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CAN INTERNATIONAL POLICY COORDINATION REALLY BE COUNTERPRODUCTIVE?

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ABSTRACT

This paper shows that international policy coordination is not counterproductive in a world where the incentive to run beggar-thy-neighbor policies internationally arises from the inefficiency that characterizes, within each country, the interaction between policymakers and private agents. The domestic inefficiency arises from the presence of nominal contracts that give central banks the power to affect real variables. In this setting we show that international cooperation belongs to central banks' dominant strategy. The paper is motivated by a common and misleading interpretation of a paper by Rogoff [1985], namely that international cooperation may be counterproductive in the presence of a domestic inefficiency.

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1. Introduction

There are two well known results in game theory, relating to the optimality of cooperative strategies. The first states that when all players cooperate, their welfare is higher than in the absence of cooperation. The second states that when only some players in a game cooperate, all players may be worse off than in a situation where nobody cooperates. When considered from the viewpoint of international policy coordination, the latter result suggests that cooperation among the monetary authorities of different countries may be suboptimal if cooperation cannot be extended to the game that takes place within each country between the authorities and private agents (see Rogoff [1985]). This paper questions the above intuition by making the simple point that in a one-stage game with three players, in which one player must move before the others, cooperation among the remaining two is still their dominant strategy, even when the player who moves first fails to cooperate.

The sequential character of the game is not crucial for the result: it may occurr even when the three players decide simultaneously. However, sequential games are important because the interaction between policymakers and private agents is often cast in a sequential framework. Consider for example the result, due to Barro and Gordon [1983], that policymakers' incentive to move output away from the natural rate may produce an inefficient outcome: this can only occur if policymakers have not only the incentive, but also the power to affect real variables. To explain why they should have such a power, one has to appeal to nominal contracts.[1] The existence of contracts makes the game sequential. Consider now a two-country world with nominal wage contracts: once wages are set in each country, the two central banks can decide whether to form a coalition or not to cooperate. Since there are only two players, cooperation is unambiguously superior. Thus, at the time when contracts are signed, wage-setters will anticipate not only the power and the incentive that central banks have to affect real wages ex-post, but also their incentive to cooperate internationally. International cooperation thus belongs to the (unique) subgame perfect equilibrium outcome of the game. We prove this result in section 3.

This paper is motivated by a common and misleading interpretation of a paper by Rogoff [1985], namely that international cooperation may be counterproductive in the presence of a domestic inefficiency. Rogoff computes an outcome in which central banks cooperate, and wage-setters expect them to cooperate, and one in which central banks do not cooperate and are expected not to cooperate. Comparing the two outcomes is misleading, because the case where central banks do not cooperate is not a (subgame perfect) equilibrium of the sequential game. The appropriate comparisons must be restricted to equilibrium outcomes.

It remains true, however, that the cooperative outcome, although an equilibrium, may not be optimal--in the sense that it may be Pareto-dominated by the non-cooperative outcome. This remark would seem to provide an argument in favor of designing "institutions" that make countries' commitment not to cooperate credible--for example cancelling

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[1] If the power to affect real variables were due to information asymmetries, the optimal policy would consist in making information freely available. See Fischer [1986].

routine OECD or G-n meetings. The argument is similar to the view that, in a closed economy, central banks' discretion should be restricted by law. We discuss this issue in section 4. There we show that preventing international cooperation may be suboptimal in a world subject to stochastic shocks.

We conclude that one has to look for explanations other than nominal contracts to argue that international cooperation may be counterproductive. One possible direction is asymmetric information, as in Bean [1986].[2] Another is to raise the number of players--for example considering the presence of a fiscal and a monetary authority within each country, or increasing the number of countries.

2. Monetary Policy Interactions in a Two-Country World

The basic structure of our example is a two-country model with six decision-makers: a representative firm, a union, and a central banker in each of the two countries. This model has been used by Canzoneri and Henderson [1988] and, in a different framework, by Giavazzi and Giovannini [1988a]; it is similar to that analyzed by Rogoff [1985]--in fact it has the same reduced form. The model is laid out in Table 1. Lower case letters indicate variables expressed in logs and in deviations from equilibrium. Upper case letters indicate the level of the same variables. The two countries are symmetric, and in each country domestic labor is the only factor of production. The technology

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[2] This explanation, however, is open to the same criticism that applies to motivations of the time-consistency problem based on information asymmetries, rather than on the assumed existence of nominal contracts. See the previous footnote.

is Cobb-Douglas with decreasing returns.

Table 1: The Model

(1)	$y = (1-\alpha)n - x$
(1')	$y^{*} = (1-\alpha)n^{*} - x$
(2)	$y - y^{*} = \delta(e + p^{*} - p)$
(3)	$m - p = y$
(3')	$m^{*} - p^{*} = y^{*}$
(4)	$q = p + \beta(e + p^{*} - p)$
(4')	$q^{*} = p^{*} + \beta(p - e - p^{*})$
(5)	$V_F = PY - WN$
(5')	$V^{*}_F = P^{*}Y^{*} - W^{*}N^{*}$
(6)	$V_U = -(n)^2$
(6')	$V^{*}_U = -(n^{*})^2$
(7)	$V_B = -\sigma(n - k)^2 - (q)^2$
(7')	$V^{*}_B = -\sigma(n^{*} - k)^2 - (q^{*})^2$

(1) and (1') are output supply equations: (the log of) output in the domestic and foreign (*) country is an increasing function of (the log of) employment, and a decreasing function of a productivity disturbance, x. Domestic and foreign output are imperfect substitutes. Relative prices, the (log of the) level of the real exchange rate, $e+p^{*}-p$, determine the allocation of world demand: this is equation (2). Domestic and foreign money are the only assets, and are non-traded: money demand (equations (3) and (3')) is simply a function of the level of income.

Equations (5), and (5'), (6), and (6'), (7), and (7') describe the objectives of the players in each country. Firms maximize one period profits, and unions aim at stabilizing employment around its natural rate, ($n=n^{\star}=0$).[3] Central banks have two objectives: they minimize the fluctuations of the domestic CPI (defined in equations (4) and (4')), and of the deviation of domestic employment from a target, k, that exceeds the natural rate. This assumes that the natural rate of output lies within the country's production possibility frontier, for example because of the presence of distortions or externalities. The inefficiency of the natural rate of output is the motivation of the game that takes place between the union and the central bank inside each country, and among central bankers internationally. If the natural rates of output were socially optimal, central bankers would have no incentive to affect real variables, and both games would vanish.

The "rules of the game" are as follows.

1) The game is sequential. In period 0 unions set nominal wages for period 1. When period 1 comes, firms choose output and employment, and central bankers set the money stock. The existence of nominal contracts gives central bankers the power to affect real variables ex-post. The realization of the productivity shock is known to firms and central bankers before they make their decisions, but is unknown to unions: the expectation of x when unions set wages is equal to 0. Hence, unions maximize the expected value of equations (6) and (6'): wages are set in period 0 based on the expectation of the price level that will prevail in period 1. With rational expectations, unions anticipate that

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[3] The main point of the paper remains valid if unions also care about fluctuations of the domestic CPI.

equilibrium prices in period 1 will be the outcome of the game involving the domestic and the foreign central bank.

2) Firms are passive players in the game: given wages and the realization of the productivity shock, firms compute their profit-maximizing demand of labor taking monetary policy (that is the price level) as given. This is equivalent to assuming an infinite number of competitive firms in each country, whose aggregate strategy consists in maximizing (5) and (5').[4] From (1) and (1'), we have:

(8) $$n = -(1/\alpha)(w-p) - x/\alpha$$

(8') $$n^{*} = -(1/\alpha)(w^{*}-p^{*}) - x/\alpha$$

3) Central bankers set the money stock given the domestic nominal wage and the reaction function of domestic firms. The equilibrium of the international game between the two central banks can be cooperative or non cooperative. We define cooperation as the outcome of a Nash bargaining process assuming that central banks can committ themselves to the cooperative strategy.

The above "rules of the game" simplify the structure of the problem by restricting the number of strategic interactions among the players in the game to only two: one between the union and the central bank in each country, and one between the central banks of the two countries. We rule out other possible interactions since they would make the equilibrium too difficult to compute analytically. Notice, for example,

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4 This assumption implies that all outcomes of the game must belong to the firms' reaction functions.

that firms do not use foreign output as a factor of production: given wages, employment only depends on the domestic price level, so that unions do not have to take into account what happens abroad.

To provide a simple and stronger proof of our main result we proceed as follows. We start from a non stochastic world with no productivity shocks. Later we allow for stochastic productivity shocks.[5]

3. Optimal Monetary Policies and International Cooperation

3.a A non-stochastic world

In period 0, when they set wages, unions ignore the policy regime that will prevail in period 1. It is straightforward to show that maximization of the unions' expected payoffs implies the following wage-setting rules:

$$w = p^e \qquad\qquad w^* = p^{*e} \tag{9}$$

The wage is equal to the expected price level. This expectation is computed anticipating the international policy regime that will prevail in period 1. Given wages, central banks will decide whether to cooperate or not to cooperate and will choose the optimal level of the money stock accordingly. The anticipation of this choice determines the

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5 Rogoff [1985] shows that in the absence of real shocks, international cooperation is unambiguously counterproductive. The comparison between the two regimes becomes ambiguous in the presence of real disturbances.

expectation of the price level that will prevail in period 1. We restrict our analysis subgame perfect equilibria: this means that in equilibrium central bankers' incentive to achieve n=k, n^*=k by fooling the unions is perfectly anticipated. We compute the subgame perfect equilibrium of the one-stage game in the following way. We first determine the optimal strategy of central banks in period 1; then we compute the optimal strategy of unions in period 0 under the assumption that central banks' behaviour in period 1 is perfectly anticipated.

In period 1, central banks maximize their payoff functions under the following constraints:

Reduced Form in Period 1 (x=0)

(10) $$n = m - w$$

(10') $$n^* = m^* - w^*$$

(11) $$q = \alpha m + (1-\alpha)w + \theta[(m-m^*) - (w-w^*)]$$

(11') $$q^* = \alpha m^* + (1-\alpha)w^* + \theta[(m^*-m) - (w^*-w)]$$

$$\theta = \alpha(1-\beta)/\delta$$

where w and w^* are the wage rates set by unions in period 0.

Central banks can either cooperate or not cooperate.[6] Consider

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[6] In principle the international monetary system could also work asymmetrically, with one country controlling the money stock, while the other controls the exchange rate. We could thus have four regimes: cooperation and non cooperation, under flexible and managed rates. The relevant regimes, however, are only two. This is because when central banks cooperate, the exchange rate regime is irrelevant; when they do not cooperate, managed rate are unstable. In one case the explanation is that the cooperative solution is computed maximizing a single objective function by choosing two out of three possible instruments (e, m, m^*), that are linearly dependent. The instability of a non cooperative regime of managed exchange rates is

first the case of non cooperation. Each central bank sets the money stock taking the partner's money stock as given. Therefore, each central bank believes that a change in its money stock can affect the exchange rate. Because the exchange rate feeds back into domestic prices, each central bank believes that monetary policy can improve the output-price level trade off. For any given level of wages, the non cooperative equilibrium in period 1 is:

(12) $$n = [\sigma k-(\alpha+\theta)w]/[\sigma+\alpha(\alpha+\theta)]$$

(12') $$n^{*} = [\sigma k-(\alpha+\theta)w^{*}]/[\sigma+\alpha(\alpha+\theta)]$$

(13) $$q = \sigma(\alpha k+w)/[\sigma+\alpha(\alpha+\theta)]$$

(13') $$q^{*} = \sigma(\alpha k+w^{*})/[\sigma+\alpha(\alpha+\theta)]$$

which implies the following payoffs[7]:

(14) $$V_B = -\sigma[(\sigma k-(\alpha+\theta)w)/(\sigma+\alpha(\alpha+\theta))-k]^2 - [\sigma(\alpha k+w)/(\sigma+\alpha(\alpha+\theta))]2 \equiv V^{o}_B$$

(14') $$V^{*}_B = -\sigma[(\sigma k-(\alpha+\theta)w^{*})/(\sigma+\alpha(\alpha+\theta))-k]^2 - [\sigma(\alpha k+w^{*})/(\sigma+\alpha(\alpha+\theta))]^2 \equiv V^{*o}_B$$

where the superscript o denotes the non cooperative outcome.

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discussed in Giavazzi and Giovannini [1988b].

7 In equations (14) and (14'), we denote with the same symbol, V_B and V^{*}_B, the payoff functions and their value at maximum. We do this throughout the paper to keep the notation simple, since it never gives rise to ambiguity.

If instead the two central banks agree to cooperate and to form a coalition, they will determine their optimal policy by maximizing a joint objective function. We define the cooperative equilibrium as the outcome of a Nash bargaining problem, and we compute it by maximizing the product of the gains from agreement:[8]

$$\max_{m,m^*} [V_B(m,m^*,w,k)-V^o_B)][V^*_B(m^*,m,w^*,k)-V^{*o}_B)] \tag{15}$$

where V^o_B and V^{*o}_B, defined in equations (14) and (14'), are the payoffs in the absence of international cooperation. Because the two countries are symmetric, the solution of this problem is such that $m = m^*$, and is thus easy to compute. For any given level of wages, the cooperative equilibrium in period 1 is:

$$n = (\sigma k-\alpha w)/(\sigma+\alpha^2) \tag{16}$$

$$n^* = (\sigma k-\alpha w^*)/(\sigma+\alpha^2) \tag{16'}$$

$$q = \sigma(\alpha k+w)/(\sigma+\alpha^2) \tag{17}$$

$$q^* = \sigma(\alpha k+w^*)/(\sigma+\alpha^2) \tag{17'}$$

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8 The Nash bargaining solution has recently been discussed and clarified by Binmore, Rubinstein and Wolinski [1986], Rochet [1986]. An application to an international policy game is contained in Bean [1986]. We compute the cooperative equilibrium assuming that central banks can sign binding agreements to cooperate. No cooperative agreement could instead be signed between the union and the central bank within each country, because central banks and unions make their decision at different times. Cooperative agreements would also be impossible if we assumed that the union were a fictitious agent whose strategy derives from aggregating the strategies of an infinite number of atomistic agents. Carraro [1985, 1988] discusses the implications of the sequential character of the one-stage game when the game is repeated.

which implies the following payoffs:

(18) $$V_B = -\sigma[(\sigma k-\alpha w)/(\sigma+\alpha^2)-k]^2-[\sigma(\alpha k+w)/(\sigma+\alpha^2)]^2 \equiv V^c_B$$

(18') $$V^*_B = -\sigma[(\sigma k-\alpha w^*)/(\sigma+\alpha^2)-k]^2-[\sigma(\alpha k+w^*)/(\sigma+\alpha^2)]^2 \equiv V^{*c}_B$$

where the superscript c denotes the cooperative outcome.

The comparison of V^c_B and V^o_B (V^{*c}_B and V^{*o}_B respectively) proves the following result:

Proposition 1*: Each central bank achieves a larger payoff in the presence of international cooperation, whatever the wage set by the domestic union in period 0.*

Proof: It is possible to write:

(19) $$V^c_B - V^o_B = (w+ak)^2 \left[\frac{\sigma^2+\sigma(\alpha+\theta)^2}{(\sigma+\alpha(\alpha+\theta))^2} - \frac{\sigma\alpha^2+\sigma^2}{(\sigma+\alpha^2)^2}\right]$$

where the term in square brackets can easily be shown to be positive. Hence, $V^c_B > V^o_B$ <u>whatever</u> w. In the same way, it is possible to show that $V^{*c}_B > V^{*o}_B$ <u>whatever</u> w^*. International cooperation is the central banks' dominant strategy in period 1, independently of the wage set by unions in period 0. Thus cooperation is the only subgame perfect equilibrium of the game. To compute this equilibrium we must turn to the behavior of unions in period 0. Before doing so we note that international cooperation implies the following values for the two money stocks:

$$m = (\sigma k-\alpha w)/(\sigma+\alpha^2) + w \tag{20}$$

$$m^* = (\sigma k-\alpha w^*)/(\sigma+\alpha^2) + w^* \tag{20'}$$

In period 0 unions set wages maximizing (6) and (6') subject to the following constraints:

<u>Reduced Form in Period 0 (x=0)</u>

$$n = m - m^e \tag{21}$$

$$n^* = m^* - m^{*e} \tag{21'}$$

$$e = [1-\alpha(1-\delta)](m-m^*)/\delta - [(1-\alpha)(1-\delta)](m^e-m^{*e})/\delta \tag{22}$$

$$q = m^e + \alpha(m-m^e) + \theta[(m-m^*)-(m^e-m^{*e})] \tag{23}$$

$$q^* = m^{*e} + \alpha(m^*-m^{*e}) + \theta[(m^*-m)-(m^{*e}-m^e)] \tag{23'}$$

where m and m^* are defined in (20) and (20'). The optimal wage is:

$$w = w^* = \sigma k/\alpha \tag{24}$$

Substituting equation (24) in equations (18) yields the subgame perfect equilibrium of the sequential game, and the central banks' payoffs that are, respectively:

$$n = n^* = 0 \tag{25}$$

$$q = q^* = \sigma k/\alpha \tag{26}$$

$$V_B = V^*_B = -\sigma k^2 - (\sigma k/\alpha)^2 \tag{27}$$

The result that the equilibrium where the two central banks cooperate is the only subgame perfect equilibrium of the sequential game can also be shown in the following way. Let the unions choose between w^c and w^o in period 0, where w^c is the wage when unions expect international cooperation in period 1, and w^o is the wage when they expect that central banks will not cooperate. Let m^c and m^o denote the central banks' strategy in the presence and absence of international cooperation respectively. The game can be described by the following decision tree:

<u>The Extensive Form of the Game (x=0)</u>

```
               Union
                /\
           w^c /  \ w^o
              /    \
       C.Bank        C.Bank
         /\            /\
    m^c /  \ m^o  m^c /  \ m^o
       /    \        /    \
     2,1    1,0    4,0    3,1
```

where the numbers indicate the ranking assigned to the different payoffs by the central bank and the union respectively. As previously shown, m^c is a dominant strategy for the central bank whatever w. Anticipating this outcome, the union maximizes its payoff setting the wage equal to w^c. The sequence (w^c, m^c) is the only subgame perfect euilibrium. Notice that the sequence (w^o,m^o) would yield the following outcome:

$$n = n^{*} = 0 \tag{28}$$

$$q = q^{*} = \sigma k/(\alpha+\theta) \tag{29}$$

$$V_B = V^{*}_B = -\sigma k^2 - (\sigma k/(\alpha+\theta))^2 \tag{30}$$

The sequence (w^O, m^O) Pareto-dominates the sequence (w^C, m^C). However, the outcome (28)-(29) is not a subgame perfect equilibrium and can only be achieved if central banks can sign in period 0 a binding agreement not to cooperate. If this were possible, however, central banks could commit themselves to even better strategies. In particular, they could achieve the Pareto optimum by precommitting to set $m=m^{*}=0$.[9]

[9] The sequential character of the game is not crucial for the result that cooperation belongs to central banks' dominant strategy. The same result holds when the four players decide simultaneously, and the two central banks set the money stock taking nominal wages as given. In the specific model used in this paper, the subgame perfect equilibrium of the sequential game and the Nash equilibrium of the game in which all players decide simultaneously coincide. This is due to the particular form of the unions' loss function. If we modify this loss function (for instance including the domestic CPI among the unions' targets), the two equilibria would not coincide, altough it would still be true that cooperation belongs to central banks' dominant strategy.

3.b A stochastic world

We now compute the subgame perfect equilibrium of the international policy game allowing for stochastic real shocks. In the presence of a common productivity shock, x, in the two countries, the reduced form of the model in period 1 is:

Reduced Form in Period 1 ($x \neq 0$)

(31) $$n = m - w$$

(31') $$n^* = m^* - w^*$$

(32) $$q = \alpha m + (1-\alpha)w + x + \theta[(m-m^*) - (w-w^*)]$$

(32') $$q^* = \alpha m^* + (1-\alpha)w^* + x + \theta[(m^*-m) - (w^*-w)]$$

Central bankers maximize their payoff function given domestic wages and the above constraints. We consider again two regimes: cooperation and non cooperation. In the case of non cooperation, the outcome of the game and the payoffs of central banks are respectively:

(33) $$n = [\sigma k-(\alpha+\theta)(w+x)]/[\sigma+\alpha(\alpha+\theta)]$$

(33') $$n^* = [\sigma k-(\alpha+\theta)(w^*+x)]/[\sigma+\alpha(\alpha+\theta)]$$

(34) $$q = \sigma[\alpha k+w+x]/[\sigma+\alpha(\alpha+\theta)]$$

(34') $$q^* = \sigma[\alpha k+w^*+x]/[\sigma+\alpha(\alpha+\theta)]$$

(35) $$V_B = -\sigma[(\alpha+\theta)(w+x)+\alpha(\alpha+\theta)k]^2/[\sigma+\alpha(\alpha+\theta)]^2 - \sigma^2[\alpha k+w+x]^2/[\sigma+\alpha(\alpha+\theta)]^2 \equiv V^o_B$$

(35') $$V^*_B = -\sigma[(\alpha+\theta)(w^*+x)+\alpha(\alpha+\theta)k]^2/[\sigma+\alpha(\alpha+\theta)]^2 - \sigma^2[\alpha k+w^*+x]^2/[\sigma+\alpha(\alpha+\theta)]^2 \equiv V^{*o}_B$$

If the two central banks decide to cooperate and form a coalition, the Nash bargaining outcome and the central banks' payoffs are instead:

(36) $$n = [\sigma k-\alpha(w+x)]/[\sigma+\alpha^2]$$

(36') $$n^* = [\sigma k-\alpha(w^*+x)]/[\sigma+\alpha^2]$$

(37) $$q = \sigma[\alpha k+w+x]/[\sigma+\alpha^2]$$

(37') $$q^* = \sigma[\alpha k+w^*+x]/[\sigma+\alpha^2]$$

(38) $$V_B = -\sigma[\alpha^2k+\alpha(w+x)]^2/(\sigma+\alpha^2)^2 -\sigma^2[\alpha k+w+x]^2/(\sigma+\alpha^2)^2 \equiv V^c{}_B$$

(38') $$V^*{}_B = -\sigma[\alpha^2k+\alpha(w^*+x)]^2/(\sigma+\alpha^2)^2 -\sigma^2[\alpha k+w^*+x]^2/(\sigma+\alpha^2)^2 \equiv V^{*c}{}_B$$

The comparison of the central banks' payoffs in the two regimes proves the following result:

Proposition 2: *Each central bank achieves a larger payoff in the presence of international cooperation, whatever the wage set by the domestic union in period zero, and whatever the productivity shock occurring in period 1.*

Proof: The inequality

(39) $$V^c{}_B-V^o{}_B = (w+x+ak)^2\left[\frac{\sigma^2+\sigma(\alpha+\theta)^2}{(\sigma+\alpha(\alpha+\theta))^2} - \frac{\sigma\alpha^2+\sigma^2}{(\sigma+\alpha^2)^2}\right] > 0$$

is always satisfied because the term in square brackets is always positive. Simmetrically, we have $V^{*c}{}_B-V^{*o}{}_B > 0$, whatever w^* and x.

Proposition 2 shows that international cooperation is the only subgame perfect equilibrium of the game even in the presence of real disturbances. We compute this equilibrium proceeding as in the previous section. The money stocks in period 1 are:

$$(40) \qquad m = (\sigma k-\alpha(x+w))/(\sigma+\alpha^2) + w$$

$$(40') \qquad m^* = (\sigma k-\alpha(x+w^*))/(\sigma+\alpha^2) + w^*$$

In period 0, the unions maximizes the expected value of (6) and (6') subject to:

<u>Reduced Form in Period 0 ($x \neq 0$)</u>

$$(41) \qquad n = m - m^e$$

$$(41') \qquad n^* = m^* - m^{*e}$$

$$(42) \qquad e = [1-\alpha(1-\delta)](m-m^*)/\delta - [(1-\alpha)(1-\delta)](m^e-m^{*e})/\delta$$

$$(43) \qquad q = me + \alpha(m-m^e) + x + \theta[(m-m^*)-(m^e-m^{*e})]$$

$$(43') \qquad q^* = m^{*e} + \alpha(m^*-m^{*e}) + x + \theta[(m^*-m)-(m^{*e}-m^e)]$$

where m and m^* are defined in (40) and (40'). Recalling that the expected value of x, as of period 0, is zero, we have:

$$(44) \qquad w = w^* = \sigma k/\alpha$$

The outcome of the sequential game and the central banks' payoffs are therefore:

$$(45) \qquad n = n^* = -\alpha x/(\sigma+\alpha^2)$$

(46) $$q = q^{*} = \sigma k/\alpha + \sigma x/(\sigma+\alpha^{2})$$

(47) $$V_{B} = V^{*}_{B} = -\sigma[k + \alpha x/(\sigma+\alpha^{2})]^{2} - [\sigma k/\alpha + \sigma x/(\sigma+\alpha^{2})]^{2} \equiv V^{cc}_{B}$$

For example, following a positive realization of x (i.e. when output is negatively affected by the productivity shock), employment falls and the CPI rises.

Notice however that, contrary to the deterministic case, even if central banks could precommitt not to cooperate, the resulting equilibrium would no longer be unambiguously superior to the cooperative outcome (45)-(46). If, in period 0, central banks committ themselves not to cooperate, the equilibrium outcome of the game and the central banks' payofs are respectively:

(48) $$n = n^{*} = -(\alpha+\theta)x/[\sigma+\alpha(\alpha+\theta)]$$

(49) $$q = q^{*} = \sigma k/(\alpha+\theta) + \sigma x/[\sigma+\alpha(\alpha+\theta)]$$

(50) $$V_{B} = V^{*}_{B} = -\sigma[k + (\alpha+\theta)x/(\sigma+\alpha(\alpha+\theta))]^{2} - [\sigma k/(\alpha+\theta) + \sigma x/(\sigma+\alpha(\alpha+\theta))]^{2} \equiv V^{oo}_{B}$$

(51) $$V_{U} = V^{*}_{U} = -\sigma^{2}x^{2}/[\sigma+\alpha(\alpha+\theta)]^{2} \equiv V^{oo}_{U}$$

It is easy to show that employment is higher when unions expect central banks to cooperate, and central banks indeed cooperate, than in the case where unions expect central banks not to cooperate, and they do not cooperate. In contrast, the CPI is lower in this latter case. The welfare comparison therefore depends on central banks' preferences. Some algebra shows that $V^{cc}_B > V^{oo}_B$ iff:

$$x\theta[2(\sigma+\alpha^2)(\sigma+\alpha(\alpha+\theta))\sigma k - x\sigma\alpha\theta(\alpha+\theta)]/A + B < 0 \tag{52}$$

where $A \equiv \alpha(\sigma+\alpha^2)(\alpha+\theta)[\sigma+\alpha(\alpha+\theta)]^2$, and $B \equiv 2k^2\theta(2\alpha+\theta)/\alpha^2(\alpha+\theta)$.
The non cooperative outcome is unambiguously superior to the cooperative outcome only if the productivity shock is contained in an interval that lies in a neighborhood of x=0.[10]

For x relatively large, the extensive form of the game can be written as:

<u>The Extensive Form of the game (x "large")</u>

```
              Union
               /\
          w^c /  \ w^o
             /    \
       C.Bank      C.Bank
         /\          /\
   m^c  /  \ m^o m^c /  \ m^o
       /    \       /    \
     3,3    1,0   4,2    2,1
```

m^c is still the central banks' dominant strategy and (w^c,m^c) is the only subgame perfect equilibrium of the game. Furthermore, the sequence

10 (52) a quadratic inequality in x: denote by r1 and r2 the two roots of the associated equation, where r1 can be shown to be positive and r2 negative. $V^{cc}_B < V^{oo}_B$ only if the productivity shock is contained in the interval (r1,r2), that lies in a neighborhood of x=0.

(w^c, m^c) dominates the sequence (w^o, m^o), which is not an equilibrium.[11]

4. Concluding remarks

The paper has studied international policy coordination in a world where the incentive to run beggar-thy-neighbor policies arises from the inefficiency that characterizes, within each country, the interaction between wage-setters and the central bank. We have shown that if central banks can decide, period by period, and after having observed wages and real shocks, whether or not to form international coalitions, the only subgame perfect equilibrium is the cooperative equilibrium. However, if real shocks are "small", the equilibrium outcome is dominated by the outcome that would obtain if central banks could precommitt not to form coalitions. If one wished to interpret this result as suggestive of whether central banks should be prevented from forming international coalitions, the choice would depend on the variance of real shocks, relative to the inefficiency associated with central banks' incentive to affect real variables ex-post. The condition is:

$$\text{var}(x) < \phi(\sigma)k^2 \tag{53}$$

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[11] As in the deterministic case, the result that cooperation is the dominant strategy in the second stage of the game is robust with respect to different specifications of unions' loss functions, and holds even when the players decide simultaneously. In the latter case, however, the presence of a stochastic shock would be irrelevant. The assumption that unions do not observe the shock makes the presence of stochastic disturbances relevant and justifies the sequential structure of the game.

where:

$$\Phi(\sigma)=2(\sigma+\alpha^2)[\sigma+\alpha(\alpha+\theta)]^2(2\alpha+\theta)/[\sigma\alpha^2\theta(\alpha+\theta)]$$

the smaller is the incentive to be "time-inconsistent"--i.e. the larger are k and σ--the smaller is the range of shocks for which a precommitment not to cooperate is optimal. If the probability of large real shocks is high, restricting central banks from forming international coalitions would yield Pareto-inferior outcomes. But even if such probability were sufficiently small, the optimal rule would not prevent central banks from forming international coalitions, but would restrict their ability to create surprise inflation. The bottom line is that international cooperation is either unavoidable, because it is the only subgame perfect equilibrium in the absence of precommitment, or irrelevant, because the "optimal" precommitment eliminates the need for international cooperation.

We conclude that one has to look for explanations other than nominal contracts to argue that international policy coordination may be counterproductive. One direction is to increase the number of players in the game. Suppose that two authorities coexist in each country: a fiscal and a monetary authority. If fiscal and monetary policy decisions are simultaneous, non cooperation between the two domestic authorities may render international cooperation among central bankers counterproductive. This would not be true if fiscal policy, like nominal wages, were set before monetary policy. The same argument would hold if we dropped the assumption of competitive firms. In oligopolistic markets firms can form coalitions that may be threatened by other players in the game. Finally, international cooperation may be counterproductive in a world with many countries of similar size if only a subset of countries agrees to cooperate. In all these cases the general result stated in the Introduction can be applied: the outcome of a game when only a subset of players cooperate may be dominated by the non cooperative outcome.

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