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The Welfare Effects of Imperfect Harmonization of Trade and Industrial Policy

by

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NONTECHNICAL SUMMARY

In recent years countries have invested significant amounts of political capital in efforts to coordinate trade and industrial policy. Examples include the recent U.S. - Canada free trade agreement and the European attempt to complete the EC internal market by 1992. The design of welfare improving policy reform is complicated by the presence of policy-induced distortions and by the imperfectly competitive nature of many industries. This paper examines complications that arise when reform is carried out under conditions of imperfect competition.

The principal conclusion of the analysis is that limited cooperations, as occurs in customs unions, may be worse for members of the union than no cooperation. This possibility arises because comparison of welfare in the two situations (with and without cooperation) amounts to a comparison of two second-best equilibria. We model the situation where the countries that form the union (i.e., cooperate) attempt to coordinate production and export tax policy, and in that way to alter the incentives faced by imperfectly competitive firms. By assumption, these firms produce for export only.

The first model considers the case where n firms, each of which is identified with a single country, choose output, taking their rivals' output and trade policies as given; the exporters compete for the market of a third country. Governments have an incentive to subsidize domestic production to increase the domestic share of oligopoly profits. Countries that form a union internalize a portion of the negative externality that their subsidy has on industry profits. The union members can not credibly commit to using the subsidy that they would have chosen had the union not been formed. Consequently, a small union may be worse for the member countries than no union.

In the second model we analyze the case where two large countries (firms) produce for export to the Rest of World, where the excess demand is a fixed function of price. The cost of production in each exporting firm depends on a previous decision, such as investment in capital or R & D. Prior to selecting the production policy, governments choose an investment tax or subsidy non-cooperatively; this affects investment, which is chosen prior to the announcement of the production policy. Cooperation in setting production (export) taxes alters the incentives in setting investment policies; this is the source of the possibility of disadvantageous cooperation.

A third model show that the above conclusions tend to be strengthened if the excess demand function in ROW is endogenous, as may occur is investment decisions in ROW depend on whether or not a union forms.

Movements toward cooperation are achieved by costly negotiations. These negotiations are entered with the understanding that a completely cooperative agreement is unlikely to emerge. There is, however, usually the implicit belief that partial cooperation represents a step in the right direction. This belief is too optimistic. Partial cooperation can be worse than no cooperation.

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Abstract

Partial cooperation in setting trade policy may be worse than no cooperation for countries who form a customs union. The paper investigates three situations where this is likely to occur. First, if the countries forming the union comprise too small a percentage of the non-competitive sector of the industry, their cooperation may be disadvantageous for essentially the same reason that a merger may be disadvantageous in oligopolistic industries. Second, even if the countries forming the union comprise the entire non-competitive sector of industry, cooperation on trade policy may be disadvantageous if industrial policy (e.g. investment subsidies) are chosen non-cooperatively. The reason is that cooperation in trade policy may exacerbate the inefficiencies created by non-cooperation at an earlier stage. Third, cooperation in choosing trade policies may encourage excessive investment by competitive importers and thus reduce the demand faced by the oligopolists.

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The Welfare Effects of Imperfect Harmonization of Trade and Industrial Policy

Introduction

In recent years several countries have invested significant amounts of political capital in efforts to coordinate trade and industrial policy. Examples include the recent U.S.-Canada free trade agreement, and the European attempt to complete the E.C. internal market by the year 1992. The design of welfare improving policy reform is complicated by the presence of a large number of policy-induced distortions and by the imperfectly competitive nature of many industries.

The question of policy reform in the presence of fixed distortions when markets are competitive is a well-studied problem in the theory of the second best. Recent contributions to the literature include Hatta (1977), Fukushima (1979), and Dixit and Newbery (1985). The general conclusion is that the nominal reduction of a set of distortions, holding other distortions fixed, does not necessarily improve welfare. This conclusion, which arises because the reform occurs in a second-best environment, certainly survives the introduction of imperfect competition.

This paper examines additional complications that arise when reform is carried out under conditions of imperfect competition. This subject, which is of general theoretical interest, is also of immediate practical interest due to the current attempts to harmonize European trade policy.

The principal conclusion of the analysis is that limited cooperation, as occurs in customs unions, may be worse for members of the union than no cooperation. This possibility arises because comparison of welfare under the two situations (no cooperation and partial cooperation) amounts to a comparison of two second-best equilibria. Such a comparison is, in general, ambiguous. An equivalent explanation of the result is that different degrees of cooperation induce different games. A comparison of the equilibria of these different games is, in general, ambiguous. In view of these remarks, the possibility that limited cooperation may be disadvantageous is not surprising. The contribution of this paper is to identify circumstances under which the possibility is likely.

We restrict attention to partial equilibrium models. This greatly simplifies the analysis and has the added advantage of allowing us to concentrate on the role of imperfect competition in a single market in determining the welfare effects of limited cooperation among governments. A general equilibrium model would introduce two types of complications which would obscure the main point. First, distortions in other markets would influence the welfare effects of a policy change in the market under study. This raises the types of second-best considerations familiar from the study of competitive markets, alluded to above. Second, a general equilibrium framework makes it necessary to consider the effects on, for example, the factor markets of imperfect competition in the product market. Although both of these types of complications are important, it seems reasonable to begin with a partial equilibrium model. This leads to a clear understanding of the direct welfare effects in the primary market.

We consider the case where the countries that form the union (i.e., cooperate) attempt to coordinate trade policy, and in that way to alter the incentives faced by imperfectly competitive domestic industries. By assumption, these industries, each of which is treated as a single firm, produce for export only. This simplifies the analysis by making it unnecessary to take into account consumer welfare. Since export enhancement appears to be an important objective of many governments, and since relatively little weight is apparently attached to consumers' interests, the assumption provides a reasonable starting point.

We analyze three variations of a partial equilibrium trading model.(1) These variations illustrate different reasons why limited cooperation may be worse than no cooperation for members of a union. For each of the models, we study complete information subgame perfect equilibria.

Section 1 considers the case where n firms, each identified with a different country, choose output, taking their rivals' output and domestic trade policies as given. Governments have an incentive to subsidize domestic production in order to increase the domestic share of excess profits [Brander and Spencer, (1985)]. Each country's subsidy has a negative externality on other countries. Union members internalize a portion of these externalities, making it optimal for them to decrease the subsidy; a sufficiently large union will tax its members. In equilibrium, members' welfare is non-monotonic in the size of the union: a small union may be worse for countries than no union. This is one sense in which partial cooperation may be

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(1) This partial equilibrium model can be interpreted as a simple general equilibrium model in which each nation's utility function is of the form $U(x) + z$, where z is the numeraire commodity. The exporting nations export x and import the numeraire. In such a model, income effects are absorbed by z.

disadvantageous compared to no cooperation.

This conclusion extends the result that horizontal mergers may be disadvantageous [Salant et al.(1983)]. It may seem that since the feasible set of actions of a union includes the sets of feasible actions of each member, the agreement to cooperate could not lower welfare. This reasoning is incorrect, and illustrates why intuition gained from optimization problems does not carry over to games. The equilibrium in the game without a union is not a perfect equilibrium of the game with a union.

In the second section we analyze the case where two large firms (countries) produce for export to the Rest of World (ROW). The excess demand in ROW is a fixed function of price. For example, production in ROW may be 0, or it may be positive but competitively determined. Since the union consists of all non-competitive producers, the source of disadvantageous cooperation in the previous model is now ruled out. The cost of production in each firm depends on a previous decision such as investment in capital or R&D. In this section we assume that ROW's investment is exogenous. This assumption is relaxed in the subsequent section. As in the first model, countries use a production subsidy if they do not cooperate and a production tax if they do cooperate. In either case, we assume that prior to selecting the <u>production</u> policy, governments choose an <u>investment</u> tax or subsidy non-cooperatively; this affects investment, which is chosen prior to the announcement of the production policy.[2]

This model describes important features of the problems faced by negotiators attempting to harmonize European trade policy by 1992 [Gatsios and Seabright (1989)]. Considerable progress has been made in reducing barriers to trade; however, there has been less progress in reaching agreement on issues concerning state aids and investment policies. In the context of its 1985 White Paper "Completing the Internal Market", the European Commission promised to prepare a special paper dealing with the problem of state aids. This paper was to have been published in 1986. It has not yet been prepared. In fact, it was not until February 1989 that a comprehensive survey appeared regarding the extent of state aids in the Community [European Commission (1989)]. The problems commonly associated with reaching agreement on coordination of output tax/subsidies are even more severe when dealing with investment policies. The latter policies are difficult to define and to monitor. For example, if an industry receives a bank loan which is later forgiven, it is nearly impossible to determine whether this constitutes an investment subsidy; the question turns on the firm's subjective probability, at the time the loan was made, of being forgiven the loan.

We show that the failure to choose investment policies cooperatively can erode the benefits of setting production policies

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(2) Spencer and Brander (1983) studied this model, but they did not analyze the equilibrium we have described. They considered the case where a single country chose an investment and then a production policy sequentially, and also the case where both countries chose both policies noncooperatively at the initial stage (before investment by the firms). The timing of the decisions is critical; for the reasons discussed in the text, we believe that we have selected the more plausible ordering of decisions.

cooperatively. Indeed, the countries' welfare may be higher when they set production policies non-cooperatively. The reason for this is that the degree of cooperation in choosing production policies influences the incentives that the countries have in choosing their investment policies. Cooperation in setting production policies involves a tax on production. This discourages investment undertaken by the firm. However, even when production policies are chosen cooperatively, each nation's profits increase with its own production, given the level of investment. Therefore cooperation in choosing the production policies is likely to cause each country to subsidize investment. Non-cooperation in choosing production policies, on the other hand, involves a subsidy on production. This encourages investment by the firms. In this circumstance the noncooperative choice of investment policy is likely to entail an investment tax.

For a given level of investment, cooperation in setting production policies induces the optimal level of output; this is the obvious source of gains from cooperation. However, as suggested above, it is plausible that cooperation in choosing production policies leads to larger investment subsidies than is the case where production policies are set non-cooperatively. Moreover, this effect can be so pronounced that in the former regime the equilibrium level of investment, as well as the investment subsidy level, is greater than in the latter. Consequently, it may be the case that the inefficiencies associated with a larger level of investment outweigh the benefits associated with choosing production policies cooperatively. We establish this possibility using a linear model.

In the third model we allow ROW, as well as the exporters, to invest. Therefore the supply function in ROW and, consequently, the excess demand facing the two exporters, depends on whether or not the exporters cooperate in setting production policies. For example, producers in ROW know that if the countries cooperate in setting production policies, then they will choose an output tax; in this case, for a given level of world investment, world output will be relatively low and world price relatively high. This causes producers in ROW to increase their own investment, causing the excess demand facing the two countries to shift in. Partial cooperation may still be disadvantageous, for the same reason as in the previous model. In the previous model it is clear that complete cooperation (i.e. cooperation in setting both production and investment policies) increases the welfare in the union, relative to either partial cooperation or to the complete absence of cooperation. Surprisingly enough, in the present model complete cooperation may be worse for the union than the complete absence of cooperation. (We establish this result by means of an example.) In this case, monopoly power is disadvantageous. The reason is that under either partial or complete cooperation it is very costly for the countries to discourage investment in ROW, since they cannot credibly promise to keep price low except by investing heavily.

The motivation for studying these three models is that the degree of cooperation between nations is not exogenous. Rather, movements towards cooperation are achieved by long and generally painful negotiations which involve considerable political risks. These negotiations are entered with the understanding that a completely cooperative agreement is unlikely to emerge. There is, however, usually the implicit belief that partial cooperation represents a step in the right direction. This belief is too optimistic. Partial cooperation may be worse than no cooperation.

The next three sections develop the models discussed above and establish the results we have outlined. The conclusion provides our assessment of the practical importance of the results and elaborates the connection between this paper and earlier work.

1. A One Period Model

This section studies a model in which world production is non-competitive and countries use production tax/subsidies to increase the level of profits accruing to the domestic industry. This attempt to increase national profits reduces aggregate (world) industry profits. A union consisting of a group of countries restrains their individually rational behaviour in a manner similar to that of a group of firms which merge. A merger, if it accounts for too small a fraction of the market, may leave the merged firms worse off [Salant et al. (1983)]. A similar possibility arises if the union is too small.

Suppose that there are n countries, in each one of which a firm produces a homogeneous product. Firms are identical and compete for the market of an importing country. In this situation each government has an incentive to subsidise the exports of its domestic firm; this increases its share in the market of the importing countries and shifts excess profits from its competitors to itself. [Brander and Spencer (1985)].

In the second stage of the game, firms choose their output levels x_i to maximise profits π_i, treating subsidies s parametrically. We assume that the second order conditions hold, i.e. $a_i \equiv \frac{\partial^2 \pi_i}{\partial x_i^2} < 0 \quad \forall i$, and that for stability the matrix obtained from totally differentiating the first order condition is diagonal dominant, i.e. $a_i + (n-1)b_i < 0 \quad \forall i$, where $b_i \equiv \frac{\partial^2 \pi_i}{\partial x_i \partial x_j}$.

Now, suppose m < n countries form a union and choose their common subsidy to maximise joint welfare. The impact of a union's subsidy on the output level of its members is given by [see Dixit (1986)]

$$\frac{\partial x_i}{\partial s_m} = -\frac{1}{a-b}\,\frac{a+(n-m-1)b}{a+(n-1)b} > 0\,, \qquad \forall i \in m \qquad (1)$$

For m = 1 equation (1) gives the effect on output of the subsidy in a degenerate one-member coalition.

The impact of a union's subsidy on the output of non-members is

$$\frac{\partial x_k}{\partial s_m} = \frac{mb}{(a-b)[a+(n-1)b]} < 0, \quad \forall\, k \in (n-m) \qquad (2)$$

Hereafter the subscript i indicates a union member and k indicates a non-union member.

The optimal subsidy of a m-member union maximises joint welfare $W_m = mW_i$, $i \in m$, by symmetry, where $W_i = \pi_i - sx_i$. Therefore $\frac{\partial W_m}{\partial s_m} = 0 \Leftrightarrow \frac{\partial W_i}{\partial s_m} = 0$. Hence, for i, j $\in$m and k $\in$ (n − m) we have

$$\frac{\partial W_i}{\partial s_m} = (m-1)\frac{\partial \pi_i}{\partial x_j}\frac{\partial x_j}{\partial s_m} + (n-m)\frac{\partial \pi_i}{\partial x_k}\frac{\partial x_k}{\partial s_m} - s\frac{\partial x_i}{\partial s_m} = 0$$

which implies, by noting that $\frac{\partial x_j}{\partial s_m} = \frac{\partial x_i}{\partial s_m}$ by symmetry, that

$$s_m^* = \frac{\dfrac{\partial \pi_i}{\partial x_{-i}} \cdot \left[(m - 1) \dfrac{\partial x_i}{\partial s_m} + (n - m) \dfrac{\partial x_k}{\partial s_m} \right]}{\dfrac{\partial x_i}{\partial s_m}} \qquad (3)$$

The sign of s_m^* depends on the sign of the square bracket, since $\frac{\partial \pi_i}{\partial x_{-i}} < 0$ and $\frac{\partial x_i}{\partial s_m} > 0$. After routine manipulations and by using (1) and (2) the expression in square bracket becomes $(m - 1)a - (n - 1)b$. For $m \lesseqgtr [a + (n - 1)b]/a$ we have $s_m \gtreqless 0$. If the members of the coalition exceed a crucial number, the optimal policy of the union is to tax rather than subsidize exports [see, also Dixit (1984)]. In the case of linear demand, for instance, export taxes will be used if $m \geq (n + 1)/2$, since in such a case $a = 2P'$ and $b = P'$.

We now show that for an arbitrary (common) subsidy by non-union members, the best response by the union entails a lower subsidy than the m individual countries, each acting on its own, would have chosen. This follows by noting that (see Appendix A for the derivation)

$$\left. \frac{\partial W_i}{\partial s_i} \right|_{s_i = s_m^*} = \frac{\partial \pi_i}{\partial x_{-i}} \cdot \left[\frac{\partial x_i}{\partial s_m} \right]^{-1} \cdot \frac{1}{(a - b)[a + (n - 1)b]} \cdot (1 - m) > 0 ,$$

since $\frac{\partial \pi_i}{\partial x_{-i}} < 0$, $\frac{\partial x_i}{\partial s_m} > 0$, $a - b < 0$, $a + (n - 1)b < 0$ by diagonal dominance, and $m > 1$.

[Figure 1 about here]

This implies that the equilibrium subsidy of a union with $m > 1$ members is less than the common subsidy used by the m members in the equilibrium without the union. Figure 1 illustrates this point. The vertical axis gives the common subsidy of the non-members, s_k, and the horizontal axis gives the subsidy of the m (potential) union members. The curve $s^k(\cdot)$ shows the equilibrium subsidy of the non-members. This curve is obtained by finding the symmetric Nash equilibrium to the non-coöperative game among non-members, for an arbitrary common subsidy by the m potential union members. The dashed curve $s^m(\cdot)$ shows the best response of the m-member union to an arbitrary subsidy by non-members. The curves are downward sloping since the goods are homogeneous (and therefore substitutes); the stability assumption implies the relative slopes of the curves at the equilibrium. The curve $s^i(\cdot)$ graphs the symmetric Nash equilibrium to the non-cooperative game among the m potential union members, for an arbitrary common subsidy by non-members. By the previous inequality, this curve lies to the right of the union's best response function. Therefore, if the union forms, the new equilibrium involves a higher level of subsidy set by the non-union members.

The next step is to show that the welfare of an m member union is a decreasing function of the subsidy set by non-members. This follows from the inequality (see Appendix A for the derivation)

$$\left.\frac{\partial W_i}{\partial s_k}\right|_{s_m=s_m^*} = \frac{\partial \pi_i}{\partial x_{-i}} \cdot \left[\frac{\partial x_i}{\partial s_m}\right]^{-1} \cdot \frac{1}{(a-b)[a+(n-1)b]} < 0 .$$

The possibility of losses from cooperation is shown in Figure 2.

[Figure 2 about here]

W_m^c denotes the joint welfare of the m countries, as a function of the subsidy level set by the countries outside the union when the former create a union; W_m^n gives the joint welfare of the m countries when they do not create a union. By the optimality of s_m^*, W_m^c lies above W_m^n. Since $s_k^c > s_k^{nc}$, where s_k^c (respectively s_k^n) denotes the equilibrium subsidy of the countries outside the union when the m countries form (respectively, do not form) a union, we see that it is possible that the joint welfare of the m countries is higher when they do not cooperate rather than when they do.

To show that this possibility can indeed exist we need more structure in the model. Suppose the demand is given by

$$P = 1 - \sum_i x_i ,$$

where by the choice of units of both prices and quantities we set the demand slope and intercept equal to 1. If m < n countries form a union the non-cooperative equilibrium in output space is given by

$$x_i = \frac{1 - c + ns_m - (m - 1)s_m - (n - m)s_k}{n + 1} \tag{4}$$

where $i \in m$ and $k \in (n - m)$.

The optimal policy of the union (equation (3)) is now given by

$$s_m^* = \frac{x_i(n + 1 - 2m)}{n - m + 1} \tag{5}$$

Clearly $s_m^* \gtreqless 0$ iff $m \lesseqgtr \frac{n + 1}{2}$. Setting m = 1 in the above formula gives the optimal policy of each country k outside the union,

$$s_k^* = x_k \frac{n - 1}{n} > 0 \qquad \text{for } k \in (n - m). \tag{6}$$

Using (5) and (6) in (4) gives the subgame perfect equilibrium output levels,

$$x_i = [n(n + 2 - m) + (1 - m)](1 - c)/m\Delta , \qquad \text{for } i \in m \qquad (7)$$

where $\Delta \equiv (n^2 + 1)(2 + n - m) + 2n(1 - m)$, and

$$x_k = n(n + 1)(1 - c)/\Delta , \qquad \text{for} \qquad k \in (n - m) \qquad (8)$$

For $m = 1$, $x_i = x_k$, the equilibrium output levels when there is no cooperation and each nation acts independently.

Routine calculations using (7) and (8), give the profits net of subsidy payments received by a firm in a m-member union

$$W_i^c = [n(n + 1)^2 + (n + 1)^2 (1 - m)](1 - c)^2/m\Delta^2 \qquad (9)$$

If there were no cooperation ($m = 1$) the net profits of the same firm would be

$$W_i^n = [n(n + 1)^2](1 - c)^2/m\cdot\Delta^2 = n(1 - c)^2/(n^2 + 1)^2$$

The joint welfare of the m countries, being the sum of net profits accruing to their domestic firms, would be given in each case by $W_m^c = m W_i^c$ and $W_m^n = m W_i^n$.

Their difference is a function of m and is given by

$$f(m) \equiv W_m^c - W_m^n$$

$$= (1 - c)^2 [(n + 1)^2(n^2 + 1)^2 (n + 1 - m) - nm\Delta^2]/\Delta^2(n^2 + 1)^2.$$

This is a cubic function in m. For $m = 1$ we have $f(1) = 0$. So $m = 1$ is one of the three roots of the equation. For $m = n$, i.e. when all n countries cooperate, we have

$$f(n) = \frac{(1 - c)^2 (n^2 - 1)^2}{4(n^2 + 1)^2} > 0$$

Cooperation by all exporting countries is beneficial. To obtain the sign of the derivative of f(m) at m = 1 write f(m) as

$$f(m) = \frac{(1 - c)^2}{(n^2 + 1)^2} g(m)$$

where $g(m) = [(n + 1)^2(n^2 + 1)^2 (n + 1 - m) - nm\Delta^2]/\Delta^2$. The sign of $f'(m)$ equals that of $g'(m)$; but

$$g'(m) = - [(n + 1)^2(n^2 + 1)^2 \Delta [\Delta + 2\Delta'n + 1 - m)] - n\Delta^4]/\Delta^4.$$

For m = 1 the numerator of $g'(1)$ is equal to

$$-(n + 1)^4 (n^2 + 1)^3 (n^2 - 1)(n - 1) < 0$$

Therefore, $g'(1) < 0$.

Since $f'(1) < 0$, $f(1) = 0$, $f(n) > 0$ and f is a continuous function in m, there must be some value of m, denoted m^*, lying between 1 and n for which $f(m^*) = 0$. This is unique since f(m) is a cubic function of m and, therefore, the third root must lie outside the domain (1, n). (Otherwise there would be four or, more generally, an even number of roots.) The function f(m) reaches its minimum at $\bar{m}$.

Figure 3 below depicts the function f(m).

[Figure 3 about here]

We summarise the results of the linear model in the following Propositions.

Proposition 1: For $m \in (1, m^*)$ cooperation is harmful. Cooperation is beneficial for the member-states only if the number of countries forming a union is large enough ($m > m^*$).

Proposition 2: For those values of m between 1 and $\bar{m}$ a further (small) expansion of an existing union makes the situation worse for its member-states.

2. A Two Period Model Without ROW Investment

We modify the previous model by assuming that there are only two non-competitive firms and that firm i invests in capital, k_i, in the first period. Firm i's (variable) cost function is now $c_i(x_i, k_i)$, which decreases in k_i and increases in x_i. ROW is assumed to be competitive; in this case, cooperation by the two exporters represents a union by all non-competitive agents. Consequently, the reasons for disadvantageous cooperation cannot be the same as those in the previous section. Furthermore in this section we assume that investment in ROW is fixed. This assumption is relaxed in the next section. These assumptions imply that firm i's revenue net of subsidy (i.e., "social revenue") can be written as $R_i(x)$; this is the revenue corresponding to ROW's residual demand. The ith component of the vector x is x_i. Hereafter we assume that firms 1 and 2 are identical, and we consider only symmetric equilibria.

In period 2 firm i chooses output to maximize gross revenue minus variable cost, taking subsidies and its rival's output as given. This non-cooperative game induces the vector of output functions $x = x(s, k)$, where k is the vector of investment levels and s the vector of investment subsidies. As before, we assume that the firms' best response functions are downward sloping and that the standard stability condition is satisfied. Therefore an increase in s_i or in k_i increases x_i and decreases x_j, $j \neq i$.

In period 2 country i chooses the output subsidy s_i taking k as given. Non-cooperative behaviour by the countries induces the policy rule $s^n(k)$, and cooperative behavior induces the policy rule $s^c(k)$. The superscripts n and c designate, respectively, non-cooperative and cooperative behaviour by the governments in the second period. The governments' and the firms' equilibrium behaviour induce the equilibrium output functions $x^t(k) \equiv x(s^t(k), k)$, for $t = n, c$; these functions correspond to non-cooperation and cooperation between the governments in the second period.

It is straightforward to show that $s^c < 0 < s^n$, as in the previous model. If countries cooperate, they tax their domestic firms in order to move joint output to the monopoly level. If countries behave non-cooperatively they subsidize the domestic firm, in order to capture the monopoly rents.

Even under the assumptions that the Nash equilibrium is stable and the countries' best response functions are downward sloping in subsidy space, the comparative statics of the model are ambiguous. The reason is that the effect of k on the equilibrium level of s involves second derivatives of the endogenous function $x(s, k)$. The results of this section are based on a linear example, so we make no claim to generality. Before turning to the example we discuss the intuition behind the results. In order to avoid having to consider every possibility we adopt the following assumptions, which make the effect of an increase in investment on the production subsidy unambiguous:

<u>Assumption 1a</u> $$\frac{\partial^2 W_i}{\partial k_i \, \partial s_i} > 0 > \frac{\partial^2 W_j}{\partial k_i \, \partial s_j}, \text{ evaluated at } s^n(k)$$

<u>Assumption 1b</u> $$\frac{\partial^2 W}{\partial k_i \, \partial s_i} > 0 > \frac{\partial^2 W}{\partial k_k \, \partial s_j}, \text{ evaluated at } s^c(k).$$

where we define $W_i(s, k) \equiv R_i(x(s, k)) - c_i(x_i(s, k), k_1)$ and $W(s, k) \equiv W_1 + W_2$. Assumption 1a states that at the non-cooperative equilibrium in production subsidies, $s^n(k)$, an increase in k_i causes an outward shift in the marginal profit to country i of an increase in its own subsidy, and a decrease in the marginal profit to country j. Assumption 1b states that at the cooperative equilibrium in production subsidies, $s^c(k)$, an increase in k_i shifts out the marginal joint profit due to an increase in s_i and shifts in the marginal joint profits due to an increase in s_j. It is possible to write the assumptions in terms of the primitive functions (residual demand and cost) but the result is too complicated to be illuminating. These assumptions are plausible, hold for the linear model we discuss below, and imply:

<u>Proposition 3</u>: An increase in k_i causes an increase in the equilibrium level of s_i and a decrease in the equilibrium level of s_j, regardless of whether or not the countries cooperate: k_i and s_i are "strategic complements".

<u>Proof</u>: If the countries do not cooperate, the sign of $\partial k_i/\partial s_i$ equals the sign of $|J_1|$ and the sign of $\partial k_j/\partial s_i$ equals the sign of $|J_2|$,

where

$$J_1 = \begin{bmatrix} \dfrac{-\partial^2 W_1}{\partial s_1 \partial k_1} & \dfrac{\partial^2 W_1}{\partial s_1 \partial s_2} \\ \dfrac{-\partial^2 W_2}{\partial s_2 \partial k_1} & \dfrac{\partial^2 W_2}{\partial s_1^2} \end{bmatrix}, \qquad J_2 = \begin{bmatrix} \dfrac{\partial^2 W_1}{\partial s_1^2} & \dfrac{-\partial^2 W_1}{\partial s_1 \partial k_1} \\ \dfrac{\partial^2 W_2}{\partial s_1 \partial s_2} & \dfrac{-\partial^2 W_2}{\partial s_2 \partial k_1} \end{bmatrix}$$

This follows from applying Cramer's Rule to the comparative statics matrix of the non-cooperative game between the governments in the second period, and using the standard stability condition. By assumption the best response functions of the governments are downward sloping in subsidy space, so $\partial^2 W_1/\partial s_i \partial s_j < 0$. Using the second order condition $\partial^2 W_i/\partial s_i^2 < 0$ and Assumption 1a then implies that $|J_1| > 0 > |J_2|$. The proof for the case where the governments cooperate in setting production subsidies is similar.

Q.E.D.

An increase in k_i causes the marginal cost of firm i to decrease. If the production subsidies were held constant, the increase in k_i could cause output in country i to increase and output in j to decrease. The two assumptions guarantee that under either regime, the equilibrium choice of production subsidies encourages this tendency.

In the first period firms choose investment levels. The <u>social</u> cost of investment for firm i is $v_i(k_i)$. Firms pay the cost $V_i(k_i, \Phi_i)$, where Φ_i is the investment subsidy (a tax if negative) in country i. In the case of constant marginal costs of capital, for example, we have $v_i \equiv k_i$, by choice of units, and $V_i \equiv (1 - \Phi_i)k_i$. In the numerical example it is convenient to use a more general function.

The investment game between firms induces the equilibrium level of investment, $k = k^t(\Phi)$, for t = n, c, where Φ is the vector of investment subsidies, and, as before, the superscript denotes non-cooperation or cooperation in the choice of production subsidies. In all cases we assume that the investment subsidies are chosen non-cooperatively. If firms' best response functions are downward sloping in investment space and if the usual stability condition holds at the equilibrium, the comparative statics are as expected: an increase in Φ_i causes the equilibrium level of k_i to increase and causes k_j to decrease.

In period 1 country i chooses Φ_i, taking its rival's investment policy as given, and recognizing the effect its own action will have on the final equilibrium. That is, country i takes the investment tax or subsidy in j as given, and understands how its own investment policy will affect investment levels, and thus indirectly affect production subsidies and final output. The non-cooperative symmetric equilibrium in investment subsidies for the two regimes is Φ^t, t = c, n.

The timing in the model is important (see note 2). The model describes the situation where countries attempt to create institutions which will permit them to cooperate on the choice of future trade and production policies. These institutions must be sufficiently flexible to accomodate future changes; therefore cooperative trade policy must be conditional on factors which influence demand and supply. The requirement of subgame perfection ensures that the institutions do not incorporate ex post inefficiency. By assumption, the countries are not able to negotiate an agreement on the choice of investment policies. This inability may arise because of monitoring problems, or simply because of the piecemeal approach adopted in negotiating customs unions. Therefore the countries are not able to avoid the ex ante inefficiencies caused by individualistic investment policies. The question the model addresses is whether it is likely that a reduction in ex post inefficiency (cooperation on production policies) exacerbates the problem of ex ante inefficiency to such an extent that welfare decreases.

Designate $J^t(k)$ as the joint social welfare minus the social cost of investment: $J^t(k) = W_1^t + W_2^t - v_1 - v_2$, where $W_i^t \equiv W_i(s^t(k), k)$ for $t = n,c$. Once again, we remind the reader that the superscript t indicates whether or not there is cooperation in the second period; in both cases the countries behave non-cooperatively in choosing investment policies. Clearly, for any levels of investment, k, $J^c(k) > J^n(k)$. If countries were to cooperate on investment policies in the first period they would be in a position to induce the optimal level of investment by appropriate choice of investment policies. In that case, second period cooperation would certainly increase joint social welfare. However, if the countries choose investment policies non-cooperatively, there is no guarantee that cooperation on output policies raises their welfare.

Figure 4 about here

Figure 4 illustrates a situation where second period cooperation lowers welfare. The horizontal axis gives $\bar{k}$, the level of investment in a symmetric equilibrium. The function J^n lies below J^c, for the reason given above. The graphs are drawn as concave in $\bar{k}$. Under both regimes non-cooperation in setting investment policies leads to an excessive level of investment in equilibrium, since each country maneuvers for a favourable position in the second stage of the game. Investment in country i has a negative externality on welfare in j. At the non-cooperative equilibrium in investment policies country i fails to take this externality into account and therefore induces a level of investment greater than the jointly optimal level. Figure 4 illustrates the case where $\bar{k}^c$, the equilibrium level of investment given second period cooperation, exceeds $\bar{K}^n$, the equilibrium level of investment given non-cooperation in the second period. The increased inefficiency induced by second period cooperation more than offsets the ex post increase in efficiency.(3)

Example: We show by example that the above discussion, which is summarized in Figure 4, is quite plausible. Let the world inverse demand function be linear: $p = 1 + \theta - (x_1 + x_2)/2$. Variable cost is $c_i = [(1 - \alpha k_i) + \gamma x_i/2]x_i$. A unit increase in investment causes the marginal cost curve to shift down by α; γ gives the slope of the marginal cost curve. The parameter θ gives the amount by which the demand intercept exceeds the marginal cost of the first unit of production when investment is zero. The social cost of investment is

(3) The figure shows the investment at which J^c reaches its maximum lies to the right of the investment that maximizes J^n. We regard this as the likely situation, but it is not important to our argument. If countries do not cooperate in setting the production policy, a lower level of investment provides a partial substitute for a commitment not to use large subsidies. This is due to the assumption of strategic complementarity between production subsidies and investment. This indirect commitment is not needed when firms know that their governments will cooperate in setting production policy.

quadratic in k: $v_i = (1 + \rho k_i/2)k_i$. There are two interpretations for this function. The first is that the investment function incorporates nonlinear adjustment costs, given by $\rho k_i^2/2$; adjustment costs are commonly invoked to explain why the level of capital stock is not in long run equilibrium at every point in time, i.e., to explain why adjustment is not instantaneous. The second interpretation, which gives a general equilibrium flavour to the model, is that firms face an upward sloping cost function of capital.(4) With the second interpretation, ρ gives the slope of the supply curve for capital. We assume that countries use a unit production subsidy/tax and a unit investment subsidy/tax, so that firm i's cost of investment is $V_i = (1 - \phi_i - \rho k_i/2)k_i$.

These functional forms are chosen for their simplicity, since the objective is to demonstrate that cooperation in choosing production subsidies can be disadvantageous. The formulae for the equilibrium policy rules and the players' payoffs are sufficiently complicated that they defy closed form analysis even for these simple functions. This is because there are four steps (stages) in the game, and also because the domain of the parameter values must be such as to ensure that each agent's programme is concave. For example, it is necessary to choose ρ not only positive, but also sufficiently large to guarantee concavity; this precludes simplifying the model by examining the limiting case where $\rho = 0$. The equilibrium formulae,

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(4) Given the second interpretation of v_i, the model could be extended by assuming that there is a world market for investment goods, so that v_i would depend on both k_i and k_j. This extension would be straightforward, but is tangential to our main point.

and their derivation, are provided in Appendix B. For the results reported below, the parameters θ, α, ρ and γ are chosen so that each agent's problem is concave and so that the decisions result in positive prices and production and positive levels of k less than $1/\alpha$ (so that marginal cost of output is everywhere positive[5]).

[Table 1 about here]

Table 1 summarizes the chief results for a range of values of γ, the slope of the marginal cost of production, and for the parameter values $\theta = 4$, $\rho = 2$, $\alpha = 1$. For small values of γ, second period cooperation is disadvantageous. If the marginal cost curve is very steep, partial cooperation benefits the members of the union.

The possibility of disadvantageous cooperation arises because the incentives to overinvest are very sensitive to the production subsidies. Whether or not the countries cooperate in the second

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(5) This last restriction is unnecessarily strong. It makes sense to consider levels of investment for which marginal cost is negative at low levels of production, provided that at the equilibrium level of production marginal cost and total cost are both positive. That is, since the linear model can be regarded as an approximation, it makes sense to consider cases where the linear marginal cost curve intersects the quantity axis at a positive level. If we choose parameter values to satisfy the weaker restriction that marginal and total cost are positive at the equilibrium (rather than positive for all levels of production), results much more extreme than those presented in table 1 can be found. For example, for $\theta = 4$, $\gamma = .95$, $\rho = 2$ and $\alpha = 1.1$ (rather than $\alpha = 1$ as in Table 1), the equilibrium level of investment under second period cooperation results in negative marginal cost for low levels of production. However, at the equilibrium level of production both marginal and total cost are positive. The ratio of social welfare with cooperation to social welfare without cooperation (J^{*c}/J^{*n}) is then .71. For this example, second period cooperation results in a loss of welfare of almost 40%.

period, the equilibrium production subsidy received by country i is an increasing (linear) function of k_i and a decreasing function of k_j. That is, Assumptions 1a and 1b are satisfied by the linear model. In this sense, the governments' intervention in the second period enhances the firms' incentive to invest for strategic reasons. Although the qualitative effects are the same with and without second period cooperation, there is a considerable difference in degree.

For example, for $\gamma = .95$ and the base parameter values shown in Table 1, when the countries do not cooperate, a $1 increase in k_i causes approximately a .07 (dollar) increase in the production subsidy for i and a .02 decrease in the subsidy for j; when the countries do cooperate, a $1 increase in k_i causes a decrease of .18 in i's production tax (i.e., an increase in the negative subsidy) and an increase of .35 in j's production tax.(6) The difference between the two regimes (second period cooperation and non-cooperation), in the equilibrium incentives (i.e., the effect of investment on the production subsidy), decreases with larger values of γ.

A small value of γ (i.e., a relatively flat marginal cost of production curve) encourages high output; small changes in

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(6) Notice that since the equilibrium subsidy rules are linear in k, the results described in the text imply that $\partial s_i/\partial k_i > -\partial s_j/\partial k_i$ in the non-cooperative case. This means that the best response function of government i intersects that of government j in (s_j, s_i) space from above; that is, the standard stability condition is met. Of course, it is not clear that this stability condition has any relevance in a multistage game, such as we are considering. When the governments cooperate in the second stage, the above inequality regarding the partials of s_i and s_j is reversed. However, when the governments cooperate they solve a maximization problem, so there is no question of invoking a stability condition at this stage.

investment, which lead to changes in the marginal cost of production, cause a relatively large reallocation in the jointly optimal implicit quota for each firm. Since the firms behave non-cooperatively, this requires a large change in the production tax (by which means firms are induced to accept the implicit quota). The sensitivity (to investment levels) of the production tax rule gives each government an incentive to subsidize investment. When the governments behave non-cooperatively in the second period the implicit quota is not jointly optimal; in our example this has the effect of making the equilibrium production subsidy received by firm j less sensitive to the level of investment in firm i. This lessens the governments' incentive to encourage investment in the first period. For large values of γ the optimal implicit quota is small and is less sensitive to changes in marginal cost caused by changes in investment. This decreases the incentives governments have to subsidize investment; in this case, second period cooperation is less likely to be disadvantageous.

For all the simulations we performed using the linear model, second period cooperation causes governments to subsidize investment in the first period; second period non-cooperation causes governments to tax investment in the first period[7]; that is $\Phi^n < 0 < \Phi^c$. This result is consistent with the previous discussion on the governments' incentives to tax or subsidize investment; the

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(7) Spencer and Brander (1983) showed that if a single country used a production and investment policy, they would subsidize production and tax investment in a perfect equilibrium. Thus, our result shows that a non-cooperative game between governments leads to the same type of behaviour, at least for the linear model.

result is also due to the fact that second period cooperation leads to a production tax, whereas non-cooperation involves a production subsidy. Under cooperation, for example, firms are discouraged from investing due to the expectation of a production tax; the investment subsidy offsets this effect.

In all the simulations, the equilibrium level of investment is higher when there is second period cooperation; this is the case regardless of whether joint welfare is higher under second period cooperation. In addition, the output price is always higher under second period cooperation; that is, the decreased cost, induced by the higher investment, is not sufficient to cause output to be higher under second period cooperation. The conclusion is that the consuming nations are always hurt and producing nations are likely to be hurt by second period cooperation.

The choice of units allows us to set the demand slope and the intercept of the marginal cost, when $k = 0$, both equal to one. Changes in θ, which alter the demand intercept, cause the equilibrium level of investment to change, but do not substantially alter the relative advantage of second period cooperation.

For small values of ρ the maximization problem of some agent becomes convex, and the game has no interior equilibrium. For large values of ρ investment is very costly. In this case the incentives, created by second period cooperation, to subsidize investment, have very little effect on the equilibrium outcome of the game, and second period cooperation is advantageous for all values of γ. This is easy to see in the limiting case of $\rho \to \infty$, where investment is always zero and cooperation in setting production subsidies is equivalent to full cooperation.

An increase in the parameter α increases the value of a unit of capital, since for large α an extra unit of capital causes the marginal cost to shift down more. For small α capital has little value, either to reduce costs or for strategic purposes. (For small α the subsidy rule is not sensitive to capital; this is apparent from equation (B.4) of Appendix B, which shows that capital levels and α interact linearly in the subsidy rule). Therefore, for small α governments have little incentive to subsidize investment, and second period cooperation is not likely to be disadvantageous. This is easy to see in the limiting case where $\alpha \to 0$; there, investment is zero and cooperation in setting production subsidies is equivalent to full cooperation. For large values of α second period cooperation is more likely to be disadvantageous since the incentive to subsidize investment increases. (See footnote 5) However, for very large values of α one or more agent's maximization problem becomes convex.

Keeping in mind the restrictions on the domain of α, ρ and γ discussed above, we summarize the comparative static results for the linear model in the following proposition:

Proposition 4: If a unit of investment is very expensive (large ρ) or not very effective in reducing costs (small α) there is little incentive to invest and cooperation in setting only production policies is unlikely to be disadvantageous. If, on the other hand, investment is either inexpensive or very effective in reducing costs, governments create large inefficiencies by subsidizing domestic investment; these efficiencies are exacerbated by cooperation in setting production policies, and such cooperation is likely to reduce welfare. For given levels of ρ and α, second period cooperation is more likely to be disadvantageous if the marginal cost of production rises slowly.

3. A Two-Period Model with ROW Investment

The previous section assumed that ROW's investment was exogenous, which meant that the excess demand function facing the two firms was independent of whether the countries formed a union which entailed setting trade policy optimally. This section assumes that there is the possibility for investment in ROW, as in the two exporting countries. In this case, the equilibrium level of investment in ROW, and hence the excess demand curve facing the firms, depends on both the level of investment by the two firms and on whether the countries will cooperate in the second period. As in the previous model, for given levels of investment by all producers, the equilibrium price is higher when the exporting countries cooperate in the second period; the reason is that cooperation involves a production tax. Therefore cooperation in setting production policies induces greater investment in ROW, for a given level of investment by the two firms: second period cooperation causes the excess demand curve to shift in. This effect compounds the incentive problem discussed in the previous section, and makes it more likely that partial cooperation is disadvantageous.

One way to see this is to replace the social payoff functions J^t graphed in Figure 4 by the functions $J^{*t}(k, k_r^t(k))$, where $k_r^t(k)$ is the equilibrium level of investment in ROW for a given common level of investment, k, by the two firms, for $t = c,n$ (which, as before, correspond to cooperation and non-cooperation in setting production policies). Since $k_r^c(k) \geq k_r^n(k)$, by the argument in the previous paragraph, and since $\partial J^{*t}/\partial k_r < 0$ (since an increase in k_r shifts down the residual demand curve facing the two exporters), the vertical distance between J^{*c} and J^{*n} tends to be less than the distance between the functions in figure 4. This tends to make second period cooperation less advantageous. It may for example be the case that for some values of k J^{*n} lies above J^{*c}. (This cannot occur when investment in ROW is fixed.) If this occurs where J^{*c} reaches its maximum then it may be the case that the countries are worse off cooperating in both periods than behaving non-cooperatively in both periods.

In order to demonstrate this possibility, we take an extreme example, in which J^{*n} lies above J^{*c} for all values of k(8). Suppose that production in ROW occurs at constant marginal cost, which for simplicity we take to be 0, up to some capacity level; a unit of capacity can be purchased by ROW for the constant marginal cost β. Production in the two countries occurs under increasing marginal cost, which can be reduced by first period investment (as in the previous section). This describes a situation where ROW is capable of purchasing and storing a commodity at constant unit cost, β, and where the two countries are capable of producing the good in the next period.

[Figure 5 about here]

(8) A similar example was used by Karp (1988) to show that market power may be disadvantageous when a dominant firm faces a dynamic competitive fringe with rational expectations.

The only equilibrium price is β. Take an arbitrary level of investment for the two countries and a corresponding marginal cost, labelled MC in figure 5; MC is the marginal cost of producing the total level of exports and thus represents an aggregation of the two exporters' marginal cost curves. (That is, MC gives the marginal cost of a multiplant monopolist). If the countries cooperate in the second period they will choose a tax to induce production at the point where marginal revenue equals marginal cost. For this to result in the price β, the excess demand curve must be the curve AB, shown in figure 5. If, on the other hand, the countries do not cooperate in the second period, marginal revenue will be less than marginal cost, and production will occur at a point like x^n in the figure. The excess demand function A´B´ is induced by the equilibrium level of investment by ROW. The shaded area in the figure represents the increase in profits (i.e., producer surplus) resulting from non-cooperation in the second period. The same argument holds for any level of investment in the two exporting countries. Therefore J^{*n} lies above J^{*c}.

We summarize the implications of this example as

Proposition 5: The welfare ranking of regimes for the exporting countries is as follows: the first best is to cooperate on setting investment policies, but not production policies; the next best is to cooperate on neither type of policies; the third best is to cooperate on both types of policies; the worst is to cooperate on production policies but not investment policies.

This section demonstrates that making the model more realistic, by including investment in ROW, is likely to strengthen rather than weaken the conclusion of the previous section.

Conclusion

The principal point of this paper has been to show that limited international cooperation in setting policies that influence non-competitive industries may backfire: partial cooperation may be worse than no cooperation. This conclusion is very much in the spirit of the "theorem of the second best", which tells us that in a market with many distortions, the nominal reduction of one distortion does not necessarily increase efficiency. Similarly, in an economy with many missing markets, the addition of one market may lower the welfare of all agents [e.g., Newbery and Stiglitz (1984)]. The contribution of this paper has been to describe situations under which the possibility of disadvantageous international cooperation is likely.

This paper brings together several strands of literature. Section 1 extends the Salant et al. (1983) paper to a trade setting. Section 2 uses the basic Spencer and Brander (1983) model, but examines a different equilibrium and addresses a very different question.

The basic point of the paper, however, is closely related to many other papers; this is most evident in the third section. The logic of that section is similar to that of Maskin and Newbery (1988), who show that monopsony power may be disadvantageous in a two period game with a nonrenewable resource. Okuno et al. (1981) show that mergers may be disadvantageous in a general equilibrium framework; this paper also discusses previous work on disadvantageous monopoly and disadvantageous syndicates. Karp (1987) shows that monopsony power may be disadvantageous in a reproducible good model with adjustment costs. Lapan (1988) uses a two period general equilibrium model to show that the optimal tariff is time inconsistent, and that both the importer and exporter are worse off at the perfect equilibrium than at the inconsistent equilibrium.(9) Farrell and Gallini (1987) show that a monopolist who sells a product that requires consumers to incur a "start-up cost" may benefit from future competiton; if we think of future competition as being like failure of a group of firms to cooperate, their result is similar to the others discussed here. Rogoff (1985) shows that international monetary coordination may be disadvantageous. Kehoe (1986) shows that international fiscal cooperation in a two period game may be disadvantageous; the reason has to do with the effect of cooperation on the savings decisions of individuals. This list, although certainly not complete, demonstrates growing recognition that the inability to make commitments may alter a problem to such an extent that conclusions which might once have seemed obvious are now seen to be incorrect.

Deneckere and Davidson (1985) demonstrate that the disadvantageous merger result of Salant et al. does not hold if firms play a price setting rather than a quantity setting game. We conjecture that the customs union is less likely to be disadvantageous if firms choose price rather than quantity.

Perry and Porter (1985) show that the disadvantageous merger result is less likely to hold if a merger leads to a decrease in the marginal cost of production; Farrell and Shapiro (1988) provide a

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(9) Lapan does not mention the possibility of disadvantageous monopoly power, although the general equilibrium properties of the model do not rule out that possibility.

more general treatment of this issue. This consideration is also relevant to the international trade model of Section 1. If the marginal cost of the union's production lies below the marginal cost of a single nation's production, the imperfectly competitive nature of rivals is less likely to make cooperation amongst a subset of nations disadvantageous. In this sense, taking capital into account, as in Perry and Porter, leads to the conclusion that cooperation is unlikely to be disadvantageous. However, their modification accommodates capital in a restricted manner: viz, aggregate capital is assumed to be fixed, so that a merger can be viewed as a reallocation of capital. As section 2 of our paper shows, making the aggregate level and not simply the distribution of capital endogenous introduces a powerful force that may make cooperation disadvantageous.

The critical assumption in section 2 is that nations may be able to cooperate on certain clearly defined policies, such as production and export tax/subsidies, but find it difficult to cooperate on more fundamental policies which directly affect investment. This appears to be a reasonably accurate description of international attempts at cooperation, such as those between the U.S. and Canada and among the EC nations. In these situations the common belief that partial cooperation is a step in the right direction may be wrong.

Section 3 contains the starkest example of disadvantageous cooperation; this is based on an extreme form of supply response in ROW. This example shows that the results of Section 2 are strengthened if capital in ROW is made endogenous.

In negotiating bilateral trade agreements, nations have paid insufficient attention to the possibly adverse incentives created by partial cooperation. We interpret the results of this paper as an encouragement for more comprehensive agreements rather than an indictment of previous attempts to foster cooperation.

Appendix A

1. $$\left.\frac{\partial W_i}{\partial s_i}\right|_{s_i=s_m^*} = (m-1)\frac{\partial \pi_i}{\partial x_j}\frac{\partial x_j}{\partial s_i} + (n-m)\frac{\partial \pi_i}{\partial x_k}\frac{\partial x_k}{\partial s_i} -$$

$$- \frac{\partial \pi_i}{\partial x_{-i}}\left[(m-1)\frac{\partial x_j}{\partial s_m} + (n-m)\frac{\partial x_k}{\partial s_m}\right]\frac{\partial x_i}{\partial s_i}\left[\frac{\partial x_i}{\partial s_m}\right]^{-1},$$

by using (3). Noting that $\frac{\partial \pi_i}{\partial x_{-i}} = \frac{\partial \pi_i}{\partial x_j}$ and that $\frac{\partial x_j}{\partial s_m} = \frac{\partial x_i}{\partial s_m}$ by symmetry we can write the above expression as

$$\left.\frac{\partial W_i}{\partial s_i}\right|_{s_i=s_m^*} = \frac{\partial \pi_i}{\partial x_{-i}}\left[(m-1)\frac{\partial x_i}{\partial m_m}\left[\frac{\partial x_{-i}}{\partial s_i} + \frac{\partial x_i}{\partial s_i}\right] +\right.$$

$$\left. + (n-m)\left[\frac{\partial x_k}{\partial s_i}\frac{\partial x_i}{\partial s_m} - \frac{\partial x_k}{\partial s_m}\frac{\partial x_i}{\partial s_i}\right]\right]\left[\frac{\partial x_i}{\partial s_m}\right]^{-1}$$

By using (1) and (2) and after some calculations we finally get the expression in the text.

2. $$\left.\frac{\partial W_m}{\partial s_k}\right|_{s_m=s_m^*} = m\left.\frac{\partial W_i}{\partial s_k}\right|_{s_m=s_m^*}.$$ But, by using (3)

$$\left.\frac{\partial W_i}{\partial s_k}\right|_{s_m=s_m^*} = \frac{\partial \pi_i}{\partial x_{-i}}\left[(n-2)\frac{\partial x_{-k}}{\partial s_k} + \frac{\partial x_k}{\partial s_k}\right] -$$

$$- \frac{\partial \pi_i}{\partial x_{-i}}\left[(m-1)\frac{\partial x_i}{\partial s_m} + (n-m)\frac{\partial x_k}{\partial s_m}\right]\frac{\partial x_i}{\partial s_k}\left[\frac{\partial x_i}{\partial s_m}\right]^{-1}$$

After routine manipulations and by using (1) and (2) we finally get the expression in the text.

Appendix B: Sketch of Equilibrium for Linear Model

Inverse demand is given by $p = 1 + \theta - (q_1 + q_2)/2$; variable cost is $c_i = [(1 - \alpha k_i) + \gamma q_i/2]q_i$; investment cost is $v_i = (1 + \rho k_i/2)/k_i$. The solution to the non-cooperative quantity setting game between firms is

$$q = A_0(s + \alpha k + \theta \ell) \tag{B.1}$$

where $A_0 = \begin{bmatrix} 1+\gamma & .5 \\ .5 & 1+\gamma \end{bmatrix}^{-1}$, $\qquad \ell' = (1, 1)$

and s and k are vectors. The payoff to firm 1 in the second period is the quadratic form

$$\pi_1 = B_0 + B_1'(s + \alpha k) - \frac{1}{2}(s + \alpha k)B_2(s + \alpha k) \tag{B.2}$$

This expression uses the following definition:

$$A_1 = A_0 \begin{bmatrix} 1+\gamma & .5 \\ .5 & 0 \end{bmatrix} A_0 , \qquad I_1 = \begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix}$$

$$\ell_1' = (1, 0)$$

$$B_0 = (\ell_1' A_0 \ell - \frac{1}{2} \ell' A_1 \ell)\theta^2$$

$$B_1' = (\ell_1' A_0 + \ell' A_0 I_1 - \ell' A_1)\theta$$

$$B_2 = A_1 - I_1 A_0 - A_0 I_1 .$$

If the governments behave non-cooperatively, government 1's objective is to choose s_1 to maximize π^1 minus the cost of the subsidy. Designate this function as W_1, given by

$$W_1 = B_0 + B_1'\alpha k - \frac{1}{2}\alpha^2 k'B_2 k + B_3's + \alpha k'B_4 s - \frac{1}{2}s'A_1 s , \qquad (B.3)$$

where $B_4 = I_1 A_0 - A_1$.

Government 2 has a similar maximization problem. Define the permutation matrix $P = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$. The first order condition for government 1 is

$$\ell_1' [B_3 + \alpha B_4'k - A_1 s] = 0 .$$

The system of first order conditions is then

$$C_0 + \alpha C_1 k = C_2 s,$$

where $C_0 = \ell_1' B_3 \ell$

$$C_1 = \begin{bmatrix} \ell_1' B_4 \\ \hline \ell_1' B_4 P \end{bmatrix}$$

$$C_2 = \begin{bmatrix} \ell_1' A_1 \\ \hline \ell_1' A_1 P \end{bmatrix} .$$

Define $C_3 = C_2^{-1} C_0$, $C_4 = C_2^{-1} C_1$, so that the equilibrium subsidy is

$$s = C_3 + \alpha C_4 k \qquad (B.4)$$

If the governments do cooperate, the joint payoff (firm profits less subsidy costs) is $W = W_1 + W_2$,

$$W = 2B_0 + B_1^{*\prime}\alpha k - \frac{1}{2}\alpha^2 k'B_2^* k + B_3^{*\prime}s + \alpha k'B_4^* s - \frac{1}{2}s'A_1^* s , \qquad (B.5)$$

which uses the definitions

$$A_1^* = A_1 + PA_1P$$

$$B_1^* = (I + P)B_1$$

$$B_2^* = B_2 + PB_2P$$

$$B_3^* = (I + P)B_3$$

$$B_4^* = B_4 + PB_4P$$

Maximization with respect to s require

$$s = C_3^* + \alpha C_4^* k \qquad (B.6)$$

where $C_3^* = A_1^{*-1}B_3^*$, $C_4^* = A_1^{*-1}B_4^{*\prime}$.

We now step back to period 1, and first consider the case where governments do not cooperate. Substituting (B.4) into (B.2) gives firm 1's equilibrium payoff as a function of k, as

$$\Pi_1^n = D_0 + D_1'k - \frac{1}{2} k'D_2k \ . \qquad (B.7)$$

Substituting (B.4) into (B.3) gives the payoff to government 1 as a function of k,

$$W_1^n = D_3 + D_4'k - \frac{1}{2} k'D_5k \ . \qquad (B.8)$$

The definition of D_i, i = 0,1,...,5 are obtained by performing the substitutions.

Firm 1's problem is to choose k_1 to maximize Π_1^n given by (B.7), less the private cost of investment, $[(1 - \phi_1) - \rho k_1/2]k_1$. Firm 2 faces an analogous problem. Their equilibrium decision results in a linear system

$$k = E_0 + E_1\Phi \tag{B.9}$$

where E_0 and E_1 are obtained from the parameters of the firms maximization problem, described above.

Government 1 chooses Φ_1 to maximize W_1^n given in (B.8), less the social cost of investment, $(1 - \rho k_1/2)k_1$. Using (B.9) to eliminate k gives government 1's maximand as a function of Φ. We follow a parallel procedure to obtain government 2's maximand. The equilibrium of the resulting non-cooperative game gives the equilibrium value of Φ.

When the governments cooperate in setting s, the procedure is exactly as above, except that the rule given by (B.6), rather than (B.4), is used.

Table 1 Comparison of Equilibria under Second Period Cooperation Vs Non-cooperation

	(a)	(b)	(c)	(d)	(e)
γ	J^{*c}/J^{*n}	k^c/k^n	Φ^c/Φ^n	p^c/p^n	s^c/s^n
.95	.9256	1.931	-3.18	1.082	-3.4
1.1	1.0002	1.706	-2.59	1.081	-3.59
1.3	1.0253	1.564	-2.32	1.071	-3.91
1.5	1.0297	1.500	-2.26	1.061	-4.26
1.7	1.0288	1.481	-2.30	1.052	-4.63
1.9	1.0263	1.504	-2.39	1.045	-5.005

Parameter value $\theta = 4,\ \alpha = 1,\ \rho = 2$

(a) Ratio of equilibrium social payoff under cooperation and non-cooperation
(b) Ratio of equilibrium investment levels
(c) Ratio of investment subsidies
(d) Ratio of equilibrium consumer prices
(e) Ratio of production subsidies

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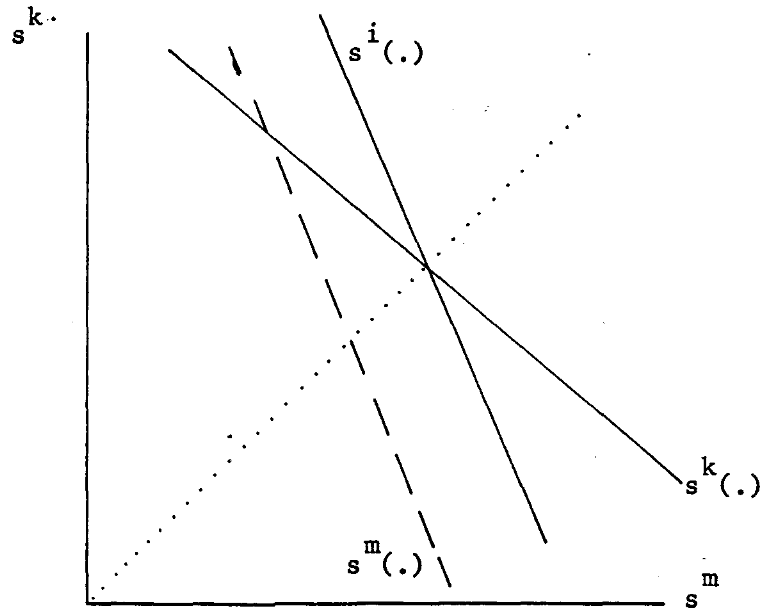
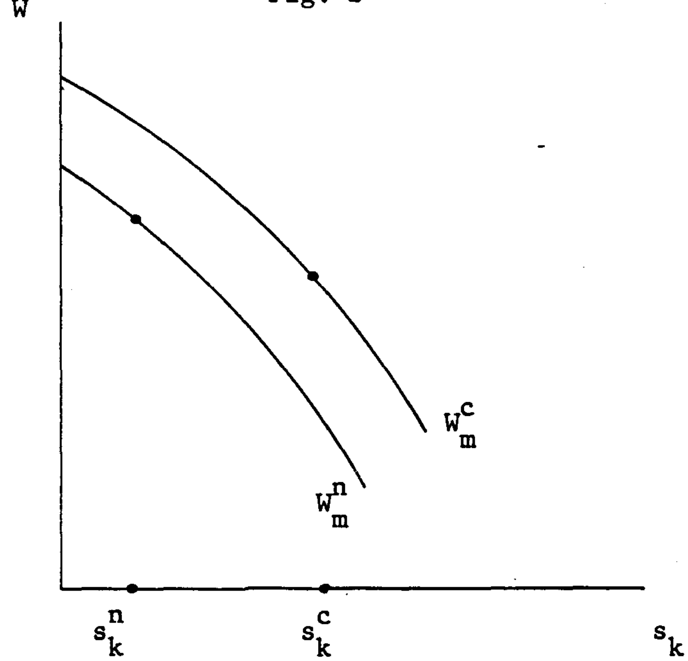
Fig. 1



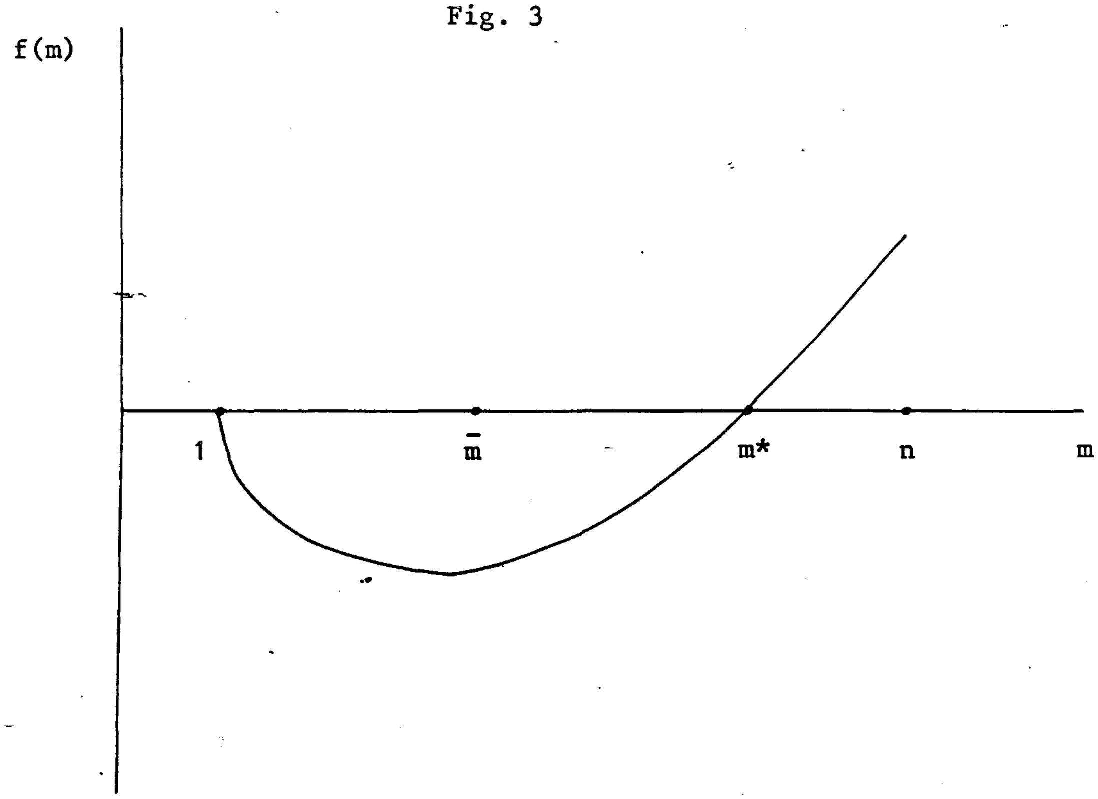
Formation of the custom union increases the equilibrium subsidy of non-members

Fig. 2



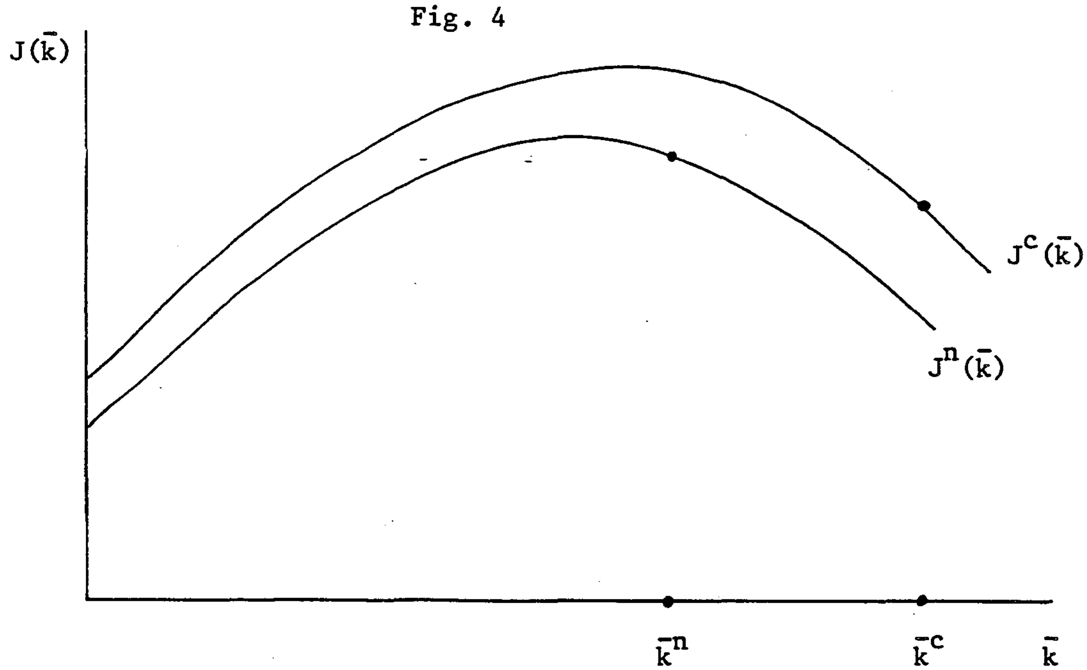
The equilibrium payoff to potential union members may be lower when the union is formed, due to the increased subsidy by non-members.

Fig. 3



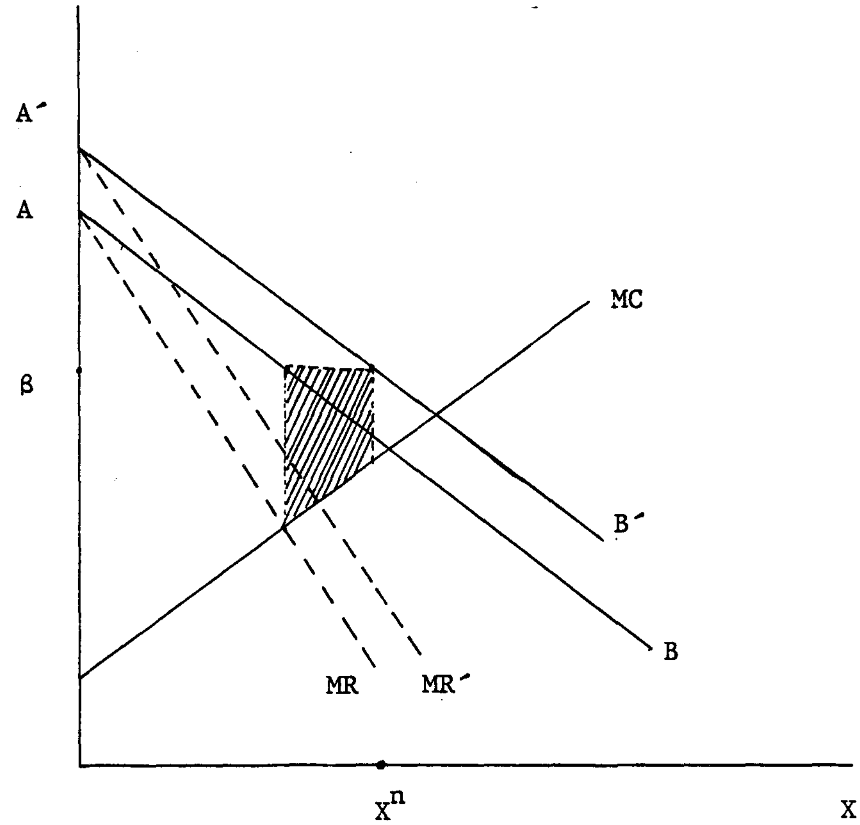
Welfare comparisons for the linear model.

Fig. 4



The possibility that second period cooperation is disadvantageous when investment is endogenous.

Fig. 5



The welfare loss due to second period cooperation when investment by ROW is endogenous.

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