants are involved in many NCRA-RJVs. The most active participant has been involved in 134 different NCRA-RJVs. Firms make up 3,628 of the participants, while government laboratories, universities and non-profit organizations account for 598 of the participants. The organizational structure of the remaining participants cannot be identified or is some other type of non-firm organization. While the intent of the NCRA was to assist American firms, there have been 2,474 foreign participants from 61 countries.

The fact that firms choose to participate in NCRA-RJVs suggests that there may be some selection bias when analyzing the effect of NCRA-RJVs. There are two ways in which this bias might occur. The first way relates to the existence of RJVs that are not registered under the NCRA. The RJVs that were in existence at the time the NCRA was passed had to decide whether or not to register. The important question, therefore, in regard to potential selection bias is what motivates existing RJVs to register under the NCRA. We would expect that the more anti-competitive a RJV's activities are, the greater the incentive it would have to register under the NCRA. The second way bias may occur relates to the incentives to form new RJVs. Since NCRA-RJVs receive more lenient antitrust scrutiny, firms that previously had not found it profitable to form a RJV may now find that it is profitable. The question, however, is why the RJV was initially not appealing. If the proposed RJV is not intended to be anti-competitive in nature, but firms feel they may still be prosecuted under antitrust laws, then this is the type of RJV that the NCRA intends to encourage. If, however, the proposed RJV is intended to promote anti-competitive behavior, then this type of RJV would run counter to the NCRA's purpose. It is not clear that there is any basis for assuming that the former type of RJV would be any more likely to form as a result of the NCRA than the latter type of RJV.

3.3 Econometric Model and Estimation Methods

The values of export price and quantity we observe are equilibrium values determined by both supply of American exports and demand for American exports. The underlying population model, therefore, is a simultaneous equations system composed of export supply and export demand. The export supply function is specified such that gross exports supplied in industry i in year t are a function of the export price, the average industry wages, the interest rate, wholesale prices, and firm participation in NCRA-RJVs. The export supply equation, in log form, is

$$\log QS_{it} = \alpha_0 + \alpha_1 \log P_{it} + \alpha_2 \log WAGE_{it} + \alpha_3 \log INTEREST_t + \alpha_4 \log PPI_t + \alpha_5 RJV_{it} + u^S_{it} \quad (1)$$

where QS_{it} is the total exports supplied by industry i in year t, P_{it} is the price of those exports, $WAGE_{it}$ is the average hourly wage in industry i in year t, $INTEREST_t$ is the interest rate in year t, PPI_t is the producer price index in year t, and RJV_{it} is a binary variable equal to one if at least one American firm in industry i appears in year t as a participant in an NCRA-RJV.

The export demand function is specified such that total exports demanded in industry i in year t are a function of the export price, the foreign price level, foreign income, average foreign tariff rates, and the exchange rate. The export demand equation, in log form, is

$$\log QD_{it} = \beta_0 + \beta_1 \log P_{it} + \beta_2 \log FP_t + \beta_3 \log GDP_t + \beta_4 \log TARIFF_t + \beta_5 \log EX_t + u^D_{it} \quad (2)$$

where QD_{it} is the total exports demanded from industry i in year t, P_{it} is the price of those exports, FP_t is the average foreign price level in year t, GDP_t is average foreign income in year t, $TARIFF_t$ is the average foreign tariff rate in year t, and EX_t is the average exchange rate in year t.

The export supply and export demand equations imply the following reduced form equations for price and quantity of exports[9]

$$\log P_{it} = \gamma_0 + \gamma_1 \log FP_t + \gamma_2 \log GDP_t + \gamma_3 \log TARIFF_t + \gamma_4 \log EX_t + \gamma_5 \log WAGE_{it} + \gamma_6 \log INTEREST_t + \gamma_7 \log PPI_t + \gamma_8 RJV_{it} + v^P_{it} \quad (3)$$

$$\log Q_{it} = \delta_0 + \delta_1 \log FP_t + \delta_2 \log GDP_t + \delta_3 \log TARIFF_t + \delta_4 \log EX_t + \delta_5 \log WAGE_{it} + \delta_6 \log INTEREST_t + \delta_7 \log PPI_t + \delta_8 RJV_{it} + v^Q_{it}. \quad (4)$$

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[9] $\gamma_0 = \dfrac{\alpha_0 - \beta_0}{\beta_1 - \alpha_1}$; $\gamma_j = \dfrac{-\beta_{j+1}}{\beta_1 - \alpha_1}$ for j = 1, ... , 4 and $\gamma_j = \dfrac{\alpha_{j-3}}{\beta_1 - \alpha_1}$ for j = 5, ... , 8; $v^P_{it} = \dfrac{u^S_{it} - u^D_{it}}{\beta_1 - \alpha_1}$; $\delta_0 = \dfrac{\beta_1\alpha_0 - \alpha_1\beta_0}{\beta_1 - \alpha_1}$; $\delta_j = \dfrac{-\alpha_1\beta_{j+1}}{\beta_1 - \alpha_1}$ for j = 1, ... , 4 and $\delta_j = \dfrac{\beta_1\alpha_{j-3}}{\beta_1 - \alpha_1}$ for j = 5, ... , 8; $v^Q_{it} = \dfrac{\beta_1 u^S_{it} - \alpha_1 u^D_{it}}{\beta_1 - \alpha_1}$

We should expect $\gamma_8 < 0$ and $\delta_8 > 0$ if the net effect of participation in NCRA-RJVs is to improve competitiveness. If, instead, the net effect of participation in NCRA-RJVs is to increase market power, then we should expect $\gamma_8 > 0$ and $\delta_8 < 0$.

There are two methods by which one might estimate equations (3) and (4). One method would be to estimate the structural equations, equations (1) and (2), using instrumental variable techniques to eliminate the endogeneity of price in the reduced form equations.[10] The estimated coefficients from the structural equations then could be used to derive the reduced form coefficients to determine the estimated effects of participation in NCRA-RJVs on the price and quantity of exports. Alternatively, one could estimate the reduced form equations directly. In this setting it seems most appropriate to estimate the reduced form equations directly for the following reasons. First, our interest is not in how participation in NCRA-RJVs shifts the export supply curve, but in how participation in NCRA-RJVs affects equilibrium export price and quantity. This can be determined directly from the reduced form equations. Second, obtaining good estimates of the reduced form coefficients, by estimating the structural equations, depends upon there being good instruments for export price. Since it is quite difficult to

[10] One might be concerned that the wage is endogenous in the reduced form equations as well. If we assume that wages are somewhat sticky, then changes in price and quantity in a particular industry will affect the equilibrium industry wage with a lag. Under this assumption, price and quantity at time t and the wage at time t are not determined simultaneously.

ascertain whether any particular instrument is uncorrelated with the error term, we may obtain biased estimates of the structural coefficients.

3.4 Description of Data and Data Sources

3.41 Sample Period and Industries

The sample's starting year, 1985, is the first year firms registered under the NCRA. The ending year, 1997, was determined by the availability of data. The 11 industries chosen for this study are Metal Mining (SIC 10), Nonmetallic Minerals (SIC 14), Food and Kindred Products (SIC 20), Tobacco Products (SIC 21), Textile Mill Products (SIC 22), Lumber and Wood Products (SIC 24), Paper and Allied Products (SIC 26), Printing and Publishing (SIC 27), Rubber and Misc. Plastics Products (SIC 30), Fabricated Metals Products (SIC 34), and Misc. Manufacturing (SIC 39). These industries were chosen on the basis of the quality and availability of data. These are industries for which export data is available for every year in the sample and for which there is some variation in the NCRA registrations.

3.42 Export Prices and Quantities by Industry

Export price and quantity data were obtained from the COMTRADE database maintained by the Statistics Division of the United Nations (UN). The database reports the value and quantity of U.S. exports to the rest of the world by SITC Revision 2 codes. The value of exports is reported in thousands of U.S. dollars and quantity is reported in metric tons. Each SITC Revision 2 code was assigned to a 2-digit SIC industry and then both value and quantity of exports were summed across each 2-digit SIC industry.[11] Export price was obtained by dividing the total value by the total quantity for each industry. Therefore, export price is average revenue and is measured as thousands of U.S. dollars per metric ton.

3.43 NCRA-RJVs by Industry

NCRA-RJV data were provided by Nicholas S. Vonortas from his NCRA-RJV database.[12] These are data that have been collected from the mandated registrations that are reported in the *Federal Register*. The database provides information on the names of NCRA-RJV participants, the name of the RJV to which a participant belongs, organizational structure of a participant (public firm, private firm, government laboratory, university, etc.), the main 4-digit SIC code of participants (when applicable and identifiable), the nationality of a participant, and the technical area of the RJV. The data for which SIC information was available were aggregated to create a binary variable that is equal to one if at least one American firm in 2-digit SIC industry i appears in year t as a participant in an NCRA-RJV. Unfortunately, there is no information available on the duration of a participant's membership in an NCRA-RJV or on the duration of the NCRA-RJV itself. As a result, we are only able to measure what effect becoming a registered member of an NCRA-RJV

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[11] It may be more appropriate to aggregate the export data to the 4-digit SIC level. Unfortunately, there is no good concordance between SITC Revision 2 codes and 4-digit SIC codes. The aggregation to the 2-digit level was necessary to preserve the integrity of the data. Even with this level of aggregation, some of the export data could not be assigned a 2-digit code.
[12] See Vonortas (1997a) for a description of this database.

has on the price and quantity of exports. This data does not allow us to measure the effect of actual participation in an NCRA-RJV.

3.44 Export Demand Control Variables

The control variables in the export demand equation are a trade-weighted average of each variable for the United States' top five trading partners in each year. Information on trade volume was taken from the Organization for Economic Cooperation and Development (OECD) *Monthly Statistics of Foreign Trade*. The countries, which vary by year, are Canada, Germany, Japan, Korea, Mexico and the United Kingdom. Data on the foreign consumer price index are from the UN *Monthly Bulletin of Statistics* and use 1980 as the base year. Data on foreign income are taken from the UN *Statistical Yearbook*. Gross domestic product for each country is measured in millions of constant 1990 U.S. dollars. Tariff rates are measured as customs and import duties revenue divided by the value of imports. Data on revenue are taken from OECD *Revenue Statistics*, Economic Commission for Latin America and the Caribbean *Statistical Yearbook for Latin America and the Cari*bbean, and *Statistical Abstract of Latin America*. Data on value of imports are taken from the UN *International Trade Statistics Yearbook*. The exchange rate is the average rate over the year and is measured as foreign currency per U.S. dollar. Exchange rate data are taken from the International Monetary Fund *International Financial Statistics*.

3.45 Export Supply Control Variables

The wage data were taken from the U.S. Bureau of Labor Statistics (BLS) *Average Hourly and Weekly Earnings of Production or Nonsupervisory Workers on Private Nonfarm Payrolls by Industry.* Hourly wages are measured as non-seasonally adjusted yearly averages by 2-digit SIC industry. The interest rate is the annualized prime rate and is taken from the U.S. Federal Reserve *Historical Data* series. Data on producer prices were taken from the BLS *Producer Price Index* and use 1982 as the base year. A summary of all variable definitions follows in Figure 3.

Variable	Description
Q_{it}	Quantity of American exports in industry i in year t measured in metric tons
P_{it}	Average revenue from American exports in industry i in year t measured as millions of U.S. dollars per metric ton
FP_t	Trade weighted average of the foreign consumer price index of the top 5 U.S. trade partners in year t with 1980 as the base year
GDP_t	Trade weighted average of the GDP of the top 5 U.S. trade partners in year t measured in millions of constant 1990 U.S. dollars
$TARIFF_t$	Trade weighted average of the tariff rates of the top 5 U.S. trade partners in year t
EX_t	Trade weighted average of the average exchange rates of the top 5 U.S. trade partners in year t measured as foreign currency per U.S. dollar
$WAGE_{it}$	Average hourly wage in industry i in year t, not seasonally adjusted
$INTEREST_t$	Annualized prime rate in year t
PPI_t	Producer price index in year t with 1982 as the base year
RJV_{it}	Binary variable equal to one if there is at least one American firm in 2-digit SIC industry i that appears in year t as a participant in an NCRA-RJV

Figure 3 – Variable descriptions

3.5 Effects of NCRA on U.S. Competitiveness

The model, as specified in equations (3) and (4), was estimated by OLS for each of the 11 industries in the sample. A summary of the regression results is listed in Table 3.3 and Table 3.4.[13] In four of the industries (Nonmetallic Minerals, Paper and Allied Products, Printing and Publishing, and Rubber and Misc. Plastics Products), the estimated coefficients suggest that the net effect of NCRA-RJVs is increased market power. The average increase in export price for these industries is 14.8%, while the average decrease in export quantity is 42.8%. In one industry (Metal Mining), however, the estimated coefficients suggest that the net effect is increased competitiveness. In this industry the decrease in export price is 31.9% and the increase in export quantity is 22.2%. While the estimated coefficients suggest that NCRA-RJVs have a large impact on export price and quantity, these coefficients are often estimated imprecisely. Only in the Nonmetallic Minerals and in the Printing and Publishing industries are the estimated coefficients statistically significant and they are significant only in the quantity equation. In the Nonmetallic Minerals industry, the estimated coefficients suggest that NCRA-RJVs reduce export quantity by 46.8% and raise export price by 21.8%. In the Printing and Publishing industry, exports are reduced by 83.6% and export price is increased by 9.5%. In the six other industries in the sample (Food and Kindred Products, Tobacco Products, Textile Mill

[13] See Appendix for complete regression results.

Products, Lumber and Wood Products, Rubber and Misc. Plastics Products, and Misc. Manufacturing), the estimated coefficients in the price and the quantity equation have the same sign. This result is inconsistent with either an increased competitiveness or increased market power explanation.

Table 3.3 – Industry Regressions (Price Equation)

Dependent Variable: Price	1	2		3	
	RJV	RJV	RJV(lagged)	RJV	RJV(lagged)
Metal Mining (SIC 10)	-0.3190 (0.6718)	-0.7165 (0.5801)	-1.1777 (0.6517)	-0.6797 (0.8642)	-1.0152 (0.8512)
Nonmetallic Minerals (SIC 14)	0.2184 (0.2155)	0.2130 (0.2712)	-0.0126 (0.2478)	0.2780 (0.2947)	-0.1380 (0.2309)
Food and Kindred Products (SIC 20)	-0.0374 (0.0825)	-0.0571 (0.1191)	-0.0281 (0.1043)	-0.1157* (0.0507)	-0.1322* (0.0582)
Tobacco Products (SIC 21)	-0.2233 (0.5069)	-0.1770 (0.5750)	0.2274 (0.4973)	-0.3596 (0.6351)	-0.0016 (0.5423)
Textile Mill Products (SIC 22)	0.0851 (0.3330)	-0.0679 (0.6112)	0.0612 (0.1921)	0.1176 (0.1162)	-0.0230 (0.0578)
Lumber and Wood Products (SIC 24)	0.0519 (0.0530)	0.0505 (0.0647)	-0.0041 (0.0645)	0.0298 (0.0543)	0.0225 (0.0589)
Paper and Allied Products (SIC 26)	0.2119 (0.3669)	0.3546 (0.5337)	0.3203 (0.3203)	0.4136 (0.3934)	0.2608 (0.3088)
Printing and Publishing (SIC 27)	0.0950 (0.2299)	-0.3489 (0.3637)	-0.7759 (0.5283)	0.6897 (0.3743)	0.3320 (0.3441)
Rubber and Misc. Plastics Products (SIC 30)	0.0147 (0.0965)	0.0998 (0.1465)	0.1375 (0.1714)	0.0460 (0.1241)	-0.0780 (0.1489)
Fabricated Metal Products (SIC 34)	0.0616 (0.0623)	0.0682 (0.0934)	0.0934 (0.0873)	-0.0868 (0.0976)	-0.2539* (0.1016)
Misc. Manufacturing (SIC 39)	-0.1890 (0.2759)	-0.1353 (0.1945)	0.3413 (0.5088)	-0.3760 (0.2390)	-0.0955 (0.4292)

Standard errors are in parentheses. * Indicates significance at the 10% level.

Table 3.4 – Industry Regressions (Quantity Equation)

Dependent Variable: Quantity	1	2		3	
	RJV	RJV	RJV(lagged)	RJV	RJV (lagged)
Metal Mining (SIC 10)	0.2218 (0.3211)	0.3782 (0.3222)	0.4635 (0.3620)	0.4522 (0.5365)	0.2450 (0.5286)
Nonmetallic Minerals (SIC 14)	-0.4680** (0.1246)	-0.4241* (0.1434)	0.1006 (0.1311)	-0.6230** (0.1760)	0.2118 (0.1375)
Food and Kindred Products (SIC 20)	-0.1768 (0.1482)	-0.1901 (0.2163)	-0.0190 (0.1893)	-0.1482 (0.1189)	-0.0167 (0.1224)
Tobacco Products (SIC 21)	-0.4860 (0.8008)	-0.3325 (0.7934)	0.7536 (0.6862)	-0.6420 (0.8970)	0.3786 (0.7658)
Textile Mill Products (SIC 22)	0.1250 (0.9441)	0.3848 (1.7518)	-0.1039 (0.5506)	-0.1230 (0.3278)	0.1031 (0.1608)
Lumber and Wood Products (SIC 24)	0.2033* (0.0949)	0.2583** (0.0615)	0.1694* (0.0613)	0.1874** (0.0589)	0.1117 (0.0647)
Paper and Allied Products (SIC 26)	-0.2611 (0.7933)	-0.6162 (1.1430)	-0.3348 (0.6858)	-0.5149 (0.7093)	-0.3914 (0.5782)
Printing and Publishing (SIC 27)	-0.8360** (0.2509)	-05949 (0.4929)	0.4216 (0.7159)	-2.7204*** (0.7316)	-3.0212** (0.8373)
Rubber and Misc. Plastics Products (SIC 30)	0.0097 (0.3793)	-0.5385 (0.4604)	-0.8858 (0.5386)	-0.2378 (0.3682)	-0.5750 (0.3967)
Fabricated Metals Products (SIC 34)	-0.1445 (0.4186)	0.4089 (0.3835)	0.3587 (0.3587)	-0.1779 (0.6267)	-0.5309 (0.6476)
Misc. Manufacturing (SIC 39)	-1.0300 (1.0014)	-0.3490 (0.8334)	2.4695 (1.2427)	-1.6350** (0.4673)	0.8800 (0.8490)

Standard errors are in parentheses. *Indicates significance at the 10% level; ** indicates significance at the 5% level; *** indicates significance at the 1% level.

It may be possible, given the investment-like characteristics of R&D, that the effects of NCRA-RJVs may not be realized during the period in which a participant is registered. To allow for this possibility, the model was also estimated with an additional binary variable equal to one if a firm in industry i appeared in year t-1 as a participant in an NCRA-RJV (regression 2 in Table 3.3 and Table 3.4). In four of the industries (Metal Mining, Nonmetallic Minerals, Lumber and Wood Products, and Printing and Publishing) the estimated coefficients suggest that the net (lagged) effect of NCRA-RJVs is increased competitiveness. The average reduction in export price is 49.3% and the average increase in export quantity is 28.9%. In three of the industries (Textile Mill Products, Paper and Allied Products, and Rubber and Misc. Plastics) the estimated coefficients suggest that the net (lagged) effect of NCRA-RJVs is increased market power. The average increase in export price is 17.3% and the average reduction in export quantity is 44.2%. As in the model without any lagged effect, the estimated coefficients indicate a large impact on export price and quantity but these coefficients are estimated imprecisely. Only in the Lumber and Wood Products industry is the estimated lagged effect of NCRA-RJVs statistically significant and it is only significant in the quantity equation. In this industry, the estimated coefficients suggest that the lagged effect of NCRA-RJVs is an increase in export quantity of 16.9% and decrease in export price of 0.4%. In the other four industries (Food and Kindred Products, Tobacco Products, Fabricated Metal Products and Misc. Manufacturing) the estimated coefficients in the price and quantity equations have the same sign. The lagged version of the model was also estimated with errors that are robust to heteroskedasticity. The inclusion of robust errors does not appear to materially improve the preciseness of the estimated coefficients.

The lagged version of the model was also estimated with a correction for first order serial correlation (regression 3 in Table 3.3 and Table 3.4). The estimated same year effect of NCRA-RJVs is statistically significant in five industries (Nonmetallic Minerals, Food and Kindred Products, Lumber and Wood Products, Printing and Publishing, and Misc. Manufacturing). In the Nonmetallic Minerals industry and in the Printing and Publishing industry, the estimated coefficients suggest, as in the original estimation, that the net effect of NCRA-RJVs is increased market power. The reduction in export quantities are 62.3% and 272.0% and the increase in export prices are 27.8% and 69.0% for Nonmetallic Minerals and Printing and Publishing, respectively. In the remaining three industries, Food and Kindred Products, Lumber and Wood Products, and Misc. Manufacturing, the signs of the estimated coefficients are the same in both the price and quantity equations. The estimated lagged effect of NCRA-RJVs is statistically significant in three industries (Food and Kindred Products, Printing and Publishing, and Fabricated Metal Products). In the Printing and Publishing industry, the increased market power conclusion is maintained, as the estimated lagged effect of NCRA-RJVs is a reduction in export quantity of 302.1% and an increase in export price of 33.2%. In the remaining two industries, Food and Kindred

Products and Fabricated Metals Products, the signs of the estimated coefficients are the same in both equations.

The estimation results suggest that the net effect of NCRA-RJVs differs across industries. In the Nonmetallic Minerals and the Printing and Publishing industries, the net effect of NCRA-RJVs is increased market power. The estimated magnitude of this effect is quite large, especially in the Printing and Publishing industry. In the Lumber and Wood Products industry, the net (lagged) effect of NCRA-RJVs is increased competitiveness. The estimated magnitude of the effect, however, is considerably smaller. It appears as if NCRA-RJVs have a limited effect on American competitiveness given that it seems to be important in only 3 of the 11 industries in the sample. These results, however, may be misleading. Potentially, the 11 industries chosen for this study are industries in which we would not expect the NCRA to have much of an effect. There were several industries that were excluded from the analysis because in every year of the sample there was at least one firm that appeared as a participant in an NCRA-RJV. These excluded industries include, Oil and Gas Extraction (SIC 13), Chemicals and Allied Products (SIC 28), Industrial Machinery and Equipment (SIC 35), and Electronic and Other Electric Equipment (SIC 36). These are industries we think of as being R&D intensive and most likely to be engaged in cooperative R&D. The exclusion of important industries might be eliminated if the data on NCRA-RJVs were at a more disaggregated level.

The finding of little or no effect of NCRA-RJVs may also be due to the low number of observations at the industry level. For this reason, regressions pooling the 11 industries were estimated by OLS. Pooling the data also allows for industry fixed effects to be included in the estimation. The results from these regressions are reported in Tables 3.5 – 3.8. The estimated coefficients for the effect of NCRA-RJVs are not statistically significant in either equation for both the original and lagged specification of the model (regressions 1 and 2). While not statistically significant, the estimated coefficients seem to suggest that the effect of NCRA-RJVs is increased market power. In the original model, the same year effect of NCRA-RJVs is a reduction in export quantity of 16.2% and an increase in export price of 27.1%. In the lagged model, the same year effect of NCRA-RJVs is a reduction in export quantity of 21.2 % and an increase in export price of 25.0%. The lagged model was also estimated allowing for fixed effects by including industry and year dummies (regressions 3, 4, and 5). This specification improved the statistical significance of the estimated effect of NCRA-RJVs, but the coefficients tend to have the same sign in both equations. Finally, the lagged model was estimated allowing for heteroskedasticity across industries, correlation across industries, and first order serial correlation within industries (regressions 6, 7, and 8, respectively). Again, the statistical significance of the estimated coefficients were largely improved, however, the coefficients continue to have the same sign in both equations. The results from the pooled regressions do little to enhance the results from the industry regressions. In those instances where the effect of NCRA-RJVs is clear, the pooled regressions suggest that increased market power is the net effect.

Table 3.5 – Pooled Regressions 1 – 4 (Price Equation)

Dependent Variable: Price	1	2	3	4
RJV	0.2712 (0.3134)	0.2499 (0.3288)	-0.0928 (0.1238)	0.2555 (0.3434)
RJV (lagged)	--------------	0.0770 (0.3345)	-0.0608 (0.1211)	0.0611 (0.3581)
logFP	0.1698 (1.1028)	0.1980 (1.1263)	0.3540 (0.3513)	0.0580 (0.2646)
logGDP	-0.7767 (6.8742)	-1.3522 (7.2749)	-2.2461 (2.2768)	-----------
logTARIFF	-1.0259 (2.3187)	-0.8342 (2.4533)	-0.2606 (0.8085)	-----------
logEX	-0.0472 (0.3235)	-0.0653 (0.3501)	-0.0507 (0.1089)	-0.1935 (0.2542)
logWAGE	-1.8693*** (0.7106)	-1.8323** (0.7476)	-0.5179 (1.9159)	-1.8370** (0.7654)
logINTEREST	-0.9207 (2.4542)	-0.6914 (2.7224)	-0.1604 (0.8895)	-----------
logPPI	-3.1754 (9.9515)	-3.0106 (10.1918)	-4.2527 (3.4902)	-----------
Year dummies	No	No	No	Yes
Industry dummies	No	No	Yes***	No
R^2	0.07	0.06	0.92	0.07
Number of obs.	153	143	143	143

The variables logGDP, logTARIFF, logINTEREST, and logPPI were dropped from regression 4 due to collinearity. Standard errors are in parentheses. * Indicates significance at the 10% level; ** indicates significance at the 5% level; *** indicates significance at the 1% level.

Table 3.6 – Pooled Regressions 5 – 8 (Price Equation)

Dependent Variable: Price	5	6	7	8
RJV	-0.0925 (0.1263)	-0.0987* (0.0525)	-0.0996*** (0.0056)	-0.1155 (0.0858)
RJV (lagged)	-0.0819 (0.1282)	-0.0959* (0.0530)	-0.0905*** (0.0053)	-0.0830 (0.0871)
logFP	0.0105 (0.1856)	0.0624 (0.0823)	0.0577*** (0.0189)	0.0209 (0.1765)
logGDP	-----------	------------	--------	-------------
logTARIFF	-----------	------------	--------	-------------
logEX	-0.1388* (0.0824)	-0.8867** (0.0345)	-0.0809*** (0.0056)	-0.1377** (0.0642)
logWAGE	-0.6515 (2.0969)	-0.8867 (1.0258)	-0.8893*** (0.2519)	-0.7571 (2.0499)
logINTEREST	-----------	------------	---------	-------------
logPPI	-----------	------------	---------	-------------
Year dummies	Yes	Yes***	Yes***	Yes**
Industry dummies	Yes***	Yes***	Yes***	Yes***
R^2	0.92	------------	------------	-------------
Number of obs.	143	143	143	143

The variables logGDP, logTARIFF, logINTEREST, and logPPI were dropped from regressions 5-8 due to collinearity. Standard errors are in parentheses. * Indicates significance at the 10% level; ** indicates significance at the 5% level; *** indicates significance at the 1% level.

Table 3.7 – Pooled Regressions 1 –4 (Quantity Equation)

Dependent Variable: Quantity	1	2	3	4
RJV	-0.1619 (0.4368)	-0.2119 (0.4556)	-0.3143* (0.1835)	-0.0154 (0.4752)
RJV (lagged)	------------	0.0462 (0.4634)	-0.3150* (0.1794)	-0.0250 (0.4955)
LogFP	0.3414 (1.5368)	0.3735 (1.5605)	0.3653 (0.5205)	-0.1080 (0.3662)
logGDP	-0.8857 (9.5796)	-1.7313 (10.0797)	-0.2489 (3.3738)	---------
logTARIFF	-1.5449 (3.2312)	-1.1798 (3.3992)	-1.6953 (1.1981)	---------
LogEX	-0.1109 (0.4508)	-0.1784 (0.4850)	-0.1767 (0.1614)	-0.3290 (0.3519)
logWAGE	0.9207 (0.9903)	0.7792 (1.0358)	-1.7483 (2.8390)	0.7928 (1.0592)
logINTEREST	0.0375 (3.4200)	0.6825 (3.7720)	0.3530 (1.3180)	---------
LogPPI	-6.4632 (13.8680)	-5.6494 (14.1212)	-3.7480 (5.1718)	---------
Year dummies	No	No	No	Yes
Industry dummies	No	No	Yes***	No
R^2	0.03	0.03	0.90	0.03
Number of obs.	153	143	143	143

The variables logGDP, logTARIFF, logINTEREST, and logPPI were dropped from regression 4 due to collinearity. Standard errors are in parentheses. * Indicates significance at the 10% level; ** indicates significance at the 5% level; *** indicates significance at the 1% level.

Table 3.8 – Pooled Regressions 5 – 8 (Quantity Equation)

Dependent Variable: Quantity	5	6	7	8
RJV	-0.2610 (0.1844)	-0.0239 (0.1069)	-0.0129 (0.0110)	-0.1842 (0.1315)
RJV (lagged)	-0.4192** (0.1871)	-0.0415 (0.1077)	-0.0372*** (0.0114)	-0.2962** (0.1335)
LogFP	0.1052 (0.2709)	0.0854 (0.1495)	0.0895*** (0.0300)	-0.0346 (0.2799)
logGDP	-------------	-------------	-------------	------------
logTARIFF	-------------	-------------	-------------	------------
LogEX	-0.3186*** (0.1203)	-0.2533*** (0.0663)	-0.2549*** (0.0057)	-0.3165*** (0.1002)
logWAGE	-1.0464 (3.0608)	-0.0470 (1.7489)	-0.1533 (0.3904)	0.4026 (3.2509)
logINTEREST	-------------	-------------	-------------	------------
LogPPI	-------------	-------------	-------------	------------
Year dummies	Yes**	Yes***	Yes***	Yes***
Industry dummies	Yes***	Yes***	Yes***	Yes***
R^2	0.91	-------------	-------------	------------
Number of obs.	143	143	143	143

The variables logGDP, logTARIFF, logINTEREST, and logPPI were dropped from regressions 5-8 due to collinearity. Standard errors are in parentheses. * Indicates significance at the 10% level; ** indicates significance at the 5% level; *** indicates significance at the 1% level.

3.6 Conclusion

This paper has examined the effect of the NCRA on the international competitiveness of the United States. A sample of 11 industries was examined to determine the effect on export price and quantity of NCRA-RJVs. In two of the industries, NCRA-RJVs led to lower export quantities and higher export prices. In one industry, NCRA-RJVs led to higher export quantities and lower export prices, but with a lagged effect. In the remaining 8 industries, NCRA-RJVs did not have any statistically significant effect on export quantities or prices. A pooling of the industries suggests that NCRA-RJVs lead to lower export quantities and higher export prices.

One of the objectives of the NCRA was to improve the competitiveness of American firms relative to foreign firms. This legislation was passed during a period of high trade deficits, conflicts over foreign market access, and shrinking domestic market share of American firms. The analysis conducted here suggests that to the extent the NCRA has had any effect, it has not been to improve competitiveness. The main effect has been to enhance the ability of firms to behave anti-competitively. This result, however, may be attributable to the sample of industries selected for the study. The study excludes many industries, due to data limitations, that we think of as being R&D-intensive and most likely to engage in cooperative R&D. Including these industries may significantly affect the results of this study.

APPENDIX

Table A1 – Industry Regression 1 (Price equation for industries 10, 14, 20 and 22)

Dependent Variable: Price	SIC 10	SIC 14	SIC 20	SIC 21	SIC 22
logFP	0.9127 (1.9024)	1.1898 (0.53626)	0.1731 (0.2070)	-0.3597 (0.6871)	0.0016 (0.1919)
logGDP	-10.5457 (12.0366)	-3.4098 (3.6780)	0.2415 (1.3364)	-5.9120 (4.0018)	-0.0297 (3.9574)
logTARIFF	-2.3155 (5.1995)	-0.1196 (1.5436)	-0.9039 (0.7019)	-1.5866 (1.3740)	0.2317 (1.2692)
logEX	0.1316 (0.6186)	-0.4050 (0.1771)	-0.1891 (0.0638)	0.3519 (0.2729)	0.0019 (0.2398)
logWAGE	-8.0436 (23.4096)	-0.0830 (6.8276)	-4.5214 (3.5941)	2.4597 (2.6940)	1.2907 (6.8599)
logINTEREST	-1.4332 (6.2479)	1.7542 (1.7541)	0.1657 (0.7471)	-1.9003 (1.7307)	0.1138 (0.6429)
logPPI	-15.4828 (25.8883)	-14.8851 (7.7538)	2.0625 (3.2343)	0.1552 (6.4327)	-0.5246 (0.3330)
R^2	0.85	0.85	0.94	0.87	0.79
Number of obs.	13	13	13	13	13

Table A2 – Industry Regression 1 (Price equation for industries 24, 26, 27, 30, 34 and 39)

Dependent Variable: Price	SIC 24	SIC 26	SIC 27	SIC 30	SIC 34	SIC 39
logFP	0.04752 (0.1746)	0.0257 (0.4777)	0.5340 (0.7524)	-0.0336 (0.1874)	-0.0618 (0.0951)	0.4514 (0.6164)
logGDP	1.2828 (1.0104)	1.0869 (3.1204)	3.8279 (4.2879)	0.4560 (1.2389)	-2.1695 (0.5891)	-3.8833 (3.8309)
logTARIFF	-0.9840 (0.5303)	0.1241 (0.8515)	1.5009 (1.8767)	-0.8552 (0.5290)	-0.0858 (0.2898)	-0.2940 (1.9661)
logEX	-0.1003 (0.0445)	-0.0387 (0.0571)	-0.6588 (0.2167)	0.0096 (0.0573)	0.2341 (0.0297)	0.0003 (0.2067)
logWAGE	-5.9019 (2.6566)	3.3806 (3.9035)	-2.2672 (13.4146)	-0.9396 (3.8405)	-2.3003 (1.8123)	2.7912 (8.2979)
logINTEREST	-0.4668 (0.4948)	0.7780 (0.6670)	-0.6664 (2.2350)	-0.4658 (0.6700)	-1.5730 (0.3179)	-0.2837 (2.2778)
logPPI	1.7304 (2.6262)	-3.5358 (2.8641)	-0.0105 (10.2597)	-1.2358 (3.3206)	2.9370 (1.5974)	-11.0084 (9.6582)
R^2	0.88	0.87	0.97	0.80	0.97	0.85
Number of obs.	13	13	13	13	13	13

Table A3 – Industry Regression 1 (Quantity equation for industries 10, 14, 20, 21 and 22)

Dependent Variable: Quantity	SIC 10	SIC 14	SIC 20	SIC 21	SIC 22
logFP	-0.0368 (0.9093)	-0.8297 (0.3100)	0.4350 (0.3720)	-0.5987 (1.0854)	0.3345 (0.5440)
logGDP	4.1458 (5.7531)	4.0094 (2.1264)	-0.0880 (2.4015)	-8.6043 (6.3215)	3.2104 (11.2215)
logTARIFF	2.8658 (2.4852)	-0.4603 (0.8924)	0.0355 (1.2614)	-2.3745 (2.1705)	-1.9229 (3.5990)
logEX	-0.3619 (0.2957)	0.1310 (0.1024)	-0.2753 (0.1147)	0.7074 (0.4311)	-0.3894 (0.6798)
logWAGE	13.1429 (11.1890)	-4.6649 (3.9474)	-0.1311 (6.4588)	5.7396 (4.2557)	-6.9803 (19.4516)
logINTEREST	3.8487 (2.9863)	-0.7245 (1.0141)	1.1512 (1.3426)	-3.3782 (2.7340)	-0.1315 (1.8231)
logPPI	4.3819 (12.3738)	16.4226 (4.4829)	-4.1154 (5.8123)	-0.9517 (10.1615)	3.9622 (13.8793)
R^2	0.96	0.94	0.86	0.86	0.91
Number of obs.	13	13	13	13	13

Table A4 – Industry Regression 1 (Quantity equation for industries 24, 26, 27, 30, 34 and 39)

Dependent Variable: Quantity	SIC 24	SIC 26	SIC 27	SIC 30	SIC 34	SIC 39
logFP	-0.1799 (0.3124)	0.5796 (1.0328)	2.4291 (0.8213)	0.8734 (0.7370)	0.1944 (0.6394)	1.7287 (2.2372)
logGDP	1.5473 (1.8008)	-1.4546 (6.7467)	-7.9856 (4.6805)	1.2745 (4.8717)	1.6467 (3.9613)	0.9154 (13.9039)
logTARIFF	-0.4160 (0.9489)	0.0755 (1.8410)	-12.1407 (2.0486)	-1.5030 (2.0803)	-5.3790 (1.9491)	-3.4931 (7.1361)
logEX	0.0878 (0.0797)	-0.1832 (0.1235)	0.4384 (0.2366)	-0.4038 (0.2253)	-0.3912 (0.1999)	-1.4224 (0.7502)
logWAGE	4.2659 (4.7535)	-1.2075 (8.4399)	-66.4469 (14.6431)	-15.4411 (15.1018)	-21.5573 (12.1873)	-5.6287 (30.1168)
logINTEREST	0.3337 (0.8854)	1.0441 (1.4421)	-10.5067 (2.4397)	0.1303 (2.6347)	-1.5421 (2.1379)	6.0657 (8.2673)
logPPI	1.9387 (4.6991)	-1.9080 (6.1927)	3.6519 (11.1993)	8.4704 (13.0574)	5.9485 (10.7422)	-26.3505 (35.0540)
R^2	0.97	0.89	0.99	0.94	0.91	0.80
Number of obs.	13	13	13	13	13	13

Table A5 – Industry Regression 2 (Price equation for industries 10, 14, 20, 21 and 22)

Dependent Variable: Price	SIC 10	SIC 14	SIC 20	SIC 21	SIC 22
logFP	0.0686 (1.5901)	1.1740 (0.6935)	0.1545 (0.2460)	-0.4892 (0.8177)	-0.0626 (0.2967)
logGDP	-3.5942 (10.3577)	-3.3238 (4.5725)	0.3914 (1.6230)	-5.6441 (4.5061)	-1.7300 (6.9767)
logTARIFF	-6.1335 (4.6607)	-0.1378 (1.8175)	-0.8604 (0.8170)	-1.8748 (1.6585)	0.9997 (2.8086)
logEX	0.3354 (0.5069)	-0.4046 (0.2046)	-0.1840 (0.0752)	0.3677 (0.3066)	0.1043 (0.4211)
logWAGE	-24.6107 (20.8295)	0.0421 (8.2606)	-4.2549 (4.2183)	2.8610 (3.1332)	5.6250 (15.6760)
logINTEREST	-5.8434 (5.5565)	1.7492 (2.0269)	0.1947 (0.8592)	-1.9613 (1.9369)	0.4245 (1.2180)
logPPI	4.0770 (23.3448)	-14.8889 (8.9499)	2.0102 (3.6954)	0.3956 (7.2010)	-3.0933 (9.7922)
R^2	0.93	0.85	0.94	0.88	0.80
Number of obs.	13	13	13	13	13

Table A6 – Industry Regression 2 (Price equation for industries 24, 26, 27, 30, 34 and 39)

Dependent Variable: Price	SIC 24	SIC 26	SIC 27	SIC 30	SIC 34	SIC 39
logFP	0.0505 (0.2067)	-0.0668 (0.5795)	1.1687 (0.7911)	-0.0421 (0.1967)	-0.0630 (0.1101)	0.6496 (0.8671)
logGDP	1.2798 (1.1668)	0.8067 (3.5646)	5.9442 (4.0419)	-0.3179 (1.6176)	-2.1973 (0.7241)	-4.2900 (4.4486)
logTARIFF	-1.0013 (0.6691)	0.2011 (0.9729)	3.5039 (2.1428)	-0.7551 (0.5682)	-0.0919 (0.3386)	-0.5287 (2.3004)
logEX	-0.1004 (0.0514)	-0.0225 (0.0748)	-1.2254 (0.4304)	0.0286 (0.0645)	0.2334 (0.0348)	-0.0697 (0.2964)
logWAGE	-6.0439 (3.7817)	4.5218 (5.1546)	5.2070 (12.8638)	-1.6919 (4.1321)	-2.5076 (2.8092)	2.4518 (9.3984)
logINTEREST	-0.4771 (0.5930)	0.7266 (0.7584)	4.4407 (3.9958)	-0.8169 (0.8273)	-1.6009 (0.4447)	0.1542 (2.8122)
logPPI	1.7936 (3.1868)	-3.9417 (3.3562)	-9.3520 (11.0500)	-0.2044 (3.7094)	3.1537 (2.6915)	-14.4317 (14.0988)
R^2	0.88	0.88	0.98	0.84	0.97	0.95
Number of obs.	13	13	13	13	13	13

Table A7 – Industry Regression 2 (Quantity equation for industries 10, 14, 20, 21 and 22)

Dependent Variable: Quantity	SIC 10	SIC 14	SIC 20	SIC 21	SIC 22
logFP	0.2954 (0.8833)	-0.7027 (0.3667)	0.4225 (0.4467)	-1.0276 (1.1283)	0.4434 (0.8504)
logGDP	1.4102 (5.7536)	3.3200 (2.4180)	0.0132 (2.9469)	-7.7165 (6.2177)	6.0974 (19.9964)
logTARIFF	4.3683 (2.5889)	-0.3145 (0.9611)	0.0650 (1.4834)	-3.3296 (2.2885)	-3.2270 (8.0498)
logEX	-0.4420 (0.2816)	0.1274 (0.1082)	-0.2719 (0.1365)	0.7596 (0.4231)	-0.5632 (1.2068)
logWAGE	19.6625 (11.5705)	-5.6702 (4.3683)	0.0488 (7.6590)	7.0694 (4.3233)	-14.3399 (44.9299)
logINTEREST	5.5842 (3.0865)	-0.6849 (1.0719)	1.5315 (1.5600)	-3.5804 (2.6726)	-0.6589 (28.0662)
logPPI	-3.3155 (12.9677)	16.4528 (4.7328)	-4.1507 (6.7095)	-0.1550 (9.9363)	8.3237 (28.0662)
R^2	0.97	0.95	0.86	0.90	0.91
Number of obs.	13	13	13	13	13

Table A8 – Industry Regression 2 (Quantity equation for industries 24, 26, 27, 30, 34 and 39)

Dependent Variable: Quantity	SIC 24	SIC 26	SIC 27	SIC 30	SIC 34	SIC 39
logFP	-0.3007 (0.1966)	0.8098 (1.2409)	2.0842 (1.0719)	0.9284 (0.6180)	0.0968 (0.4520)	4.2452 (2.1177)
logGDP	1.6672 (1.1099)	-0.7571 (7.6333)	-9.1354 (5.4768)	6.2620 (5.0832)	-0.6855 (2.9733)	-4.2474 (10.8641)
logTARIFF	0.2950 (0.6365)	-0.1160 (2.0834)	-13.2289 (2.9036)	-2.1481 (5.0832)	-5.8955 (1.3905)	-6.4726 (5.6179)
logEX	0.0929 (0.0489)	-0.2235 (0.1601)	0.7462 (0.5832)	-0.5259 (0.2027)	-0.4471 (0.1429)	-2.3112 (0.7239)
logWAGE	10.0845 (3.5973)	-4.0476 (11.0382)	-70.5076 (17.4305)	-10.5932 (12.9847)	-38.9437 (11.5352)	-9.9375 (22.9521)
logINTEREST	0.7545 (0.5641)	1.1719 (1.6240)	-13.2814 (5.4144)	2.3923 (2.5998)	-3.8745 (1.8260)	11.6245 (6.8678)
logPPI	-0.6520 (3.0314)	-0.8980 (7.1870)	8.7270 (14.9727)	1.8244 (11.6567)	24.1187 (11.0517)	-69.8059 (34.4311)
R^2	0.99	0.90	0.99	0.97	0.97	0.91
Number of obs.	13	13	13	13	13	13

Table A9 – Industry Regression 3 (Price equation for industries 10, 14, 20, 21 and 22)

Dependent Variable: Price	SIC 10	SIC 14	SIC 20	SIC 21	SIC 22
logFP	0.8183 (1.2448)	1.0343 (0.4622)	0.1536 (0.0786)	0.1210 (0.8495)	0.0355 (0.1745)
logEX	-0.6991 (0.5037)	-0.5936 (0.1792)	-0.1411 (0.0416)	0.2941 (0.3692)	-0.0102 (0.0817)
logWAGE	27.6350 (18.6572)	8.8813 (5.6071)	1.1352 (1.1248)	-1.1268 (4.2126)	-0.8559 (2.4237)
logINTEREST	6.4862 (3.4274)	3.3370 (1.0614)	0.8917 (0.2406)	-0.6850 (2.0685)	-0.1791 (0.2677)
logPPI	-50.3656 (23.3349)	-24.0209 (7.7493)	-1.6973 (1.5020)	-0.1493 (9.9928)	1.6153 (1.8288)
R^2	0.88	0.88	0.99	0.46	0.99
Number of obs.	13	13	13	13	13

The variables, logGDP and logTARIFF were dropped from these regressions due to the low number of observations.

Table A10 – Industry Regression 3 (Price equation for industries 24, 26, 27, 30, 34 and 39)

Dependent Variable: Price	SIC 24	SIC 26	SIC 27	SIC 30	SIC 34	SIC 39
logFP	0.2763 (0.1296)	-0.0792 (0.3327)	-0.1104 (0.8504)	0.0284 (0.1184)	-0.1602 (0.0729)	0.0163 (0.5540)
logEX	-0.1254 (0.0474)	0.0184 (0.0652)	0.0340 (0.2452)	-0.0440 (0.0400)	0.2544 (0.0412)	-0.0614 (0.2682)
logWAGE	-1.8751 (1.0600)	3.1986 (3.2137)	-16.4251 (11.7889)	6.6943 (1.4308)	7.7139 (1.5493)	8.8900 (4.9810)
logINTEREST	0.3588 (0.3024)	0.3248 (0.3752)	-6.3675 (1.3985)	0.9383 (0.3668)	-0.6194 (0.2477)	0.4019 (2.0067)
logPPI	-2.4237 (1.7355)	-2.6497 (1.6382)	19.8751 (8.8263)	-7.9631 (1.6122)	-6.5709 (1.7545)	-13.9596 (12.2381)
R^2	0.94	0.91	0.98	0.99	0.99	0.89
Number of obs.	13	13	13	13	13	13

The variables, logGDP and logTARIFF were dropped from these regressions due to the low number of observations.

Table A11 – Industry Regression 3 (Quantity equation for industries 10, 14, 20, 21 and 22)

Dependent Variable: Quantity	SIC 10	SIC 14	SIC 20	SIC 21	SIC 22
logFP	-0.2371 (0.7698)	-0.5789 (0.2410)	0.4708 (0.1839)	0.0296 (1.2025)	0.3368 (0.4875)
logEX	0.1926 (0.3116)	0.2644 (0.0957)	-0.2768 (0.0936)	0.6472 (0.5236)	-0.2551 (0.2297)
logWAGE	-17.0755 (11.5825)	-11.7318 (2.9091)	0.7080 (2.6772)	1.3853 (5.9746)	3.9977 (6.8423)
logINTEREST	-2.7287 (2.1157)	-1.3767 (0.5648)	1.6162 (0.5532)	-1.4967 (2.9210)	1.3767 (0.7423)
logPPI	34.2241 (14.5100)	23.9930 (4.2164)	-5.6078 (3.3847)	-2.1034 (14.2455)	-5.7438 (5.1320)
R^2	0.99	0.99	0.99	0.85	0.99
Number of obs.	13	13	13	13	13

The variables, logGDP and logTARIFF were dropped from these regressions due to the low number of observations.

Table A12 – Industry Regression 3 (Quantity equation for industries 24, 26, 27, 30, 34 and 39)

Dependent Variable: Quantity	SIC 24	SIC 26	SIC 27	SIC 30	SIC 34	SIC 39
logFP	-0.1073 (0.1418)	0.7895 (0.6091)	5.7882 (1.9828)	1.2791 (0.3567)	0.7734 (0.4703)	2.6911 (1.0054)
logEX	0.1234 (0.0515)	-0.2580 (0.1184)	-1.6813 (0.6156)	-0.4595 (0.1188)	-0.4357 (0.2638)	-1.7639 (0.4920)
logWAGE	4.7864 (1.1332)	-1.4591 (5.8640)	-32.8819 (25.9515)	-5.5193 (4.2156)	29.4384 (9.9360)	14.8587 (9.3302)
logINTEREST	0.3638 (0.3293)	1.6212 (0.6743)	11.7793 (5.0074)	3.0496 (1.0813)	5.5910 (1.5901)	12.5932 (3.7256)
logPPI	2.1136 (1.9007)	-3.8603 (2.8500)	-40.6200 (22.0082)	-1.6202 (4.5036)	-40.3149 (11.2461)	-60.3960 (23.8894)
R^2	0.99	0.99	0.91	0.99	0.99	0.99
Number of obs.	13	13	13	13	13	13

The variables, logGDP and logTARIFF were dropped from these regressions due to the low number of observations.

REFERENCES

REFERENCES

Baranson, J. 1981. *The Japanese Challenge to U.S. Industry.* Lexington, MA: D.C. Heath and Company.

Bourgeois, Jacques & Paul Demaret. 1995. The Working of EC Policies on Competition, Industry and Trade: A Legal Analysis. In Pierre Buigues, Alexis Jacquemin &Andre Sapir, editors, *European Policies on Competition, Trade and Industry.* Brookfield, VT: Edward Elgar.

Brod, Andrew & R. Shivakumar. 1997. R&D Cooperation and the Joint Exploitation of R&D. *Canadian Journal of Economics*, 30: 673-684.

Dasgupta, P. 1986. The Theory of Technological Competition. In Joseph E. Stiglitz & G. Frank Mathewson, editors, *New Developments in the Analysis of Market Structure.* London: Macmillan.

d'Aspremont, Claude & Alexis Jacquemin. 1988. Cooperative and Noncooperative R&D in Duopoly with Spillovers. *American Economic Review*, 78: 1133-1137.

Deneckere, R. & C. Davidson. 1985. Incentives to Form Coalitions with Bertrand Competition. *RAND Journal of Economics*, 16 (Winter): 473-486.

Dick, A. "Are Export Cartels Efficiency-Enhancing or Monopoly-Promoting?" *Research in Law and Economics* 15 (1992): 89-127.

Eaton, J. & G. Grossman. 1986. Optimal Trade and Industrial Policy Under Oligopoly. *Quarterly Journal of Economics*, 101: 383-406.

Economic Commission for Latin America and the Caribbean. *Statistical Yearbook for Latin America and the Caribbean.* Chile: United Nations, 2000.

Federal Reserve. *Federal Reserve Statistical Release: H15 Selected Interest Rates Historical Data.*

Fourteenth Report on Competition Policy. 1985. Luxembourg: Office for Official Publications of the European Communities.

Geroski, P. 1993. Antitrust Policy towards Co-Operative R&D Ventures. *Oxford Review of Economic Policy*, 9: 58-71.

Goel, Rajeev. 1999. *Economic Models of Technological Change: Theory and Application*. Westport, CN: Quorum.

Hamphill, T. 1997. U.S. Technology Policy, Intra-industry Joint Ventures, and the National Cooperative Research and Production Act of 1993. *Business Economics*, 32 (October): 48-54.

International Monetary Fund. *International Financial Statistics*.

Jacquemin, Alexis. 1988. Cooperative Agreements in R&D and European Antitrust Policy. *European Economic Review*, 32: 551-560.

Kamien, Morton I., Eitan Muller & Israel Zang. 1992. Research Joint Ventures and R&D Cartels. *American Economic Review*, 82: 1293-1306.

Leahy, D. and J. P. Neary. "R&D Spillovers and the Case for Industrial Policy in an Open Economy." *Oxford Economic Papers* 51 (1999): 40-59.

Leyden, D. and A. Link. "Federal Laboratories as Research Partners." *International Journal of Industrial Organization* 17 (1999): 575-592.

Link, A. "Research Joint Ventures: Patterns from Federal Register Filings." *Review of Industrial Organization* 11 (1996): 617-628.

Motta, M. "Research Joint Ventures in an International Economy." *Ricerche Economiche* 50 (1996): 293-315.

Neary, J. P. and P. O'Sullivan. "Beat'Em or Join'Em?: Export Subsidies Versus International Research Joint Ventures in Oligopolistic Markets." *Scandinavian Journal of Economics* 101 (1999): 577-596.

Organization for Economic Cooperation and Development. *Monthly Statistic of Foreign Trade*.

Organization for Economic Cooperation and Development. *Revenue Statistics of OECD Member Countries 1965-1989*. Paris, France: OECD, 1990.

Organization for Economic Cooperation and Development. *Revenue Statistics 1965/1994*. Paris, France: OECD, 1995.

Organization for Economic Cooperation and Development. *Revenue Statistics 1965/1995*. Paris, France: OECD, 1996.

Organization for Economic Cooperation and Development. *Revenue Statistics 1965/1996*. Paris, France: OECD, 1997.

Organization for Economic Cooperation and Development. *Revenue Statistics 1965/1998*. Paris, France: OECD, 1999.

Salant, Stephen W., Sheldon Switzer & Robert J. Reynolds. 1983. Losses from Horizontal Merger: The Effects of an Exogenous Change in Industry Structure on Cournot-Nash Equilibrium. *Quarterly Journal of Economics*, 98: 185-199.

Scott, J. "Diversification Versus Cooperation in R&D Investment." *Managerial and Decision Economics* 9 (1988): 173-186.

Spencer, B. and J. Brander. "International R&D Rivalry and Industrial Strategy." *Review of Economic Studies* 50 (1983): 707-722.

Thirteenth Report on Competition Policy. 1984. Luxembourg: Office for Official Publications of the European Communities.

United Nations. *1991 International Trade Statistics Yearbook*. New York, NY: United Nations, 1993.

United Nations. *1997 International Trade Statistics Yearbook*. New York, NY: United Nations, 1999.

United Nations, Department of Economic and Social Affairs, Statistical Division. *Statistical Yearbook 1993*. New York, NY: United Nations, 1995.

United Nations, Department of Economic and Social Affairs, Statistical Division. *Statistical Yearbook 1997*. New York, NY: United Nations, 2000.

United Nations, Department of Economic and Social Affairs, Statistical Division. *Monthly Bulletin of Statistics*.

United Nations, Statistical Division. *Commodity Trade Statistics Data (COMTRADE)*.

Vonortas, N. "Research Joint Ventures in the U.S." *Research Policy* 26 (1997a): 577-595.

Vonortas, N. *Cooperation in Research and Development*. Boston, MA: Kluwer Academic, 1997b.

Wilkie, J., Contreras, C. and C. Weber, editors. *Statistical Abstract of Latin America*. Los Angeles, CA: UCLA Latin American Center Publications, University of California, 1993.