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PRODUCTIVE AND COUNTERPRODUCTIVE COOPERATIVE MONETARY POLICIES

by

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I. Introduction

Schemes to increase coordination among central banks of employment and inflation-rate stabilization policies have received renewed attention recently.[1/] Unfortunately, most of these schemes focus entirely on how central banks might cooperate to offset unanticipated disturbances, and pay little or no attention to the problem of systematically maintaining low expected rates of inflation. The present paper is an effort to provide a simple macroeconomic framework in which to examine both issues.[2/] Within the context of a two-country model of a managed floating exchange rate system, we simultaneously analyze the strategic interactions of sovereign monetary authorities across countries, and the strategic interactions of private agents and the monetary authorities within a given country.[3/]

The main result of this paper is that, contrary to the usual conclusion (and presumption) of earlier analyses, increased monetary policy cooperation between two governments does not automatically increase welfare in either country. In fact, welfare in one or both countries may be higher when central banks conduct their monetary policies independently. It is true that a cooperative regime does produce better responses to certain types of unanticipated disturbances (such as supply shocks or relative shifts in aggregate demand). But when monetary policy is fully discretionary, inter-central bank cooperation can also lead to systematically higher expected rates of inflation: private sector wage setters will choose higher rates of nominal wage growth if they rationally fear that the central banks will coordinate their efforts to lower real wages and raise employment. (The conflict between wage setters and the central banks is generated by some type of labor market distortion which causes the natural rate of unemployment to be too high.) Therefore, monetary policy cooperation is unambiguously beneficial only in institutional frameworks which eliminate or ameliorate the central banks' credibility problem vis-a-vis wage setters.[4/]

Except for the fact that it incorporates rational expectations (*cum* wage contracting), the stochastic, two-good, two-country model we employ is quite similar to ones which have been used to characterize the benefits of inter-governmental cooperation. Although sterilized intervention is ineffective here (since bonds denominated in different currencies are perfect substitutes),[5/] domestic open market operations can still be used to temporarily offset the real effects of unanticipated disturbances. Nominal wage contracts, negotiated a period in advance and only partially indexed to the current price level, provide the fulcrum for monetary policy. Unanticipated foreign monetary policy similarly can have real effects on the domestic economy (through the real exchange rate and through real interest rates). The equations and solution of the underlying macroeconomic model are relegated to Appendix A so as to focus on the game-theoretic aspects of the analysis in the text. Nevertheless, many readers may find it useful to at least glance at Appendix A before proceeding to the main body of the text.

Section II describes the home and foreign welfare functions, which depend on own employment and CPI inflation. Section III details the objectives of wage setters, as well as the nature of a time-consistent equilibrium. Section IV describes the cross-effects of home and foreign monetary policy; the real exchange rate plays a key role here. Section V derives the stochastic equilibrium path of the world economy when central banks conduct stabilization unilaterally, and are unable to guarantee to wage setters that they will not try to systematically raise employment. Section VI contrasts the results of Section V with social welfare under a regime in which central banks again lack credibility with wage setters, but are able to cooperate with each other in conducting stabilization policy. Section VII stresses that an optimal cooperative regime -- one which contains institutional constraints on systematic inflation -- is definitely superior to any non-cooperative regime.

II. Domestic and Foreign Social Objective Functions

Each central bank attempts to minimize a social loss function which depends on deviations of own-country employment and inflation from their optimal (socially-desired) values:[6/]

(1a) $\Lambda_t = (n_t - \tilde{n})^2 + \chi(\pi_{It} - \tilde{\pi}_I)^2,$

(1b) $\Lambda_t^* = (n_t^* - \tilde{n}^*)^2 + \chi(\pi_{It}^* - \tilde{\pi}_I^*)^2,$

where Λ (Λ^*) is the home (foreign) social loss function. Star superscripts denote foreign country variables, t subscripts denote time, and lower case letters are used to represent logarithms. (Henceforth, we will discuss only domestic variables and equations in circumstances where discussion of their foreign counterparts is superfluous.) Employment is given by n, and π_I is the rate of consumer price level inflation; e.g., $\pi_{It} = (p_I)_t - (p_I)_{t-1}$, where p_I is the consumer price level.[7/] The socially-preferred values of n and π_I are denoted by $\tilde{n}$ and $\tilde{\pi}_I$. χ is the relative weight which society places on inflation stabilization versus employment stabilization. As with most of the technological and behavioral parameters of the model of Appendix A, χ is assumed to be the same for both countries (though $\tilde{\pi}_I$ and $\tilde{\pi}_I^*$ may differ).[8/] The objective functions (1) are static, but the results below would be unchanged even if we replaced equations (1) by objective functions which also depended on expected future values of inflation and employment. The same results would obtain because the real effects of unanticipated monetary policy last for only one period, the length of the wage contracts.[9/]

III. The Conflict Between Wage Setters and the Central Banks

The tension between wage setters and the central bank within each country derives from the assumption that $\tilde{n}$, society's target employment rate, is greater than $\bar{n}$, wage setters' target employment rate. Possible factors which might distort the labor-leisure decision, thereby causing wage setters to target levels of employment which are too low and levels of real wages which are too high, include income taxation and unemployment insurance.[10/] Monopolistic unions might also cause the average real wage to be too high to sustain society's target employment rate $\tilde{n}$.

Despite the fact that their targets are socially suboptimal, wage setters are able to frustrate any effort by their home central bank to systematically raise the level of employment or lower real wages. They can do so by setting base nominal wage increases at a sufficiently high level so that, in the absence of disturbances, the central bank will not <u>choose</u> to inflate the money supply beyond the point consistent with wage setters' desired real wage.[11/] At this sufficiently high level of inflation, the central bank finds that the marginal utility gain from inflating (further) to raise employment above wage setters' desired level is fully offset by the marginal disutility from the added inflation. Thus equilibrium is characterized by "stagflation."[12/]

It is, of course, possible to consider a cooperative equilibrium between wage setters and their home central bank, in which the central bank promises not to systematically inflate for the sake of raising the average level of employment. The problem is how to design a system to enforce such a promise without constraining the ability of the central bank to offset unanticipated shocks. For example, if it were possible to anticipate every type of disturbance, one could write a law specifying a path of the money supply contingent on each possible disturbance. We shall return to this issue in Section VII.

IV. Mutual Elements in the Home and Foreign Central Bank Objective Functions and the Potential for Cooperative Stabilization Policy

Using equations (16), (17) and (18) of Appendix A, we can rewrite the home and foreign social objective functions as

$$(2a)\quad \Lambda_t = [z_t/\alpha + \gamma(p_t - \bar{w}_t) - \tau q_t - (\tilde{n} - \bar{n})]^2 + \chi[p_t - p_{t-1} + .5(q_t - q_{t-1}) - \tilde{\pi}_I]^2$$

$$(2b)\quad \Lambda_t^* = [z_t/\alpha + \gamma(p_t^* - \bar{w}_t^*) + \tau q_t - (\tilde{n}^* - \bar{n}^*)]^2 + \chi[p_t^* - p_{t-1}^* - .5(q_t - q_{t-1}) - \tilde{\pi}_I^*]^2,$$

where p is the home-currency price of the home good, p* is the foreign-currency price of the foreign good, and q is the real exchange rate: $q \equiv e + p^* - p$ (e is the home-currency price of foreign currency). $\bar{w}$ ($\bar{w}^*$) is the home (foreign) base nominal wage rate, and z is a supply shock common to both countries.

The first term in the home social objective function Λ represents squared deviations of home employment from its socially-desired value; it consists of four components: The first component depends on the productivity disturbance, z, and on the coefficient of the Cobb-Douglas production function, α. The second component depends on the difference between the actual period t price level, p_t, and the base wage rate $\bar{w}$; $\bar{w}$ is set a period in advance equal to the expected value of the consumer price index. The coefficient γ is equal to $(1-\beta)/\alpha$, where β is the degree to which wages are indexed to unanticipated changes in the CPI. It is assumed that $0 \leq \beta < 1$.[13/] The third component involves the real exchange rate, q, and arises because wages are indexed to a price index which includes the foreign good. (The two goods have equal weights in the CPI.[14/]) By construction of the model of Appendix A, the expected value of q is zero and $\tau \equiv .5\beta/\alpha$. A similar component in q would arise if, as in the model of Daniel (1981), the foreign good entered as an intermediate good in the domestic production function. The fourth and final component depends on the difference between society's and wage setters' target levels of employment, $\tilde{n} - \bar{n}$.

The second term in the social objective function is the squared difference between the actual rate of CPI inflation and society's target rate. Again, the real exchange rate enters. Obviously, it is the presence of the real exchange rate in both objective functions which creates opportunities for cooperation or conflict.[15/] We shall begin by considering the non-cooperative or "Nash" equilibrium.

V. Equilibrium When Central Banks Do Not Cooperate to Achieve Their Stabilization Objectives

Each central bank has only one instrument at its disposal, the money supply.[16/] Once base wage rates are set, any unilateral effort by either central bank to influence its own country's price level will also have an effect on the real exchange rate (except in the case of complete wage indexation, $\beta = 1$).[17/] Only if the two central banks inflate jointly can they raise prices in both countries without altering the real exchange rate.

Here we will examine the Nash equilibrium which obtains when each central bank perceives that it cannot improve its own objective function through unilateral action. To focus on the game-theoretic aspects of the model, we will assume that central banks and private investors have full current-period information. To further simplify, we will treat the home price of the domestically-produced good as the home central bank's control variable, though implicitly it is actually controlling the home money supply. This simplification can only be rigorously justified because both countries are assumed to experience identical goods market demand and productivity disturbances. (The analysis in Appendix B allows for relative shifts in aggregate demand, and explicitly treats the money supplies as the control variables.)

The solution algorithm used here may be described as follows: In the two-country macro-model of Appendix A, we solve for the effects of home and foreign money supply changes, holding base wage rates constant and assuming that CPI inflation rate expectations and exchange rate depreciation expectations are static. In the analysis of the text, we employ the partial derivatives obtained in Appendix A to solve for the time-consistent path of wages. We will then confirm that static CPI inflation rate and exchange rate depreciation expectations are indeed rational (provided there are no regime changes).

Once base wage rates are set and the current-period disturbances are observed, the first-order conditions for the two non-cooperating central banks are given by[18/]

$$(3a)\quad (\partial\Lambda_t/\partial p_t)^N = 2[\gamma - \tau\Psi][z_t/\alpha + \gamma(p_t - \bar{w}_t) - \tau q_t - (\tilde{n} - \bar{n})] + 2\chi(1 + .5\Psi)[p_t - p_{t-1} + .5(q_t - q_{t-1}) - \tilde{\pi}_I] = 0,$$

$$(3b)\quad (\partial\Lambda_t^*/\partial p_t^*)^N = 2(\gamma + \tau\Psi^*)[z_t/\alpha + \gamma(p_t^* - \bar{w}_t^*) + \tau q_t - (\tilde{n}^* - \bar{n}^*)] + 2\chi(1 - .5\Psi^*)[p_t^* - p_{t-1}^* - .5(q_t - q_{t-1}) - \tilde{\pi}_I^*] = 0,$$

where N superscripts stand for "Nash" equilibrium, and $\Psi \equiv (\partial q/\partial dm)/(\partial p/\partial dm) > 0$ (m is the home money supply, v is a home money demand disturbance, $dm = m_t - v_t - E_{t-1}(m_t - v_t)$). Due to the symmetry of the underlying macroeconomic model of Appendix A, $\Psi^* \equiv (\partial q/\partial dm^*)/(\partial p^*/\partial dm^*) = -\Psi$; that is holding base wage rates constant, a unilateral foreign money supply increase has exactly the opposite effect on the real exchange rate q as a unilateral home money supply increase. Appendix A also demonstrates that $(\gamma - \tau\Psi) > 0$; i.e., an unanticipated increase in the home money supply raises home employment.

Wage setters are assumed to correctly anticipate whether a cooperative or Nash regime will be in place in the ensuing period.[19/] By examining the first-order conditions (3), wage setters can choose base wage rates so that the expected real wage equals their target real wage. The underlying macro-model is constructed so that wage setters' target (logarithm of the) real wage is zero, and so that $E_{t-1}(q_t) = 0$. Taking t-1 expectations across (3), and setting expected real wages and the expected real exchange rate equal to zero yields [20/]

$$(4a) \quad (\bar{w}_t)^N = E_{t-1}(p_t)^N = p_{t-1} + .5q_{t-1} + \bar{\pi}_I^N,$$

$$(4b) \quad (\bar{w}_t^*)^N = E_{t-1}(p_t^*)^N = p_{t-1}^* - .5q_{t-1} + (\bar{\pi}_I^*)^N,$$

where $\bar{\pi}_I^N \equiv \tilde{\pi}_I + (\gamma - \tau\Psi)(\tilde{n} - \bar{n})/\chi(1 + .5\Psi)$, and $(\bar{\pi}_I^*)^N \equiv \tilde{\pi}_I^* + (\gamma - \tau\Psi)(\tilde{n}^* - \bar{n}^*)/\chi(1 + .5\Psi)$.

By choosing $\bar{w}$ and $\bar{w}^*$ according to equations (4), wage setters assure themselves that the non-cooperating central banks will, in the absence of disturbances, produce price levels consistent with wage setters' target real wages. We see by inspection of equations (4) that the rate of nominal wage growth is an increasing function of the difference between the central banks' target employment rate, $\tilde{n}$, and wage setters' target employment rate, $\bar{n}$. Nominal wage growth is a decreasing function of the weight society places on stabilizing inflation versus stabilizing employment. Using the fact that $E_{t-1}(q_t - q_{t-1}) = -q_{t-1}$, it is easy to deduce from (4) that the expected rate of change of the CPI, $E_t(p_{t+1} + .5q_{t+1}) - (p_t + .5q_t)$, is constant and equal to $\bar{\pi}_I^N$. Thus, rational CPI inflation rate expectations are indeed static.[21/]

Using equations (3) and (4), one can analyze the responses of the non-cooperative system to unanticipated disturbances. Because the two countries are completely identical except for their labor market distortions and target inflation rates, and because they experience identical goods market demand and aggregate supply (but not money demand) shocks, the real exchange rate q always turns out to be zero in Nash equilibrium, regardless of the realization of the disturbances.[22/] To confirm that q = 0 is indeed always a Nash equilibrium, first substitute (4) into (3), and calculate $(p_t)^N$ and $(p_t^*)^N$ under the assumption that q = 0. Subtract $E_{t-1}(p_t)^N$ and $E_{t-1}(p_t^*)^N$ from the resulting expressions to obtain: [23/]

(5a) $(p_t)^N - E_{t-1}(p_t)^N \equiv (dp_t)^N = -z_t/\alpha[\gamma + \chi(1 + .5\Psi)/(\gamma - \tau\Psi)]$,

(5b) $(p_t^*)^N - E_{t-1}(p_t^*)^N \equiv (dp_t^*)^N = -z_t/\alpha[\gamma + \chi(1 + .5\Psi)/(\gamma - \tau\Psi)]$.

Feasibility of the q = 0 Nash equilibrium is confirmed by examining equations (23),(25) and (26) of Appendix A; q = 0 and $dp_t = dp_t^*$ if and only if dm = dm*.[24/] One can also prove that the Nash equilibrium is unique.[25/] Note that although the two countries may have different expected inflation rates, the unanticipated component of home and foreign price movements is the same.

To compare social welfare under the Nash regime with social welfare under a cooperative regime, it will be necessary to compute $E_{t-1}(\Lambda_t)^N$ and $E_{t-1}(\Lambda_t^*)^N$. Using the fact that $q^N = 0$, it is possible to decompose the social loss functions into three components:

$$\text{(6a)} \quad E_{t-1}(\Lambda_t)^N = (\tilde{n} - \bar{n})^2 + \chi\Pi^N + \Gamma^N,$$

$$\text{(6b)} \quad E_{t-1}(\Lambda_t^*)^N = (\tilde{n}^* - \bar{n}^*)^2 + \chi(\Pi^*)^N + (\Gamma^*)^N,$$

where $\Pi^N \equiv [(\bar{\pi}_I)^N - \tilde{\pi}_I]^2$, $(\Pi^*)^N \equiv [(\bar{\pi}_I^*)^N - \tilde{\pi}_I^*]^2$, $\Gamma^N \equiv E_{t-1}\{[z_t/\alpha + \gamma(dp_t)^N]^2 + \chi[(dp_t)^N]^2\}$, and $(\Gamma^*)^N = \Gamma^N$, since $(dp)^N = (dp^*)^N$.

The first element of $E_{t-1}(\Lambda_t)^N$ is nonstochastic and depends on the difference between the socially optimal level of employment, $\tilde{n}$, and wage setters' target level of employment, $\bar{n}$. Because monetary policy cannot systematically raise the employment rate, this term can be reduced only by directly addressing the underlying cause of the distortion. (This issue is beyond the scope of the present paper.) The second term, $\chi\Pi^N$, measures the extent to which the expected CPI inflation rate exceeds society's target rate. This second term is also independent of current-period disturbances, but as we shall later confirm, it is a function of the policy regime. The final term, Γ^N, measures the extent to which the central bank succeeds in stabilizing the employment rate and the CPI inflation rate around their expected market-determined values. Note that although the central banks actually attempt to stabilize inflation and employment around their socially-preferred values, in a time-consistent equilibrium the central banks appear to respond to disturbances as if they were trying to stabilize inflation and employment around their mean market-determined values.[26/] To evaluate Γ^N, substitute in for $(dp_t)^N$ using equation (5a):

$$(7) \quad \Gamma^N = (\sigma_z^2/\alpha^2)[(\chi')^2 + \gamma^2\chi]/(\gamma^2 + \chi')^2 = (\Gamma^*)^N,$$

where σ_z^2 is the variance of the zero mean supply shock, $E_{t-1}(z_t^2)$, and $\chi' \equiv \gamma\chi(1 + .5\Psi)/(\gamma - \tau\Psi)$.

The reason that money demand shocks do not appear in equation (7) is that, to the extent the shocks are known (here information is perfect[27/]), they can be completely neutralized. For example, consider a temporary disturbance to home money demand. The home central bank can temporarily raise the home money supply and, as one may confirm from the model of Appendix A, prevent any effect from being transmitted abroad through exchange rates or interest rates. Furthermore, the resulting stabilization of the domestic price level is consistent with both home price level stability and home employment stability. Thus the home central bank will react to the disturbance in the same fashion whether or not it takes the utility funtion of the foreign central bank into account.[28/] Clearly, if we relax the asumption that investors and central banks have complete contemporaneous information, then the home monetary authority may no longer have sufficient information to fully offset home money demand disturbances. Consequently, these disturbances will have some effects both at home and abroad. If the only problem is incomplete information, however, there is no reason to presume that a cooperative monetary policy regime will lead to better outcomes in response to money demand disturbances than would a fully discretionary non-cooperative regime. (If the central banks place weight on achieving their money supply targets, as in Canzoneri and Gray (1983), then the cooperative and non-cooperative response to money demand shocks will no longer be equivalent.)

Goods market demand shocks do not disturb the Nash equilibrium only because we have made the simplifying assumption that both countries experience the same goods market demand disturbance. (This assumption is relaxed in Appendix B.) Provided that both countries alter their money supplies equally to offset the mutual disturbance, there will be no effect on home and foreign prices and employment. The level of world real interest rates will move to offset the disturbance, but the real exchange rate will remain fixed. The resulting equilibrium is Nash because neither side will have an incentive to unilaterally alter its money supply further.

On the other hand, aggregate supply disturbances do affect the price levels which arise in Nash equilibrium in spite of our simplifying assumption that the home and foreign supply shocks are perfectly correlated. The reason is that an aggregate supply shock creates a trade-off between price level stability and employment stability. As we discuss more fully in Appendix A, an aggregate supply shock alters the market-determined full information real wage; that is, the real wage which wage setters would agree on after observing the productivity disturbance. Because the base nominal wage is set a period in advance, and because wage indexation is incomplete, the central bank can effect wage setters' desired movements in the real wage only by allowing some price level adjustment in response to supply shocks. But while such price level movements are consistent with one social objective, employment stability, they are inconsistent with another social objective, price level stability. In the next section we demonstrate that, holding base wage rates constant, the cooperative response to supply shocks is superior to the non-cooperative response.

VI. Equilibrium When Central Banks Cooperate to Achieve Their Stabilization Objectives

Examining the first-order conditions for the Nash equilibrium (equations (3)), we see that the incentives of the central banks to unilaterally inflate are reduced by their fears of the concommmitant effects on the real exchange rate. The real exchange rate depreciation caused by unilateral home money growth raises consumer price level inflation. Aside from the direct disutility of the higher inflation rate, the home country enjoys less of an increase in employment from unanticipated money growth than it would if the real exchange rate were to remain constant. The reason is that nominal wages are indexed to the CPI, which includes the domestic price of the foreign good.[29]

From the above discussion, it would appear self-evident that each central bank would prefer to increase its money supply beyond the level consistent with Nash equilibrium, provided it could count on the other central bank to increase its money supply. In this section we will assume that the two central banks agree to fix the real exchange rate at the same level which would arise if all the disturbances were zero, and to confer with each other on the most mutually advantageous set of price levels consistent with that real exchange rate.[30/] We will demonstrate below that such an agreement is mutually beneficial only if the variance of supply shocks is large relative to distortions in the labor markets.

Under the cooperative fixed real exchange rate ($q = 0$) regime, the first-order conditions for minimization of the home and foreign social welfare functions (equations (2)) are given by equations (8) below:

(8a) $\gamma[z_t/\alpha + \gamma(p_t - \bar{w}_t) - (\tilde{n} - \bar{n})] + \chi(p_t - p_{t-1} - \tilde{\pi}_I) = 0,$

(8b) $\gamma[z_t/\alpha + \gamma(p_t^* - \bar{w}_t^*) - (\tilde{n}^* - \bar{n}^*)] + \chi(p_t^* - p_{t-1}^* - \tilde{\pi}_I^*) = 0.$

In deriving equations (8), we have made use of the fact that $\partial q/\partial dm$ is zero in the cooperative equilibrium, since each central bank can count on the other to match any further unanticipated change in its money supply. Equations (9), (10), and (11) are derived using the same algorithm used to derive equations (4), (5), and (7) of the previous section: "C" superscripts stand for "cooperative regime".

(9a) $(\bar{w}_t)^C = E_{t-1}(p_t)^C = p_{t-1} + (\bar{\pi}_I)^C,$

where $(\bar{\pi}_I)^C \equiv \tilde{\pi}_I + \gamma(\tilde{n} - \bar{n})/\chi$,

(9b) $(\bar{w}_t^*)^C = E_{t-1}(p_t^*)^C = p_{t-1}^* + (\bar{\pi}_I^*)^C$,

where $(\bar{\pi}_I^*)^C \equiv \tilde{\pi}_I^* + \gamma(\tilde{n}^* - \bar{n}^*)/\chi$,

(10) $(p_t)^C - E_{t-1}(p_t)^C \equiv (dp_t)^C = (dp_t^*)^C = -z_t/\alpha(\gamma + \chi/\gamma)$,

(11) $\Gamma^C = (\sigma_z^2/\alpha^2)[\chi/(\gamma^2 + \chi)] = (\Gamma^*)^C$.

Comparison of equations (9) with their Nash counterparts, equations (4), reveals that the mean rate of CPI inflation is higher under the cooperative regime than under the non-cooperative regime. The intuitive explanation is simple: wage setters anticipate that the two central banks will have stronger incentives to inflate in a regime where each can count on the other's cooperation, so that the benefits of inflation are not reduced by real exchange rate depreciation.

A comparison of equations (10) and (5) reveals that $|(dp_t)^C| > |(dp_t)^N|$. In the Nash equilibrium, the central banks allow the supply shock to affect employment more, and inflation less, than in the cooperative equilibrium.31/ It is easy to prove that the cooperative response to disturbances is superior; i.e., $\Gamma^C < \Gamma^N$:32/

Proof: Note that expressions (11) and (7) can be written in the same general form since $\chi/(\gamma^2 + \chi) = (\chi^2 + \gamma^2\chi)/(\gamma^2 + \chi)^2$. Differentiating the expression $(y^2 + \gamma^2\chi)/(\gamma^2 + y)^2$ with respect to y yields $2\gamma^2(y - \chi)/(\gamma^2 + y)^{-3}$. Note that this derivative is strictly positive for

$y > \chi$ (since $\chi > 0$), and note that $\chi' > \chi$. Q.E.D.

So the cooperative regime produces a better response to unanticipated supply disturbances, but a higher expected inflation rate. Whether social welfare is higher under the cooperative or non-cooperative regime thus depends, in part, on the variance of the supply shock and on the size of the labor market distortion. Note that it is perfectly possible for the country with the smaller labor market distortion to prefer the cooperative regime, while the other country would be better off under a non-cooperative regime. (If the home country had no labor market distortion, it would always prefer the cooperative regime regardless of the variance of the disturbances.)

VII. Institutional Designs for Superior Cooperative Regimes

The possibility that the regime we have labeled "cooperative" might be inferior to the "non-cooperative" regime does not violate the basic tenets of game theory: the central banks are assumed to cooperate with each other, but not with private sector wage setters. Of course, if the central banks were able to credibly guarantee that they would not systematically try to raise employment, and would only use monetary policy to offset disturbances, then it would be possible to achieve a superior and truly cooperative outcome.[33/] The present analysis does suggest cases in which government to government cooperation might lead to better institutional reforms. Suppose, for example, each country passed a binding law fixing the future path of its money supply except for prespecified responses to specific disturbances.[34/] If the two countries designed their monetary constitutions independently, the prespecified response to common supply disturbances would probably be Nash, whereas if they designed their systems jointly, the prespecified response might be closer to the cooperative one.[35/] The behavior of governments in other countries will, in general, be a consideration in evaluating any institutional response to the time-consistency problem discussed here.[36/] Thus it should be clear that an optimally-designed cooperative regime is superior to any non-cooperative scheme.

VIII. Conclusions

Even though monetary policy cooperation produces superior responses to supply shocks and to unanticipated relative shifts in aggregate demand, a fully-discretionary cooperative regime may still be inferior to a fully discretionary non-cooperative regime. The reason is that a non-cooperative regime yields systematically lower time-consistent expected rates of inflation. Each central bank's incentive to inflate is lower in a non-cooperative regime because, once base wage rates are set, unilateral money supply growth causes real exchange rate depreciation. This depreciation exacerbates the inflationary consequences of money growth and, in the presence of wage indexation, reduces the employment gains. Inter-central bank cooperation may nevertheless be beneficial when the variance of the disturbances is high, or in institutional settings where the incentive to systematically inflate is controlled or eliminated.

The present analysis extends the recent game-theoretic literature on two-country monetary policy by incorporating rational expecations, and by examining paths along which wages and price expectations are time consistent. In addition to considering supply shocks as in other recent (non-rational expectations) game-theoretic analyses of two-country monetary policy, we have also analyzed money market and goods market demand disturbances. It is worth noting that the model developed here is considerably easier to manipulate than previous non-game-theoretic, rational expectations, two-country macro-models, even though it yields the same qualitative results about the transmission of disturbances. The algebra here is simpler because time-consistent rational CPI inflation rate expectations and exchange rate depreciation expectations turn out to be static (unless there is a regime shift).

Appendix A: The Underlying Two-Country Macroeconomic Model

Here we describe the two-country, two-good, rational expectations *cum* wage contracting model on which the results of the text are based.[37] Monetary policy can have short-run real effects here because nominal wage contracts are negotiated a period in advance; these contracts are only partially indexed to the current-period consumer price level.[38] To facilitate algebraic manipulation, the technological and behavioral parameters in the two countries are constrained to be equal.

1. Aggregate Supply

The good produced by home-country firms differs from the good produced by foreign-country firms. But within each country, all firms have identical Cobb-Douglas production functions. Using lower case letters to denote logarithms, the aggregate production functions can be written as

$$(12a) \quad y = c_0 + \alpha\bar{k} + (1 - \alpha)n + z,$$

$$(12b) \quad y^* = c_0^* + \alpha\bar{k}^* + (1 - \alpha)n^* + z^*,$$

where star (*) superscripts indicate the foreign country,[39] y is output, $\bar{k}$ is the fixed capital stock, n is labor, c_0 is the constant term, and z is a serially uncorrelated aggregate productivity disturbance; $z \sim N(0, \sigma_z^2)$. z and z* are assumed to be perfectly correlated so that z = z*. Time subscripts are omitted where the meaning is obvious; throughout, all parameters are non-negative.

Firms hire labor until the marginal value product of labor equals the nominal wage rate, w:

(13a) $c_0 + \log(1 - \alpha) + \alpha\bar{k} - \alpha n_d + z = w - p$,

(13b) $c_0^* + \log(1 - \alpha) + \alpha\bar{k}^* - \alpha n_d^* + z = w^* - p^*$,

where p is the nominal price of the domestically-produced good, and n_d is aggregate labor demand. The notional labor supply curve is assumed inelastic:40/

(14a) $n_s = \bar{n}$,

(14b) $n_s^* = \bar{n}^*$.

To simplify algebra, $\bar{n}$ is set equal to $\bar{k} + (1/\alpha)[\log(1 - \alpha) + c_0]$, $\bar{n} = \bar{n}^*$, $\bar{k} = \bar{k}^*$, and $c_0 = c_0^*$.

CPI-indexed wage contracts for period t are negotiated at the end of period t-1. The base wage rate is $\bar{w}$ ($\bar{w}^*$), and the indexation parameter is β:

(15a) $w = \bar{w} + \beta(p_I - \bar{w})$,

(15b) $w^* = \bar{w}^* + \beta(p_I^* - \bar{w}^*)$, $0 \leq \beta < 1$,

where

(16a) $p_I = .5p + .5(p^* + e)$,

(16b) $p_I^* = .5p^* + .5(p - e)$;

e is the (logarithm of the) exchange rate (the domestic currency price of foreign currency). The nature of the employment contract is that laborers agree to supply (ex-post) whatever amount of labor is demanded by firms in period t, provided firms pay the negotiated wage. The actual levels of employment in period t are thus found by substituting the wage equations (15) into the labor demand equations (13):

(17a) $n = \bar{n} + \gamma(p - \bar{w}) - \tau q + z/\alpha,$

(17b) $n^* = \bar{n} + \gamma(p^* - \bar{w}^*) + \tau q + z/\alpha,$

where $\gamma \equiv (1 - \beta)/\alpha$, $\tau \equiv .5\beta/\alpha$, and

(18) $q = e + p^* - p.$

As described in the text, wage setters choose $\bar{w}$ to minimize $E_{t-1}(n_t - \bar{n})^2$, where E_{t-1} denotes rational expectations based on period t-1 information. This implies that $\bar{w} = E_{t-1}[p_t - .5\beta q_t/(1-\beta)]$, and $\bar{w}^*_t = E_{t-1}[p^*_t + .5\beta q_t/(1-\beta)]$.

Equations (12) and (17), together with the assumption that $-c_0 = \alpha\bar{k} + (1 - \alpha)\bar{n}$, imply that the aggregate supply equations can be written as

(19a) $y_s = \theta(p - \bar{w}) - \kappa q + z/\alpha,$

(19b) $y^*_s = \theta(p^* - \bar{w}^*) + \kappa q + z/\alpha,$

where $\theta \equiv (1-\alpha)(1-\beta)/\alpha$ and $\kappa \equiv .5(1-\alpha)\beta/\alpha$.

2. Money and bond markets

Only domestic residents hold the domestic money and only foreign residents hold the foreign money. However, residents of both countries hold both domestic- and foreign-currency denominated bonds. The demand for real money balances in each country is a decreasing function of the nominal interest rate and an increasing function of real income:

(20a) $m - p_I = -\lambda r + \phi(p + y - p_I) + v,$

(20b) $m^* - p_I^* = -\lambda r^* + \phi(p^* + y^* - p_I^*) + v^*,$

where m is the logarithm of the nominal money supply and v is the money market disturbance term; $v \sim N(0, \sigma_v^2)$, $v^* \sim N(0, \sigma_{v^*}^2)$, and v and v* are independent.

Domestic- and foreign-currency denominated bonds are perfect substitutes so that uncovered interest parity holds:

(21) $E_t(e_{t+1}) - e_t = r_t - r_t^*.$

Agents are assumed to have full period t information (including knowledge of the period t disturbances) in making their portfolio and investment decisions.

3. Goods market demand

Demand for the good produced in each country is a decreasing function of its relative price, an increasing function of real income at home and abroad, and a decreasing function of the real interest rate:

(22a) $y_d = \eta q - \delta'\{r - E_t[p_{I(t+1)}] + p_{It}\} + \Delta(p + y - p_I) + \Delta(p^* + y^* - p_I^*) + u' + x,$

(22b) $y_d^* = -\eta q - \delta'\{r^* - E_t[p_{I(t+1)}^*] + p_{It}^*\} + \Delta(p + y - p_I) + \Delta(p^* + y^* - p_I^*) + u' - x,$

where $u' \sim N(0, \sigma^2_{u'})$, $x \sim N(0, \sigma^2_x)$ and $\Delta < .5$.[41/] The common goods market demand disturbance is u', and x represents a shift in demand from the foreign good to the home good. Using equations (16), equations (22) can be rewritten as

$$(22a')\quad y_d = \eta q - \delta\{r - E_t[p_{I(t+1)}] + p_{It}\} + u + x,$$

$$(22b')\quad y^*_d = -\eta q - \delta\{r^* - E_t[p^*_{I(t+1)}] + p^*_{It}\} + u - x,$$

where $\delta = \delta'/(1-2\Delta)$, and $u = u'/(1-2\Delta)$. In deriving equations (22'), we have made use of the fact that, because the CPI weights are the same in both countries and because home and foreign bonds are perfect substitutes, real consumption interest rates are always equal even though the real exchange rate may fluctuate in the short-run. Otherwise, the different real interest rates faced by both home and foreign consumers would enter separately in (22').

4. Solution of the model

To close the model, it is necessary to specify how wage setters and investors form expectations of future prices.[42/] The procedure for deriving time-consistent, rational, price expectations is discussed in the text. There we demonstrated that $E_t[p_{I(t+1)}] - p_{It}$ is constant and equal to $\bar{\pi}^N_I$ or $\bar{\pi}^C_I$ depending on whether the equilibrium between central banks is non-cooperative or cooperative. (See equations (4) and (9) of the text.) Using equations (16) and (21), it is easy to deduce that $E_t(e_{t+1}) - e_t = r - r^* = \bar{\pi}_I - \bar{\pi}^*_I$. In the time-consistent equilibrium, rational expectations of exchange rate appreciation are static. Exchange rate appreciation and CPI inflation expectations would change, of course, if the governments' objective functions changed. We are now prepared to solve for the expected values of the real exchange rate, outputs, and real interest rates. Taking t-1 expectations across equations (19) and (22') and recalling that wage setters set $\bar{w} = E_{t-1}[p_t - .5\beta q_t/(1-\beta)]$ and $\bar{w}^* = E_{t-1}[p_t^* + .5\beta q_t/(1-\beta)]$, one can solve for

$$(23)\quad E_{t-1}(q_t) = 0 = \bar{w} - E_{t-1}(p_t) = \bar{w}^* - E_{t-1}(p_t^*),$$

$$(24a)\quad E_{t-1}(r - \bar{\pi}_I) = E_{t-1}(y_t) = 0, \text{ and}$$

$$(24b)\quad E_{t-1}(r^* - \bar{\pi}_I^*) = E_{t-1}(y_t^*) = 0.$$

We can use the above equations together with equations (20) to obtain

$$(25a)\quad E_{t-1}(m_t) = \bar{w} - \lambda\bar{\pi}_I,$$

$$(25b)\quad E_{t-1}(m_t^*) = \bar{w}^* - \lambda\bar{\pi}_I^*.$$

We are now prepared to solve for q, p, p^*, p_I, p_I^*, n and n^* as functions of $\bar{w}$, $\bar{w}^*$, $\bar{\pi}_I$, $\bar{\pi}_I^*$, z, u, x, v, and v^*. These solutions are given below

$$(26a)\quad q = \nu[(m - \bar{w} + \lambda\bar{\pi}_I - v) - (m^* - \bar{w}^* + \lambda\bar{\pi}_I^* - v^*) - 2(\phi + 1/\theta)x],$$

$$(26b)\quad p = \bar{w} + (\nu S + H)(m - \bar{w} + \lambda\bar{\pi}_I - v) - \nu S(m^* - \bar{w}^* + \lambda\bar{\pi}_I^* - v^*) + \lambda Hu/\delta - H(\phi + \lambda/\delta)z/\alpha + [\lambda H/\delta - 2\nu S(\phi + 1/\theta)]x,$$

$$(26c)\quad p^* = \bar{w}^* + (\nu S + H)(m^* - \bar{w}^* + \lambda\bar{\pi}_I^* - v^*) - \nu S(m - \bar{w} + \lambda\bar{\pi}_I - v) + \lambda Hu/\delta - H(\phi + \lambda/\delta)z/\alpha - [\lambda H/\delta - 2\nu S(\phi + 1/\theta)]x,$$

$$(26d)\quad p_I = \bar{w} + (\nu J + H)(m - \bar{w} + \lambda\bar{\pi}_I - v) - \nu J(m^* - \bar{w}^* + \lambda\bar{\pi}_I^* - v^*)$$
$$+ \lambda Hu/\delta - H(\phi + \lambda/\delta)z/\alpha + [H\lambda/\delta - 2\nu J(\phi + 1/\theta)]x,$$

$$(26e)\quad p_I^* = \bar{w}^* + (\nu J + H)(m^* - \bar{w}^* + \lambda\bar{\pi}^* - \nu^*) - \nu J(m - \bar{w} + \lambda\bar{\pi}_I - v)$$
$$+ \lambda Hu/\delta - H(\phi + \lambda/\delta)z/\alpha - [H\lambda/\delta - 2\nu J(\phi + 1/\theta)]x,$$

$$(26f)\quad n = \bar{n} + (Q + R\nu)(m - \bar{w} + \lambda\bar{\pi}_I - v) - R\nu(m^* - \bar{w}^* + \lambda\bar{\pi}_I^* - v^*)$$
$$+ Q\lambda u/\delta + Q[-\phi - \lambda/\delta + 1/(1-\beta)]z + [Q\lambda/\delta - 2R\nu(\phi + 1/\theta)]x,$$

$$(26g)\quad n^* = \bar{n}^* + (Q + R\nu)(m^* - \bar{w}^* + \lambda\bar{\pi}_I^* - v^*) - R\nu(m - \bar{w} + \lambda\bar{\pi} - v)$$
$$+Q\lambda u/\delta + Q[-\phi - \lambda/\delta + 1/(1-\beta)]z - [Q\lambda/\delta - 2R\nu(\phi + 1/\theta)]x,$$

$$\nu \equiv [2(\eta + \kappa)/\theta + 2\phi\eta + (1 - \phi)]^{-1} > 0,$$

$$H \equiv (1 + \theta\lambda/\delta + \phi\theta)^{-1} > 0,$$

$$S \equiv H[\kappa\phi - (1 - \phi)/2 + \lambda(\kappa + \eta)/\delta] \gtrless 0,$$

$$J \equiv H\{.5\phi[(1 - \alpha)/\alpha + 1] + \lambda/\delta[.5(1 - \alpha)/\alpha + \eta]\} > 0,$$

$$Q \equiv [\phi(1 - \alpha) + \lambda(1 - \alpha)/\delta + \alpha/(1 - \beta)]^{-1} > 0,$$

$$R \equiv Q\{.5[\phi - 1/(1 - \beta)] + \lambda\eta/\delta\} \gtrless 0.$$

Using equations (26), and imposing the assumption that the income elasticity of money demand $\phi \leqq 1$, we can determine the sign of the following partial derivatives (holding $\bar{w}$, $\bar{w}^*$, $\bar{\pi}_I$ and $\bar{\pi}_I^*$ constant):

$\partial q/\partial m$, $\partial p/\partial m$, $\partial p_I/\partial m$, $\partial n/\partial m$, $\partial p/\partial u$, $\partial p_I/\partial u$, $\partial n/\partial u > 0$;

$\partial n/\partial x \geqq 0$;

$\partial p_I/\partial x$, $\partial q/\partial x$, $\partial p_I/\partial m^*$, $\partial p_I/\partial z$, $\partial p/\partial z < 0$.

The partial derivatives $\partial p/\partial x$, $\partial p/\partial m^*$, $\partial n/\partial m^*$, $\partial n/\partial z$, may be positive or negative. For example, when there is no wage indexation, a foreign money supply shock will raise or lower domestic output and employment, depending on whether the expenditure-switching effect of the real appreciation of the domestic curency outweighs the expenditure increasing effect of lower world real interest rates.[43/] Wage indexation increases the possibility that the foreign money supply shock will raise domestic employment.

In the text, we require knowledge of $\Psi \equiv (\partial q/\partial m)/(\partial p/\partial m)$, holding m^*, $\bar{w}$, $\bar{w}^*$, $\bar{\pi}_I^*$ and $\bar{\pi}_I^*$ constant. One can easily demonstrate, using (26), that $\Psi > 0$.

Appendix B: Relative Shifts in Demand

Throughout the text, shifts in the demand for each country's good are assumed to be perfectly positively correlated; that is, x = 0, so that there are no relative shifts in demand between the two goods. This assumption is analytically convenient because it turns out to imply that the real exchange rate q does not move in either the Nash or the symmetric cooperative equilibrium. To solve the model when $x \sim N(0, \sigma_x^2)$, use equations (26d) - (26g) to substitute into equations (1) for $n - \bar{n}$, $n^* - \bar{n}^*$, $\bar{\pi}_I$ and $\tilde{\pi}_I^*$:

$$(27a)\quad \Lambda = (a_1 dm + a_2 dm^* + a_3 x + \bar{n} - \tilde{n})^2 + \chi(b_1 dm + b_2 dm^* + b_3 x + \bar{w} - p_{t-1} - \tilde{\pi})^2,$$

$$(27b)\quad \Lambda^* = (a_1 dm^* + a_2 dm - a_3 x + \bar{n}^* - \tilde{n}^*)^2 + \chi(b_1 dm^* + b_2 dm - b_3 x + \bar{w}^* - p_{t-1}^* - \tilde{\pi}^*)^2,$$

where $dm \equiv m - \bar{w} + \lambda\bar{\pi} - v$, $dm^* \equiv m^* - \bar{w}^* + \lambda\pi_I^* - v^*$, and the coefficients a_i and b_i are the same as in (26d) - (26g). (As a minor expositional convenience, we are abstracting from the common disturbances u and z.) In the Nash equilibrium, $\partial\Lambda/\partial dm = 0 = \partial\Lambda^*/\partial dm^*$. The procedure for finding $\bar{w}^N$ and $(\bar{w}^*)^N$ is the same as in the text, and the resulting equations are the same as equations (4) of the text.

Furthermore,

$$(28a)\quad dm^N = -(a_1 a_3 + \chi b_1 b_3)x/[a_1(a_1 - a_2) + \chi b_1(b_1 - b_2)],$$

(28b) $(dm^*)^N = - dm^N$,

where, from equations (26), $a_1(a_1 - a_2) + \chi b_1(b_1 - b_3) > 0$, but $a_1a_3 + \chi b_1b_3 \gtreqless 0$. A positive x represents a shift in world demand from the foreign good to the home good; home CPI inflation falls and home employment rises. In a time-consistent Nash equilibrium, the home country may set unanticipated money growth at a positive a or negative level, depending (in part) on χ, the relative weight placed on inflation deviations versus employment deviations.44/

Provided that the responses to relative demand shifts are symmetric, the cooperative $\bar{w}^C$ and $(\bar{w}^*)^C$ are as in the text (equations (9)), and

(29a) $dm^C = - [(a_1 - a_2)a_3 + \chi(b_1 - b_2)b_3]x/[(a_1 - a_2)^2 + \chi(b_1 - b_2)^2]$,

(29b) $(dm^*)^C = - dm^C$.

Since $a_2 \gtreqless 0$, it is perfectly possible that dm^C and dm^N are of opposite signs.

Finally, we note that while the symmetric cooperative equilibrium characterized by (29) indeed lies on the contract curve, and indeed provides better stabilization than the Nash equilibrium, it may be especially difficult to achieve when $\tilde{n} - \bar{n}$ and $\tilde{n}^* - \bar{n}^*$ are strictly positive. In that case, either country could gain by unilaterally deflating in a no-shock cooperative equilibrium. Thus, (ex-post) the country which is asked to raise its money supply more than in the no-shock equilibrium might be reluctant to agree to take the aggregate demand disturbance into account.

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Footnotes

*/ Board of Governors of the Federal Reserve System. An earlier version of this paper was written while the author was on leave at the Research Department of the International Monetary Fund. The views expressed in this paper are the author's own, and should not be interpreted as the official views of either institution. The author has benefited from discussions with Matthew Canzoneri and Dale Henderson, and from comments on an earlier draft by seminar participants at Columbia University, Princeton University, and the University of Virginia.

1/ Hamada (1976) was the first to analyze the strategic interactions of two (or more) governments in conducting monetary stabilization policy. More recently, Jones (1982, 1983) as well as Canzoneri and Gray (1983) have examined some game-theoretic aspects of monetary policy under fixed and flexible exchange rates. The above analyses do not incorporate rational expectations. Other recent multi-country analyses of monetary policy include Carlozzi and Taylor (1983), Henderson (1984), Macedo (1983), McKinnon (1982), Miller and Salmon (1983), and Sachs (1983).

2/ The focus of the present analysis is game-theoretic and not information-theoretic. This is not to suggest that the information-theoretic aspects of exchange rate management are unimportant. Indeed, our empirical knowledge of the determinants of exchange rate movements is, as yet, rather limited; see Meese and Rogoff (1983).

3/ The analysis of the strategic interactions of private agents and the monetary authorities within a given country is based on Phelps (1967), Kydland and Prescott (1977), Barro and Gordon (1983a) and Rogoff (1983b).

4/ Whether or not it is really possible to implement a cooperative monetary system is, regrettably, an issue which is beyond the scope of this paper. Hamada (1976) stresses that the problem may best be thought of as one in which the central banks cooperate to construct a regime with the best possible (self-enforcing) non-cooperative equilibrium.

5/ There seems to be little harm in abstracting from the macroeconomic effects of sterilized intervention, since those effects appear to be extremely limited. See, for example, Rogoff (1983a).

6/ A similar specification of the social loss function is used by Barro and Gordon (1983a), and by Kydland and Prescott (1977).

7/ See equations (16) of Appendix A.

8/ Most rational expectations _cum_ wage contracting analyses include only output or employment deviations directly into the social loss function Λ, and do not include the level of the inflation rate. It is indeed difficult to rigorously justify including the anticipated component of the inflation rate into Λ. Some costs of perfectly anticipated inflation include the administrative costs of posting new prices, the costs of adjusting the tax system to be fully neutral with respect to inflation, and the costs incurred because high rates of inflation force private agents to economize on their holdings of non-interest bearing money. The optimal rate of inflation may nevertheless be non-zero; it may be optimal to make some use of the seignorage tax when other methods of taxation are also distortionary. See Phelps (1973).

9/ Even with one-period contracts, it would be necessary to explicitly allow for multiperiod objective functions in order to analyze reputational equilibria; see Barro and Gordon (1983b) or Canzoneri (1983). Sachs (1983) examines monetary policy cooperation in an interesting dynamic setting; his model does not incorporate rational expectations. Miller and Salmon (1983) examine dynamic games in a very general dynamic open-economy model. The main conclusion of the present paper would not be altered in a framework with more dynamic elements.

10/ See Barro and Gordon (1983a).

11/ Each individual group of wage setters is indeed concerned with the inflation rate, just as society is. But because the impact of an individual firm's contract on the aggregate inflation rate is small, they have little incentive to temper their nominal wage increases.

12/ Phelps (1967) and Kydland and Prescott (1977) demonstrate why a time-consistent macroeconomic equilibrium might be characterized by stagflation. While we focus here on labor market distortions, there are other factors which may cause the time-consistent rate of inflation to be too high. Examples include seignorage and the existence of nominal government debt; see Barro and Gordon (1983a).

13/ It would, of course, be attractive to extend the present model to allow for an endogenous determinaton of β. For the full information setup of the text, one can show that individual groups of wage setters would choose $\beta = 0$ if β is bounded between zero and one. Wage setters have no need to worry about aggregate goods market demand and money demand disturbances, because these are fully offset by the central banks. However, wage setters want the central banks to allow some price level movement in response to productivity shocks in order to stabilize employment around the level which would arise if nominal wages were fully flexible. (See Appendix A.) But because the central banks also care about price level stability, they do not allow sufficient price level movement to fully stabilize employment. Thus, from the point of view of wage setters at an individual firm, indexation would only serve to further damp desired movements in the real wage.

14/ The assumption that home and foreign consumers have identical consumption baskets yields considerable algebraic simplification, but is not essential to any of the main conclusions here.

15/ Sachs (1983) also stresses the role of the real exchange rate as the key variable interlocking the objective functions of the two governments.

16/ There will obviously be no trade-offs and no conflicts if the central banks have as many independent instruments as objectives.

17/ See Appendix A. We are restricting our attention to contemporaneous money supply feedback rules since, in the setup of the text, "prospective" (lagged) feedback rules are not time consistent; see Rogoff (1983b). If time consistency were not a problem, lagged feedback rules would still be inferior to contemporaneous feedback rules since both inflation rate stabilization and employment stabilization enter the social objective function. Lagged feedback rules succeed in decreasing the variance of employment only by increasing the unconditional variance of inflation; see Canzoneri, Henderson and Rogoff (1983). A similar problem with lagged feedback rules arises in the presence of multiperiod overlapping contracts.

18/ The second-order conditions for a local minimum are met; because of the quadratic forms of (1), the minimum is global.

19/ Central banks could try to fool wage setters by indicating that they have no plans to cooperate, and then turning around and doing so. They could not achieve systematic gains this way, however.

20/ Here is the first of many times where we make use of the fact that certainty equivalence obtains because the objective functions are quadratic; see Sargent (1979).

21/ We are assuming that the same regime is expected to remain in place permanently, though this assumption is easy to modify. Note that expectations of future money growth are not static; it is precisely because expectations of next period's money supplies are affected by current period disturbances that CPI inflation rate expectations are not affected. The fact that rational expectations for the rate of exchange rate depreciation are also static follows because the two goods have equal weights in both countries' CPI's.

22/ Although the real exchange rate does not turn out to move in the Nash equilibrium, the fact that it can move (out of Nash equilibrium) plays a major role in everyone's decisions. In Appendix B, we allow for relative shifts in demand between home and foreign goods. In this case, the real exchange rate does fluctuate in both the Nash and the cooperative regimes.

23/ A simpler method of obtaining equations (5) is to solve (3) for p_t and p_t^* holding q = 0. Then take t-1 expectations across the resulting expressions and form $(p_t)^N - E_{t-1}(p_t)^N$ and $(p_t^*)^N - E_{t-1}(p_t^*)^N$.

24/ If q varied, we would need to substitute into the social objective functions for q, p, and p* in terms of $\bar{w}$, $\bar{w}^*$, dm and dm* in order to solve for the Nash equilibrium. This more algebraically cumbersome approach is sketched in Appendix B.

25/ To prove uniqueness of the Nash equilibrium, take t-1 expections across equations (3), and subtract the resulting expressions from (3) to obtain two equations in dp_t, dp_t^*, and dq_t. Use equations (26) of Appendix A to substitute out for these three variables in terms of dm and dm*. The result is two linear, independent equations in dm and dm* and the solution is unique; see Appendix B.

26/ This result is due to the quadratic form of the objective functions.

27/ Rogoff (1983b) demonstrates how to extend a framework such as the present one to the case where central banks have incomplete contemporaneous information.

28/ Henderson (1984) derives a similar result.

29/ We note again that the presence of intermediate imports in the production function would imply a similar result.

30/ There are other, asymmetric, cooperative schemes which, holding wages constant, lead to Pareto improvements over the Nash equilibrium. Qualitatively, all of these schemes are similar in that they involve higher money growth at home and abroad than in the Nash equilibrium. The symmetric scheme analyzed in the text is a logical one to consider since the two countries are identical in almost every respect. Canzoneri and Gray (1983) have emphasized that fixed exchange rate regimes may be non-cooperative in that either country can unilaterally precommit to fix the exchange rate.

31/ Canzoneri and Gray (1983) analyze a one-time supply disturbance and find that the cooperative response to this disturbance may call for either smaller or larger changes in the money supply than in the Nash equilibrium. In their framework, the authorities try to stabilize employment and money growth. The present framework may also yield the result that $|dp_t|^C < |dp_t^N|$ when the central banks adopt the money supply as an intermediate monetary target, along the lines discussed in Rogoff (1983b).

32/ An alternative proof is possible : Define $\rho z_t = dp_t$, and find the value of ρ which minimizes Γ as defined in equations (6). This value turns out to be the same as for $(dp_t)^C$.

33/ A still better cooperative equilibrium could be achieved if the two countries could eliminate their labor market distortions at low cost.

34/ Buiter (1981) specifies optimal contingent rules. There are, of course, many problems involved in designing an insitutional framework in which to implement such rules.

35/ McKinnon (1982) suggests a cooperative monetary reform. His specific proposal to fix the path of the world money supply would definitely be an improvement over money-supply targeting by individual countries in a world where the main source of disturbances is currency substitution.

36/ Rogoff (1983b) and Canzoneri (1983) discuss institutional responses to the central bank's time-consistency problem in a closed economy context.

37/ Apart from its game-theoretic aspects, the model is quite similar to ones employed by Henderson and Waldo (1983), Daniel (1981), and Canzoneri and Gray (1983). Daniel's two-country model includes intermediate imports instead of wage indexation. Canzoneri and Gray's model does not incorporate rational expectations but like the present one, is highly symmetric.

38/ As Gray (1976) demonstrates, full price-level indexation is sub-optimal in the presence of supply (productivity) shocks.

39/ In the discussion below, we sometimes refer only to domestic variables and equations if discussion of their foreign counterparts is redundant.

40/ Making notional labor supply depend on the real wage, as in Rogoff (1983b), would not qualitatively affect the results here.

41/ The assumption that $\Delta < .5$ implies that, in each country, the marginal propensity to consume out of real income is less than one. (Δ is the marginal propensity to consume either one of the two goods.)

42/ The solution procedure may be described as follows: First, we assume that rational expectations are equivalent to static expectations for CPI inflation and the rate of change of the exchange rate. Imposing this assumption, we solve the model of equations (19) - (22) as a function of m, m^*, $\bar{w}$, $\bar{w}^*$, $\bar{\pi}_I$, $\bar{\pi}_I^*$ and the disturbances. Then in the text, we use the resulting partial derivatives (see equations (26) below) to solve for the time-consistent values of $\bar{w}$, $\bar{w}^*$, $\bar{\pi}_I$, $\bar{\pi}_I^*$, and $E_t(e_{t+1}) - e_t$. This procedure confirms that time-consistent exchange rate and CPI inflation rate expectations are indeed static.

43/ Daniel (1981) discusses these transmission channels, as do Canzoneri and Gray (1983). If $\beta = 0$, so that there is no wage indexation, and if the income elasticity of money demand, ϕ, equals one, then $\partial p/\partial m^*$, $\partial n/\partial m^* < 0$. If $\beta > 0$, then $\partial n/\partial m^*$ may be positive even if $\phi = 1$.

44/ In models in which employment is the only objective (such as Henderson and Waldo (1983)), both the Nash and cooperative equilibria involve fully restoring n and n^* to their pre-shock levels. A shift in demand from the foreign good to the home good produces no conflict. In models in which money growth (rather than inflation) is a second government objective (such as Canzoneri and Gray (1983)), m is decreased and m^* increased, but not enough to cause n and n^* to return to pre-shock levels. With money growth targets, the cooperative solution always involves a greater response to aggregate demand shifts than does the Nash solution, and thus greater exchange rate and employment stability. With inflation-rate targets, as in the present model, the cooperative solution does not necessarily involve greater exchange rate and employment stability than in the Nash solution.