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INTERNATIONAL COORDINATION IN THE DESIGN OF MACROECONOMIC POLICY RULES

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The paper examines international issues that arise in the design and evaluation of macroeconomic policy rules. It begins with a theoretical investigation of the effects of fiscal and monetary policy in a two-country rational expectations model with staggered wage and price setting and with perfect capital mobility. The results indicate that with the appropriate choice of policies and with flexible exchange rates, demand shocks need not give rise to international externalities or coordination issues. Price shocks, however, do create an externality, and this is the focus of the empirical part of the paper. Using a simple seven-country model — consisting of Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States — optimal cooperative and non-cooperative (Nash) policy rules to minimize the variance of output and inflation in each country are calculated. The cooperative policies are computed using standard dynamic stochastic programming techniques and the non-cooperative policies are computed using an algorithm developed by Finn Kydland. The central result is that the cooperative policy rules for these countries are more accommodative to inflation than the non-cooperative policy rules.

1. Introduction

The purpose of this paper is to examine some of the *international* economic issues that arise in the design and evaluation of macroeconomic policy rules. The focus is on the seven industrialized countries that participate in the annual summit meetings on economic policy — Canada, France, Germany, Italy, Japan, the United Kingdom and the United States. Although macroeconomic policy coordination is one of the main subjects at the summit meetings, there has been little empirical research on how the policy rules in these seven countries should in fact be coordinated.

Most empirical research on macroeconomic policy rules has been in a closed economy context. In fact in the closed economy macroeconomic

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literature there has been a considerable research effort devoted to the evaluation of policy rules in recent years.[1] In a multicountry context the design and evaluation of macroeconomic policy rules becomes considerably more difficult than in the closed economy. Not only are the empirical models more complicated, but also the issues of policy coordination and cooperation must be faced when designing rules.[2] Despite these difficulties, such research would clearly be a useful component of any attempt to construct a long-lasting macroeconomic policy for the world economy. It is certainly central to any discussion of international monetary reform.

The paper begins with a summary of some theoretical results on the effects of policy in an international economy with rational expectations. Although the rational expectations assumption may not be appropriate in the period immediately after a policy reform (when market participants are learning about the policy), it does seem appropriate for estimating the longer-term effects of a new policy. We use a two-country rational expectations model with staggered wage and price setting; expectations are assumed to be rational in all markets — labour markets as well as financial markets. Hence, wages are both 'sticky' and 'forward-looking'. Monetary policy has an effect on real output, though of a qualitatively different type than in Keynesian models without rational expectations. The demand side of the model is essentially a souped-up version of the Mundell–Fleming ISLM model with perfect capital mobility. Using representative parameter values we illustrate the domestic and foreign effects of aggregate demand and supply (or price) shocks in each country.

[1]Much recent macroeconomic research has been devoted to developing techniques to evaluate the economic impact of different policy rules on macroeconomic performance, primarily on the business cycle and inflation. Lucas (1976) outlines the case for looking at macroeconomic policy as a rule. Sargent (1984) provides a more recent discussion and addresses some of the reservations raised by Sims (1982). For some examples of applications of the rules approach see Taylor (1979, 1980, 1982). It should be emphasized that one need not take a doctrinaire view on the rules versus discretion approach to policy. A more practical view is that there are some unique (non-recurrent) macroeconomic events that require intelligent policy analysis and that are not well-suited to a rule of the game approach, but that in most business cycles there are many common recurrent features that are best approached using policy rules.

[2]Econometric research on policy coordination is rapidly expanding. The research related to that reported here can only be briefly summarized: Taylor (1982) examines optimal cooperative policy rules in a multicountry model with limited capital mobility. Johnson (1982) considers non-cooperative (Nash) policy rules in a similar two-country model, building on the work of Hamada (1979). In Carlozzi and Taylor (1983) policy rules in a two-country (symmetric) model with perfect capital mobility are considered. Papell (1984) has examined the effects of alternative monetary accommodation rules in an empirical two-country model of the United States and Germany. A careful theoretical examination of alternative solution concepts in two-country macro policy problems is presented in Canzoneri and Gray (1983). There are also several papers that consider optimal one-time paths (i.e., open loop) for the policy instruments. Sachs (1983) uses a theoretical two-country model to derive optimal cooperative and non-cooperative open loop paths for policy. More recently Qudiz and Sachs (1984) have computed optimal cooperative and non-cooperative open loop paths for policy instruments in Germany, Japan and the U.S. using empirical econometric models obtained by linearizing the Japanese Planning Agency's model and the Federal Reserve Board's multicountry model.

Although the specific two-country results are of interest in their own right (models with capital mobility, staggered price setting, and rational expectations have been difficult to analyze until recently), the more general policy implications are exploited in the rest of the paper. Under the assumptions that both monetary and fiscal policy instruments can be controlled and that the timing of their effects is known, the two-country model indicates that the effect of aggregate *demand* shocks on real output and inflation can be offset by an appropriate monetary and fiscal policy in each country without affecting economic performance abroad. Hence, with an efficient choice of policies, demand shocks need not give rise to any special international externality or coordination issues under this set of policy assumptions. On the other hand, supply shocks do create an externality. In general even an efficient monetary policy to deal with supply shocks in each country affects macroeconomic performance in the other country.[3] Unlike the case of demand shocks, this 'supply-side' externality remains if the policymakers have perfect control of the instruments. The policy implication of this supply-side externality is the main subject of this paper.

In order to measure the quantitative importance of the externality, an n-country model that simplifies the structure of the Mundell–Fleming two-country model is developed. This model is then applied to the seven large summit countries. Parameter estimates for these countries are obtained, and optimal cooperative and non-cooperative (Cournot–Nash) policy rules to minimize the fluctuations in real output and inflation are calculated. The calculation of these cooperative and non-cooperative policy rules for a group of countries can be viewed as an international extension of a similar calculation reported in Taylor (1979) for the United States as a closed economy. The cooperative policy rules are calculated using standard optimal control theory, and the non-cooperative policy rules are calculated using a control algorithm proposed by Kydland (1975). The main result is that the cooperative policy rules are more accommodative to inflation than the non-cooperative policy rules.

2. Two countries with rational expectations and mobile capital[4]

Table 1 displays the equations of the two-country model. The notation is defined in table 2. All the variables except the interest rates and the inflation rates are measured as logarithms, and all variables are deviations from means or secular trends. For example, y is the deviation of the log of real

[3] This externality was noted and measured in Carlozzi and Taylor (1983).

[4] The results reported below on monetary policy with flexible exchange rates in this model were previously reported in Carlozzi and Taylor (1983). The results on fiscal policy with flexible exchange rates, and on monetary and fiscal policy with fixed exchange rates are reported in this paper for the first time.

Table 1

Two-country macro model.

Country 1	
$x_t=(\delta/3)\sum_{i=0}^{2}\hat{w}_{t+i}+((1-\delta)/3)\sum_{i=0}^{2}\hat{p}_{t+i}+(\gamma/3)\sum_{i=0}^{2}\hat{y}_{t+i}$	(1)
$w_t=\frac{1}{3}\sum_{i=0}^{2}x_{t-i}$	(2)
$p_t=\theta w_t+(1-\theta)(e_t+p_t^*)$	(3)
$y_t=-dr_t+f(e_t+p_t^*-p_t)+gy_t^*$	(4)
$m_t-p_t=-bi_t+ay_t$	(5)
$r_t=i_t-\hat{\pi}_t$	(6)
Capital mobility condition	
$i_t=i_t^*+\hat{e}_{t+1}-e_t$	(7)
Country 2	
$x_t^*=(\delta^*/3)\sum_{i=0}^{2}\hat{w}_{t+i}^*+((1-\delta^*)/3)\sum_{i=0}^{2}\hat{p}_{t+i}^*+(\gamma^*/3)\sum_{i=0}^{2}\hat{y}_{t+i}^*$	(8)
$w_t^*=\frac{1}{3}\sum_{i=0}^{2}x_{t-i}^*$	(9)
$p_t^*=\theta^*w_t^*+(1-\theta^*)(p_t-e_t)$	(10)
$y_t^*=-d^*r_t^*-f^*(p_t^*+e_t-p_t)+g^*y_t$	(11)
$m_t^*-p_t^*=-b^*i_t^*+a^*y_t^*$	(12)
$r_t^*=i_t^*-\hat{\pi}_t^*$	(13)

GNP from secular or potential GNP. Eqs. (1) through (6) describe country 1; eqs. (8) through (13) describe country 2; an asterisk denotes the variables of country two; eq. (7) is the condition of perfect capital mobility: the interest rate in country 1 is equal to the interest rate in country 2 plus the expected rate of depreciation of the currency of country 1. Because the structure in the two countries is the same, we need describe only the equations in country 1.

Eq. (1) is the 'contract' wage (x) equation. A wage decision is assumed to last for three years, with only 1/3 of wages being negotiated in any one year. The wage set at time t depends on expectations of future wages paid to other workers, expectations of prices, and expectations of future demand conditions as proxied by the deviation of real GNP from trend. Eq. (2) defines the

Table 2

Definition of variables and parameter values.

Variables

y_t = real GNP (log)
p_t = price level (log)
i_t = nominal interest rate
r_t = real interest rate
π_t = inflation rate
w_t = nominal wage (log)
m_t = money supply (log)
x_t = contract wage (log)
e_t = exchange rate (log); country 1 price of country 2 currency
$\hat{}$ = conditional expectation based on information through period t.

Parameter values for simulations

δ = 0.5
γ = 1.0
θ = 0.8
d = 1.2
f = 0.1
g = 0.1
b = 4.0
a = 1.0

average wage in the economy as a whole. Eq. (3) is a markup pricing assumption: domestic goods prices are a weighted average of wages and the prices of imported inputs to production measured in domestic currency units. Note that we do not explicitly model the difference between the price of domestically produced goods and the price of consumption goods, due to imported final goods. This would give a further linkage between foreign prices and domestic prices and wages. However, the effects on inflation and output would be observationally equivalent to the approach used here to model price linkages. Eqs. (4) and (5) are textbook IS and LM curves, respectively. The real interest rate differs from the nominal interest rate according to the rationally expected inflation rate as described in eq. (6).

2.1. The closed economy as a frame of reference

To give some perspective to the two-country results we first examine the effects of monetary and fiscal policy in the *closed* economy described by eqs. (1) through (6) with $\theta = 1$, $f = 0$ and $g = 0$. The other parameters are reported in table 2. The co-existence of rational expectations and forward-looking, though sticky, prices gives rise to real interest rate movements which are unlike traditional ISLM models.

To illustrate the properties of the model, we consider a money shock, a fiscal shock, and a supply shock.[5] The money shock is a one percent unanticipated permanent increase in the money supply, the fiscal shock a one percent unanticipated permanent rightward shift in the IS curve [eq. (4)], and the supply shock is an unanticipated temporary shock to the wage equation (1). The results are shown in the time series charts in figs. 1 and 2. The figures show the actual values of the variables rather than their logarithms. The parameters are chosen so that the time unit is about one year, though no attempt has been made to model the dynamics of the aggregate demand side. In fig. 1 the fiscal shock is denoted by a square and the money shock is denoted by a circle. If only a circle appears for particular period, the effects of the money and fiscal shock are the same for that period. No attempt has

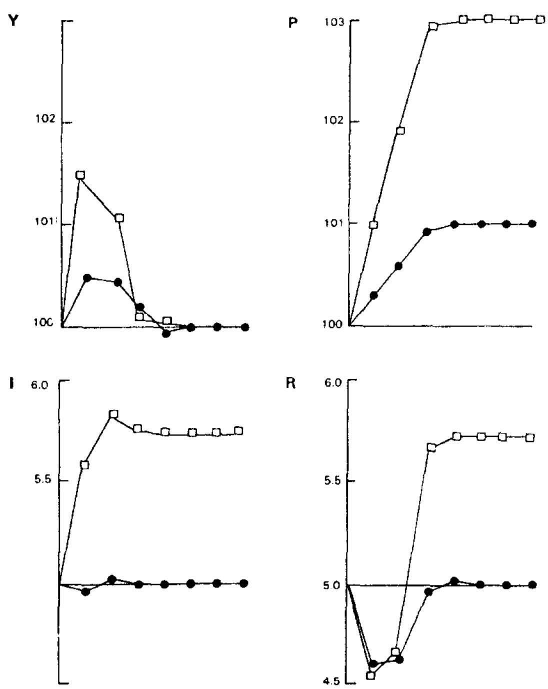

Fig. 1. Fiscal (□) and monetary (●) shocks in a closed economy.

[5]The model is solved using the extended path algorithm described in Fair and Taylor (1983). Since the model is linear the extended path algorithm, which was designed for non-linear models, is too powerful and expensive. A more efficient approach would be the iterative factorization algorithm described in Dagli and Taylor (1983). The model could also be solved by computing the roots explicitly as in Blanchard and Kahn (1980), though for the higher order models this might not be practical.

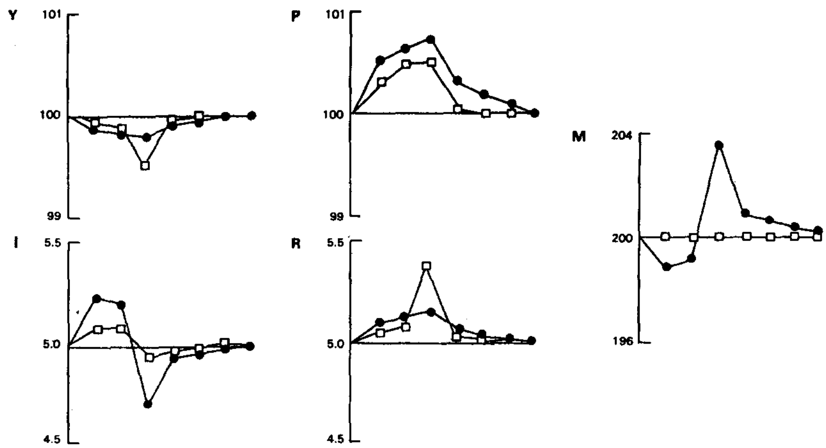

Fig. 2. Price shocks in a closed economy with constant money (□) and with money adjusted (●) for changes in velocity due to expected inflation.

been made to scale the shocks so as to give similar effects for monetary and fiscal policy.

Monetary policy has an expected positive effect on output which dies out as prices rise and reduce real money balances back to where they were at the start. Note that the real interest rate drops more than the nominal rate because of the increase in expected inflation that occurs at the time of the monetary stimulus. For this set of parameters the nominal interest rate hardly drops at all; all the effect of monetary policy shows up in the real interest rate.

Fiscal policy creates a similar dynamic pattern for real output and the price level. Note, however, that there is a strong 'crowding in' effect of fiscal policy in the short run as the increase in the expectation of inflation causes a drop in the real interest rate. Eventually the expected rate of inflation declines and the real interest rate rises; in the long run private spending is completely crowded out by government spending as in any model with price adjustment.

Before discussing the supply shock simulations it is necessary to digress on a technical point involving the effect of a shift in the expected rate of inflation on the aggregate demand curve. The aggregate demand curve is the negatively sloped relationship between y and p obtained by substituting eq. (4) into eq. (5). This curve will generally shift with the expected rate of inflation. For example, a monetary policy rule which holds the money stock constant will result in a leftward movement in the aggregate demand curve whenever there is a decline in expected inflation. A lower expected rate of inflation increases the demand for money. In order to offset such a drop in aggregate demand the monetary authorities have to increase the money supply. An efficient monetary policy rule will generally have a term to reflect this money adjustment. When expected inflation falls, the money supply is increased. Such a policy can be written as

$$m_t = \alpha p_t + \beta \pi_t, \tag{14}$$

where π_t is the expected rate of inflation. The parameter α measures how accommodative monetary policy is to price shocks; the parameter β measures the money adjustment for expected inflation.[6] When $\beta = -b$ this rule eliminates the expected inflation rate from the aggregate demand curve. In the price shock simulations reported here we consider the case where $\beta = 0$ and where $\beta = -b$, and in each case we set $\alpha = 0$. Higher values of α would represent more accommodative policies.

The supply shock results are reported in fig. 2. As expected the shock results in a decline in real output. If there is no offset for expected inflation ($\beta = 0$), then there is a large drop in output in the third period as the expected rate of inflation is sharply reduced. If there is an offset to the expectation of inflation ($\beta = -b$), then there is a much smoother response of output. Note, however, that the money supply is first reduced and then increased quite sharply to offset the decline in expected inflation.

2.2. *Two countries with a flexible exchange rate*

The effects of monetary and fiscal shocks in the full two-country model are shown in fig. 3 when the exchange rate is perfectly flexible. For these simulations the parameters are assumed to be the same in both countries and are given in table 2. In all of these experiments the policy shock occurs in country 1.

The dynamic impact in country 1 of a fiscal shock are similar to the closed economy case. The initial impact on real output is only slightly less than in the closed economy, and the effect dies out at about the same rate. There is also an initial drop in the real interest rate and this is the primary reason for the strong effect of fiscal policy in the flexible exchange rate regime. As in the fixed price Mundell–Fleming model the exchange rate of country 1 appreciates so that exports are crowded out by fiscal policy, but the drop in the real interest rate stimulates investment. Note that the long-run output effect of the fiscal shock is slightly positive in country 1. This is matched by an equal negative long-run output effect in country 2. However, there is an initial positive output effect in country 2 as the real interest rate first declines

[6]Note that if there are no demand shocks we can equivalently write policy in terms of the real interest rate as $r_t = \alpha_r p_t$ where $\alpha_r = h(1-\alpha)/d$ with $h = (a + b/d)^{-1}$. This interest rate policy is in the form of a price rule.

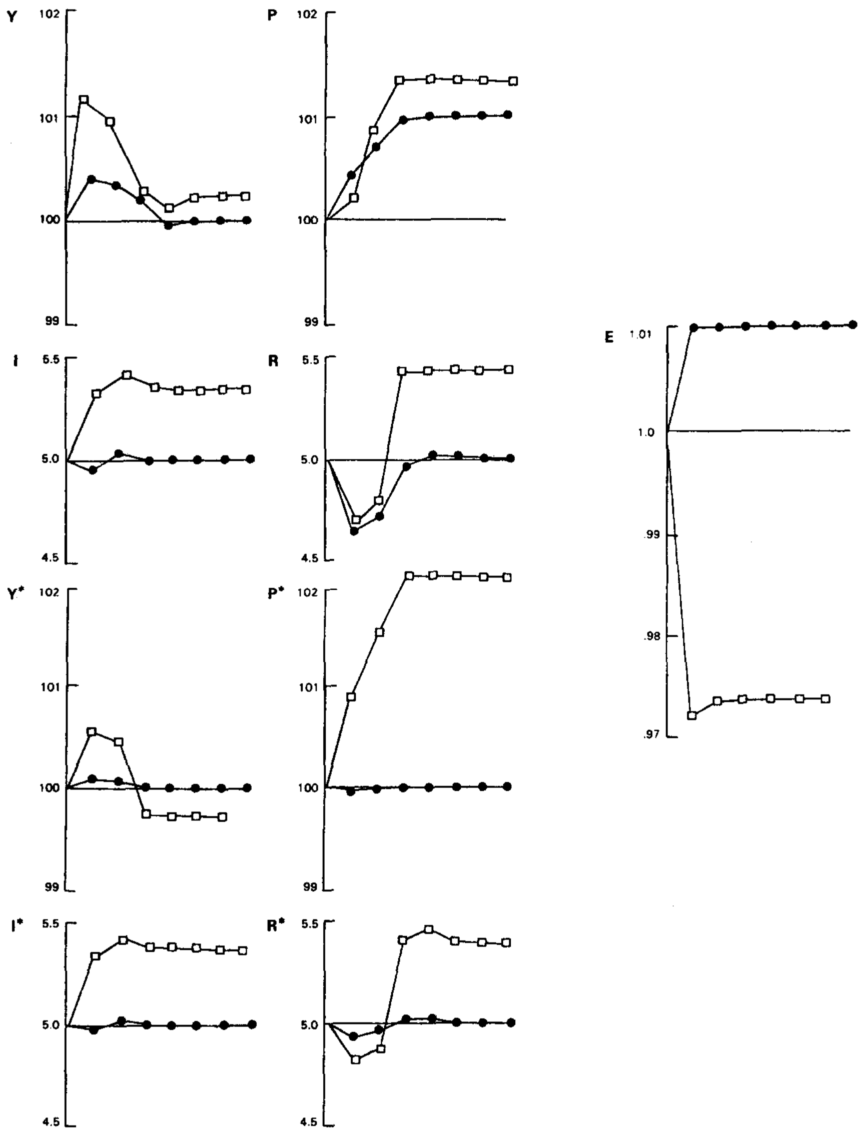

Fig. 3. Fiscal (□) and monetary (●) shocks in a two-country model with flexible exchange rates.

before increasing and crowding out investment spending there. Fiscal policy definitely has inflationary effects abroad.

The effect of an increase in the money supply in country 1 is also much like in the closed economy. There is a positive short-run effect on output that diminishes to zero over time. Part of the monetary stimulus comes from a depreciation of the exchange rate for country 1 and part comes from the decline in real interest rates. There is no significant overshooting of the exchange rate following the monetary impulse. Unlike in the Mundell–Fleming model, however, the increase in the money supply is not contractionary abroad. As noted in Carlozzi and Taylor (1983) a monetary stimulus can have a positive effect abroad because the price level is not fixed; the depreciation of the country 1 currency reduces prices in country 2 and this reduces real balances in that country. The real interest rate also declines slightly in country 2.

The response of the two countries to a supply shock in country 1 is shown in fig. 4. We assume that the money supply in both countries responds to a supply shock as in eq. (14) with $\beta=0$ (the squares) or $\beta=-b$ (the circle), and $\alpha=0$. As in the closed economy the monetary policy that offsets shifts in the expected inflation rate achieves a smoother path for output. There is a negative foreign output repercussion in response to the price shock in country 1. This foreign effect is small partly because of the small real exchange rate and foreign demand coefficients in this specification. Less accommodative policies ($\alpha<0$) would increase the size of the foreign output effect.

2.3. *Two countries with a fixed exchange rate*

For comparison we report in fig. 5 the results from similar experiments with fixed exchange rates. Again the shocks occur in country 1. But now country 2 has the responsibility for maintaining the fixed parity. With perfect capital mobility this means that country 2 must give up an independent monetary policy. The money supply in country 2 must move around in order to keep the exchange rate fixed.

The short-run output effects of fiscal policy with fixed exchange rates are a bit weaker in country 1 compared with the flexible exchange rate case. The output effects abroad are strongly negative, even in the short run. There is no short-run decline in the real interest rate in country 2 as there was when the exchange rate could adjust. In fact the real exchange rate in country 2 overshoots its new higher long-run equilibrium value. Note that in order to keep the exchange rate fixed, country 2 must reduce its money supply. This means that its price level must eventually fall; in the short run there is thus an expected deflation which raises the real interest rate in country 2 for a time above the long-run equilibrium.

Monetary policy has a slightly weaker effect on real output in country 1 than in the flexible exchange rate case. In the long run the output effect diminishes and the price level rises by the same amount that the money supply increases. The effect of this monetary policy on the other country is much stronger than in the case of flexible exchange rates. In order to keep

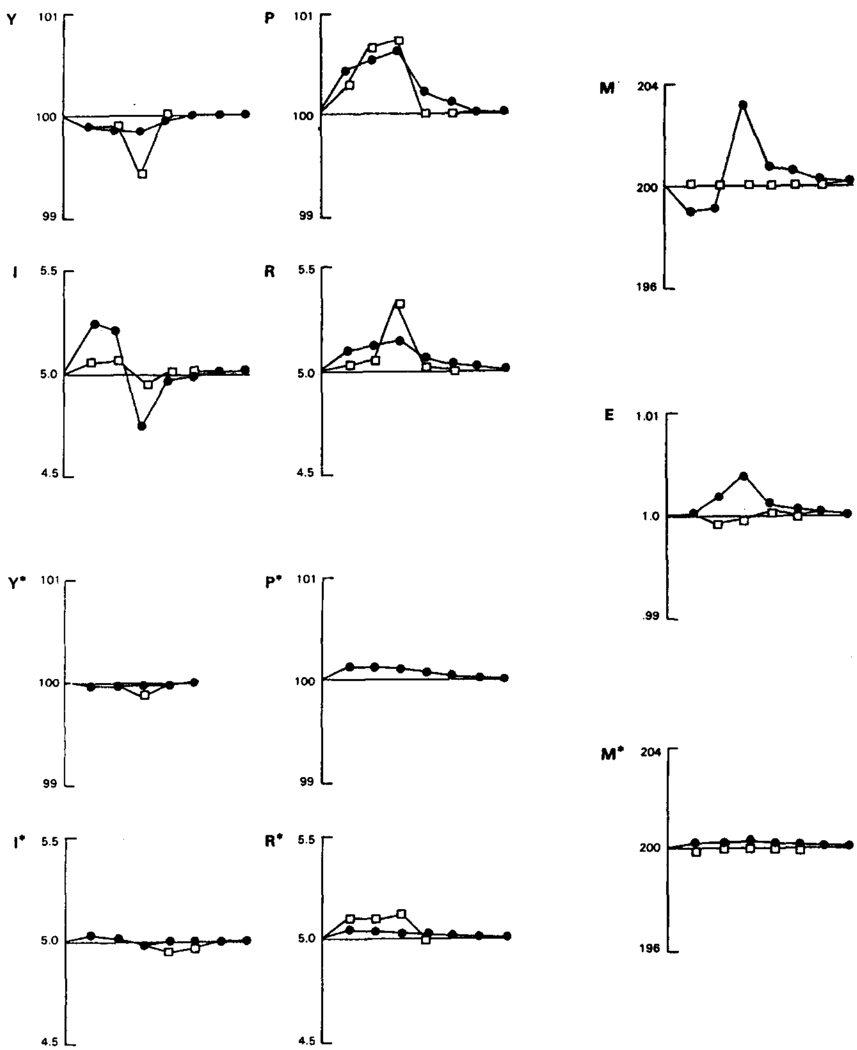

Fig. 4. Price shock in a two-country model with flexible exchange rate; constant money (□) and money adjusted (●) for changes in velocity due to expected inflation shifts.

the exchange rate fixed, the monetary authority in country 2 must expand its money supply by the same amount as the money increase in country 1. This has stimulative effects on real output that duplicate the effects of money in country 1.

Fig. 6 shows the response in the two countries to a supply shock in country 1. Country 1 has the same monetary policy rules as before ($\beta=0$ or

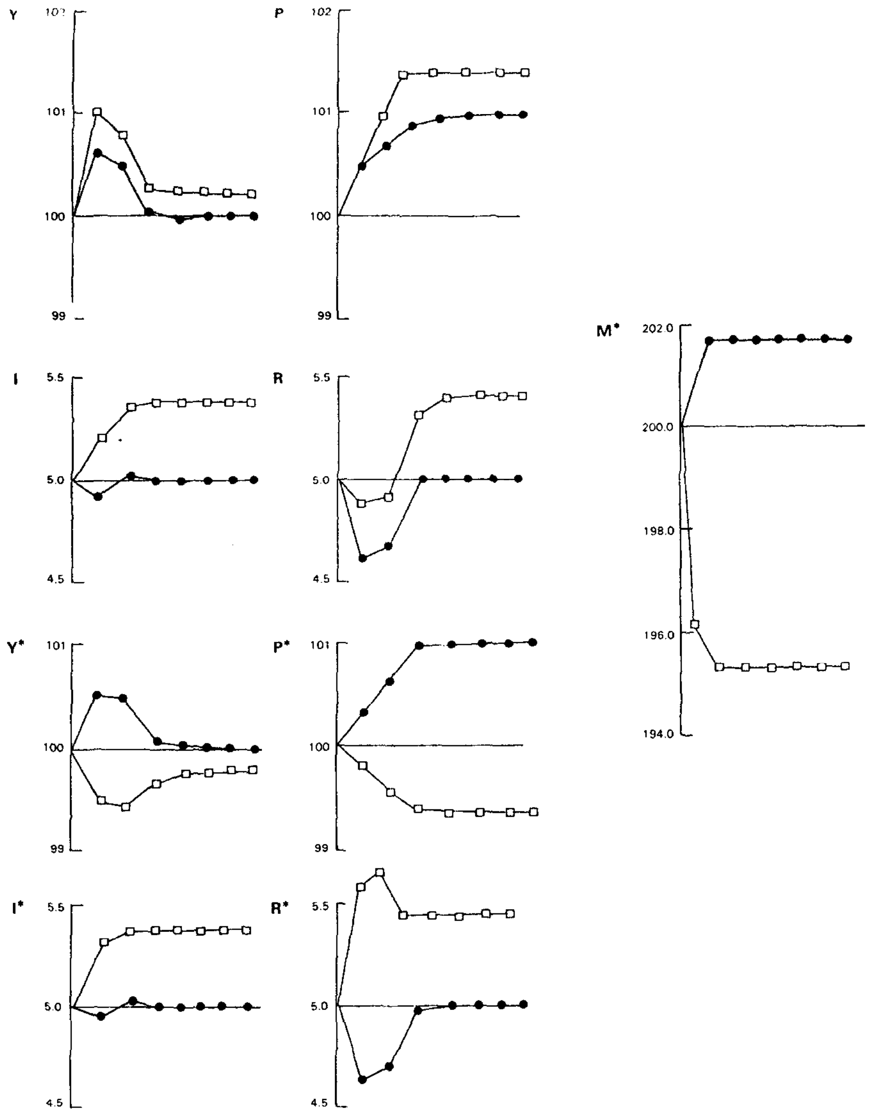

Fig. 5. Fiscal (□) and monetary (●) shocks in a two-country model with fixed exchange rates.

$\beta = -b$, and $\alpha = 0$), while country 2 must dedicate its money supply to the fixed exchange rate. Compared to the flexible exchange rate case, the fluctuations in real output are smaller in the home country and somewhat larger abroad.

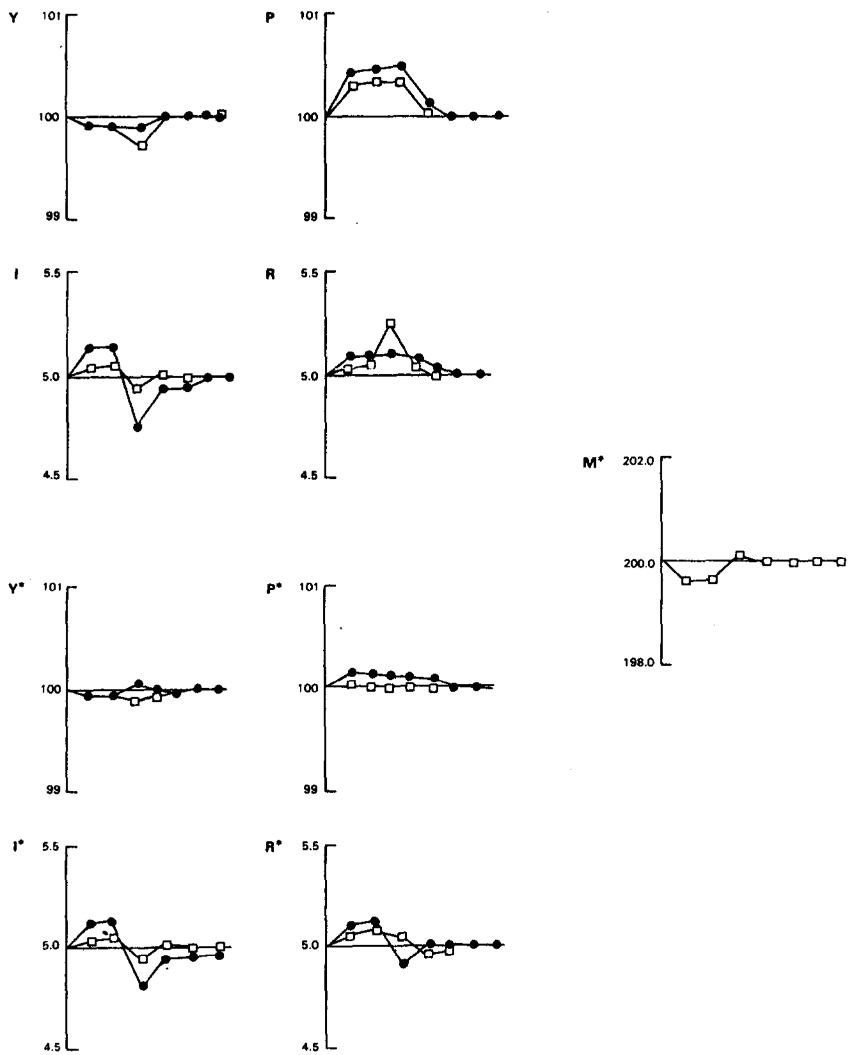

Fig. 6. Price shock in a two-country model with fixed exchange rates; constant money (□) and money adjusted (●) for changes in velocity due to expected inflation shift.

3. A class of policy rules

In the previous section we considered three types of macroeconomic shocks: (1) *IS curve shocks* which could be due to shifts in any of the behavioral components of total spending including consumption, investment, or government, (2) *LM curve shocks* which could be due to velocity as well as to money supply errors, and (3) *supply shocks* which are simply unanticipated changes in the price (or wage) setting process. As we saw, these shocks cause both economies to move temporarily from their equilibrium of full employment and stable prices. The task of macroeconomic policy is either to offset these shocks, or to keep the deviations from full employment and price stability as small as possible.

Rather than calculate the most general type of policy rules to deal with these shocks we will consider a somewhat narrower but simpler set of policy rules. We assume at the start that the instruments of policy can be controlled without error, that the shocks are observable by policymakers, and that the magnitude and timing of the effects of policy are known. These are 'textbooks' assumptions, and though they can be questioned in the real world, they are a good starting place for studying policy coordination.

The policy rules that we consider for each country have four prescriptive components: (1) use fiscal policy — government spending or taxes — to offset IS shocks (this might be called the 'stabilization' component of policy), (2) use monetary policy to offset velocity shocks by adjusting the money supply (this is the 'technical' component of monetary policy; it is already widely followed in many countries), and (3) use monetary policy to set the degree of accommodation to supply shocks — that is, to determine how large a change in output will accompany a given price shock (this is the 'accommodation' component of policy). The degree of accommodation is the central policy rule parameter that must be chosen in computing the best policy out of this class of policies given a particular social welfare function. Since this class of policy rules calls for an independent monetary policy in each country, it implies one further prescription: (4) exchange rates are flexible.

The second component of this class of policy rules seems least objectionable given the assumptions we have made about the information and control possessed by policymakers. Some would argue that the first component gives up opportunities to mix monetary and fiscal policy in order to influence the size of investment relative to consumption. (A compensating advantage is discussed in the next paragraph.) The third and fourth components are perhaps most controversial; the main alternative is to forego any choice about monetary accommodation in one of the two countries (in the two-country model) and let the money supply be dedicated to controlling the exchange rate. Fiscal policy could then have an additional role of cushioning the economy temporarily from supply shocks in the country responsible for pegging the exchange rate. Compared with pure monetary accommodation, this would cause different interest rate movements after a supply shock. It would be useful to consider some of these alternatives in future research.

For this class of policy rules aggregate demand shocks (IS or LM) do not have any external effects abroad, at least for the type of structure portrayed in the two-country model. This would not be true if monetary policy were used to stabilize the economy in the case of IS shocks; monetary stabilization policy would require fluctuations in interest rates and with perfect capital mobility this would have effects abroad. The use of fiscal policy to offset IS shocks does not require any movement in interest rates. Similarly the use of fiscal policy to offset velocity shocks would require fluctuations in interest rates that would have foreign effects.

Supply shocks have external effects under this set of policies except in the special case when they are fully accommodated. A fully accommodated supply shock does not have any effect on real output, and movements in the domestic price level do not have any effects abroad because they are matched by equal changes in the floating exchange rate. When a supply shock is not fully accommodated there will be both real output effects and price effects and these will have foreign repercussions; this was shown in the previous section. A flexible exchange rate cannot isolate other countries from both output and price movements abroad. Note also that a policy that fixes the exchange rate does avoid this problem; as was illustrated in the previous section, supply shocks have external effects whether exchange rates are fixed or flexible.

4. A simple empirical framework for computing policy rules

In this section we develop a simple framework to compute optimal cooperative and non-cooperative policies for several countries. Essentially we attempt to use a semi-reduced form model to describe the relation between inflation and output when each country is following a policy rule of the type described above. In this way we make use of the fact that more complex rules that require a full structural model to analyze are not being used.

4.1. Two countries

Consider first the following two reduced form price equations for two countries:

$$\pi_{1t}=\delta\pi_{1t-1}+\gamma y_{1t}-\beta y_{2t}+u_{1t}, \tag{15}$$

$$\pi_{2t}=\delta\pi_{2t-1}+\gamma y_{2t}-\beta y_{1t}+u_{2t}, \tag{16}$$

where the variables are defined as in section 2 except that we use the subscripts 1 and 2 to distinguish between the two countries. There are stochastic shocks to each equation denoted by u_{1t} and u_{2t}. These are the 'supply' shocks; in general they are correlated between the countries (eg., world supply shocks), and in the empirical work below we use the actual estimated correlation.

The price equations are meant to capture the interaction between the two countries that would be expected when the previously described class of policy rules is being used. The parameters are assumed to be positive. Here they are the same in each country, but this assumption will be dropped in the empirical work which follows. Inflation in each country is assumed to depend on its own lagged value — an indication of expectations of inflation as well as inertia due to contracts. Inflation in each country is also assumed to be positively related to demand in the same country as measured by real output relative to trend. Note that demand conditions in one country have an influence on inflation in the other country. This influence will be negative if exchange rates are flexible and monetary policy is used to steer aggregate demand after a supply shock, as is true of the policy rules considered here. A reduction in real output in country 2 caused by a restrictive monetary policy after an inflationary supply shock in that country will cause the exchange rate to appreciate in country 1. Due to linkages from exchange rates to prices [see eqs. (3) and (10)], the appreciation will tend to reduce inflation in country 1 (e_t goes down), and the equivalent depreciation in country 2 will tend to increase inflation in that country. Hence, the direct positive effects of aggregate demand in country 1 will be augmented by the exchange rate movements and these same movements will create a negative coefficient on aggregate demand in the inflation equation in country 2. (If exchange rates are fixed or if fiscal policy is used to cushion supply shocks, then this argument will no longer hold and β may be negative.)

The price equations (15) and (16) have abstracted from the specific dynamics of the staggered contract model in the original two-country model. In particular the explicit forward-looking behavior is now assumed to have been incorporated in the parameters. For this reason eqs. (15) and (16) are not as structural as they might be. Perhaps a better approximation of the forward-looking behavior explicit in the model of section 2 would be to replace the actual output variables on the right-hand side with expectations of these variables — this approach was taken in Taylor (1979).

Now consider the aggregate demand side of the model. The policy rules described above will give rise to the following types of reduced form aggregate demand equations for the two countries:

$$y_{1t}=g_{11}\pi_{1t-1}+g_{12}\pi_{2t-1}, \tag{17}$$

$$y_{2t}=g_{21}\pi_{1t-1}+g_{22}\pi_{2t-1}. \tag{18}$$

These equations represent the outcome of a particular policy for adjusting the level of aggregate demand in response to inflation. In writing (17) and (18) we are exploiting the first and second components of the policy rules: that aggregate demand shocks are perfectly offset without foreign repercussions; if aggregate demand shocks remained then disturbances would be added to the equations, and the correlation between these disturbances would be affected by policy. The policy parameters in (17) and (18) depend on how accommodative monetary policy is to supply shocks.

4.2. Optimal rules in the stochastic steady state

The policy problem is to find values for the g-parameters in (17) and (18) to maximize social welfare. This is a dynamic problem: there are lags and we are interested in social welfare for many periods. A practical way to deal with these dynamics is to focus on macroeconomic performance in the stochastic steady state. The stochastic equilibrium describes how the economy reacts on average to shocks — the typical business cycle fluctuations of output and inflation. It also captures the essential ways that policy can affect macroeconomic performance by altering the size of the fluctuations of output and inflation. The variance of output and inflation is a convenient measure of the size of these business cycle fluctuations.

By focussing on the stochastic equilibrium we are implicitly assuming an infinite time horizon for policy choice with no discounting. This seems appropriate for macroeconomic policy. We also are implicitly assuming that time inconsistency will not be a problem: once a policy rule is chosen we assume that it will remain in force with no attempt by the policymakers to exploit the past committments of economic agents.

Using game theory terminology we implicitly assume that the policymakers in each country are dominant players in a game with the residents of that country, and that the solution to the game is time consistent. There is also a game between countries and this is where the issue of coordination or cooperation arises. We consider two alternative solutions to this multicountry game: the cooperative solution which is motivated by positive economic considerations, and the non-cooperative (Cournot–Nash) solution which is motivated by normative or descriptive considerations. An alternative to the latter is to use a dominant player solution for the international game with the U.S. being the dominant player.

To be specific consider the following welfare loss for each country in the two country set-up:

$$\lambda \operatorname{var}(\pi_{it}) + (1-\lambda) \operatorname{var}(y_{it}), \tag{19}$$

where λ is a weight between 0 and 1 representing the relative cost of inflation and output fluctuations, and where $i=1$ or 2 for country 1 or 2. The variances in (19) are the variances of the steady state stochastic equilibrium when the policy rules in (17) and (18) are being used.

The optimal cooperative policy is easy to describe and compute. The two countries choose the g-parameters of the policy rules in (17) and (18) that minimize a weighted sum of (19) for i equal 1 and 2; determining which country gets the higher weight on its loss function in this cooperative effort is a matter for negotiation. We will assume that the weights are equal.

The non-cooperative (Cournot–Nash) optimal rules are described as follows:[7] country 1 minimizes its welfare loss (19) in the steady state (for $i=1$) taking country 2's policy rule (18) as given; similarly country 2 minimizes (19) in the steady state (for $i=2$) taking country 1's policy rule (17) as given; the Cournot–Nash equilibrium occurs when the rule that country 1 takes as given is optimal for country 2, and the rule that country 2 takes as given is optimal for country 1. In this two-country symmetric model the non-cooperative policy rules can easily be computed by iterating each country's minimization. (Note that if the two countries are the same then the optimal policies in the two countries will be the same so that $g_{11}=g_{22}$ and $g_{12}=g_{21}$.)

Example. Consider the two types of rules for the case where the welfare weight $\lambda=0.5$ in each country, and where $\delta=0.621$, $\gamma=0.266$, $\beta=0.133$, the variance of the shocks u_{1t} and u_{2t} is 1, and the covariance between the shocks is zero. (These δ and γ parameter values are what one obtains from a simple unconstrained Phillips curve regression over the 1970–82 period.) The policy rule parameters are given below:

Optimal cooperative policy rules.

	Accommodation parameters (g)	
	Inflation in 1	Inflation in 2
Country 1	−0.207	0.072
Country 2	0.072	−0.207

Optimal non-cooperative (Cournot–Nash) policy rules.

	Accommodation parameters (g)	
	Inflation in 1	Inflation in 2
Country 1	−0.223	−0.011
Country 2	−0.011	−0.223

[7]See Shubik (1983) for a discussion of Cournot–Nash non-cooperative equilibria. From a descriptive viewpoint it is not clear that this is the best non-cooperative solution concept for countries choosing macro policy rules. Moreover, if we imagine the Cournot–Nash equilibrium solution being arrived at in practice through an iterative process in real time, the process would be implausibly slow for macro policy rules. Recall that the 'reaction functions' are in terms of the *parameters* of the policy rules rather than in the actual policy instruments.

Note the cooperative solution involves more accommodation than the non-cooperative solution: both countries do not let quite as deep a recession occur after an inflation shock when the rules are chosen cooperatively. For these parameter values the differences in accommodation are not large, however.

The policies are not only different in the accommodation to domestic inflation. Both sets of policies involve some reaction to foreign inflationary developments; that is, g_{12} and g_{21} are not zero. The cooperative policies call for a stimulus to aggregate demand when there is a rise in inflation in the other country. This permits the other country to appreciate its currency by a larger amount and helps to reduce inflation there. The boost to aggregate demand at home is not considered a gain in welfare, however, so that the 'gain from trade' implicit in the cooperative solution is in the form of an agreement for the other country to help out in a similar way when the inflation situation reverses.

The non-cooperative rule has the opposite response to inflation in the other country. This occurs because without cooperation there is a tendency for each country to counteract some of the exchange rate effects caused by the policy in the other country. For example, starting from a cooperative equilibrium each country can improve its macro performance by matching the policy of the other country; if one country contracts in response to an inflation shock, the other country can reduce the inflationary consequences of the exchange rate depreciation by similarly contracting. This means changing the g_{12} coefficient from positive to negative. Of course, this action will likely result in a change in the policy rule in the other country, and eventually both countries are worse off than they were in the cooperative mode.

4.3. The general multicountry case

Generalizing the model and the policy problem in eqs. (15) through (19) to the case of an arbitrary number of countries that are not necessarily alike in their economic structure or in their macro policy preferences is fairly straighforward. Eqs. (15) and (16) become

$$\pi_{it} = \delta_i \pi_{it-1} + \sum_j \gamma_{ij} y_{jt} + u_{it}, \qquad i = 1, \ldots, n. \tag{20}$$

The policy rules for each country become

$$y_{it} = \sum_j g_{ij} \pi_{jt-1}, \qquad i = 1, \ldots, n. \tag{21}$$

The sums in (20) and (21) are from 1 to n. Finally, the welfare function is given for each of the n countries by (19) for $i=1,\dots,n$.

This model can be put in a matrix form convenient for computing the optimal steady state rules as follows:

$$z_t = Dz_{t-1} + Cx_t + u_t, \tag{22}$$

$$x_t = Gz_{t-1}, \tag{23}$$

where $z_t=(\pi_{1t},\dots,\pi_{nt},y_{1t},\dots,y_{nt})$, and where $x_t=(y_{1t},\dots,y_{nt})$. The matrix D is $2n$ by $2n$ with the only non-zero elements on the diagonal of the upper left-hand n by n block which has the δ_i parameters on the diagonal and zeros elsewhere. The matrix C is $2n$ by n and has the γ_{ij} parameters in the n by n matrix in its upper half and the n by n identity matrix in its lower half. Finally, G is an n by $2n$ matrix with the policy rule coefficients g_{ij} in the first n columns and zeros in the last n columns. [These zeros are the weights on the lagged demand terms in the policy rule which we know will be zero in this problem but not in a general optimal control problem of the form (22) and (23).]

Calculation of the cooperative equilibrium requires some way of weighting the welfare functions in each country. We take the weights to be equal. Then the optimal cooperative policy to minimize loss in the steady state is given by the solution to

$$G = -(C'HC)^{-1}C'HD, \tag{24}$$

where H is the solution to

$$H = L + (D+CG)'H(D+CG), \tag{25}$$

where the $2n$ by $2n$ diagonal matrix L has λ_i, $i=1,\dots,n$ on the first n diagonal elements, and $1-\lambda_i$, $i=1,\dots,n$ on the last n diagonal elements. This cooperative solution is that given by a standard optimal control problem [see Chow (1975), for example].

The Cournot–Nash equilibrium solution for the steady state problem is given by

$$G = -\begin{bmatrix} \gamma_{1'}H_1 \\ \gamma_{2'}H_2 \\ \vdots \\ \gamma_{n'}H_n \end{bmatrix} C \Bigg]^{-1} \begin{bmatrix} \gamma_{1'}H_1 \\ \gamma_{2'}H_2 \\ \vdots \\ \gamma_{n'}H_n \end{bmatrix} D, \tag{26}$$

where the γ_i vectors are the n columns of C, and where H_t is given by the solutions to

$$H_i = L_i + (D+CG)'H_1(D+CG), \qquad i=1,\dots,n, \tag{27}$$

where L_i is a $2n$ by $2n$ matrix with all zeros except the ith diagonal element which is equal to λ_i and the $(n+i)$th diagonal element which is equal to $1-\lambda_i$. This non-cooperative solution is given by Kydland (1975). The computation of the non-cooperative policies is actually quite similar to the computation of the optimal policies. The main computational difference is that one must calculate n different H_i matrices for each of the n countries in the non-cooperative case, but only one H matrix in the cooperative case. Solving (27) for each H_i is no different from solving (25) for H which is part of a standard optimal control problem. An iterative procedure used for example by Taylor (1979) is most convenient.

It may appear paradoxical that neither the cooperative nor the non-cooperative policy rules depend on the correlation between the supply shocks u_{it} in each country. Formally, this is due to the certainty equivalence property of the linear behavioral equations and the quadratic loss function. Of course the value of the loss function evaluated at the optimal policies will depend on the variances and covariances. When one sees the estimated outcome of the optimal policies — that is, the value of the loss function — it is likely that one would want to change the parameters of the loss function, and recompute the policies. For this reason, the actual choice of policies is likely to depend on the covariance between the shocks. This may explain the apparent paradox of the certainty equivalence result in the multicountry context.

The value of the loss function when the optimal policies are being used can be calculated by substituting (23) with the optimal value of G into (22) and evaluating the steady state covariance matrix of z_t. Let S be the covariance matrix of the shocks u_{it}. Then the steady state covariance matrix z_t denoted by Ω is given by the solution to $\Omega = (D+CG)'\Omega(D+CG)+S$. The steady state variances of inflation and output in each of the countries are on the diagonal elements of Ω. Using these variances the optimized value of the loss function in each country can be evaluated easily from eq. (19).

5. Calculating the optimal policy rules

In this section we report a set of calculations of optimal cooperative and non-cooperative policy rules, and the resulting values of the loss function for the seven summit countries. To do this we need parameter values δ_i and γ_{ij} of the inflation equations (20), the covariance matrix S of the disturbances to these equations, and values of the welfare parameters λ_i. Because the inflation equations are semi-reduced forms that partially depend on the policy rules being used, estimating them is a precarious task. Most problematical are the γ_{ij} for $i>j$, the values and even signs of which depend on whether the policy rules use flexible or fixed exchange rates. For the optimal policy calculations we need to assume that the class of policies with flexible exchange rates is being used. Yet over any recent sample period some of the seven summit countries have used fixed exchange rates and others have used flexible exchange rates. Moreover, the exchange rate policies have changed for some of the countries.

The following procedure was finally used:[8] Over the 1970–1982 period individual inflation equations for the seven countries were estimated constraining δ_i to equal 1 (the value for a vertical long-run Phillips curve), and including only the value of output for the individual country (measured as a deviation from a linear trend). From these estimates we obtained values for γ_{ii} for the seven countries. Using the residuals from these equations over the same sample period, we then estimated S, the covariance matrix between the shocks in each country. The coefficients γ_{ij} of each other country's output variables in each equation were then scaled to be less than the γ_{ii} and proportional to the trade of that country with each other country. The trade weights w_{ij} were the values used by Masson and Blundell-Wignall (1985). More specifically we set $\gamma_{ij}=aw_{ij}\gamma_{ii}$ where a is a scale parameter less than one. The scale parameter is a measure of the overall importance of the interaction between countries. Since this interaction is the focus of this study we experimented with a number of different values between 0 and 1. In general the results were qualitatively similar, though the magnitudes of the policy parameters depend on the degree of interaction. For space limitations we only report the optimal policies for $a=\frac{2}{3}$ here.

The values of all the parameters of the model for this case are presented in table 3. The effect of the 'own' demand measure on inflation is positive in each country. The coefficient is surprisingly small for Germany and large for Italy. Note that the U.S. demand variable has a relatively large impact on the inflation equations in the other countries according to these parameter values. There is also a relatively large interaction between France, Germany and Italy. Not surprisingly the covariances between the inflation shocks in each country are almost all positive: exceptions are the covariances of Japan with respect to France and the U.K. Note also that by this measure the inflation shocks are largest in Japan and the U.K. The variance for the U.K. is an order of magnitude larger than the U.S.

[8]I originally intended to estimate the inflation equations for all seven countries with the nine right-hand side variables included without constraints, but the degrees of freedom became distressingly low. I therefore considered an unconstrained estimation for only four countries, but even then parameter estimates appeared implausible for certain countries. Finally, rather than reduce the number of countries I decided to impose this plausible though somewhat arbitrary structure.

Table 3

Parameter values used for computing policy rules.

	Canada	France	Germany	Italy	Japan	U.K.	U.S.
Coefficients of output in inflation equations (γ_{ij})							
Canada	0.1944	−0.0005	−0.0031	−0.0005	−0.0021	−0.0022	−0.1203
France	−0.0003	0.0970	−0.0211	−0.0035	−0.0011	−0.0031	−0.0272
Germany	−0.0000	−0.0004	0.0080	−0.0003	−0.0001	−0.0003	−0.0033
Italy	−0.0033	−0.0458	−0.1958	1.0045	−0.0101	−0.0229	−0.3284
Japan	−0.0072	−0.0080	−0.0434	−0.0051	1.0795	−0.0174	−0.6191
U.K.	−0.0022	−0.0070	−0.0271	−0.0038	−0.0046	0.2975	−0.1304
U.S.	−0.0322	−0.0173	−0.0760	−0.0115	−0.0339	−0.0289	0.3591
Covariance matrix between shocks to inflation equations (*S*) (*actual elements times* 10^{-4})							
Canada	6.13	1.50	0.74	0.98	5.46	0.92	0.61
France	—	2.29	0.56	0.68	−0.20	5.94	1.68
Germany	—	—	2.04	0.79	2.13	2.15	1.16
Italy	—	—	—	3.16	0.97	3.66	0.30
Japan	—	—	—	—	13.53	−3.92	0.57
U.K.	—	—	—	—	—	28.30	6.64
U.S.	—	—	—	—	—	—	2.22

Table 4

Non-cooperative multicountry policy rules.

	Accommodation parameters (g_{ij})							Weight on inflation
	Canada	France	Germany	Italy	Japan	U.K.	U.S.	
Canada	−0.329	−0.009	−0.012	−0.001	−0.003	−0.008	−0.083	0.1
France	−0.004	−0.328	−0.017	−0.001	−0.001	−0.002	−0.026	0.1
Germany	−0.000	−0.000	−0.076	−0.000	−0.000	−0.000	−0.001	0.1
Italy	−0.008	−0.019	−0.022	−0.283	−0.004	−0.011	−0.090	0.1
Japan	−0.014	−0.012	−0.015	−0.002	−0.283	−0.014	−0.155	0.1
U.K.	−0.010	−0.012	−0.015	−0.002	−0.003	−0.322	−0.076	0.1
U.S.	−0.022	−0.016	−0.020	−0.003	−0.008	−0.017	−0.330	0.1
Canada	−0.928	−0.027	−0.113	−0.003	−0.009	−0.025	−0.248	0.5
France	−0.012	−0.959	−0.170	−0.004	−0.004	−0.015	−0.079	0.5
Germany	−0.001	−0.004	−0.594	−0.000	−0.000	−0.001	−0.007	0.5
Italy	−0.025	−0.059	−0.182	−0.620	−0.012	−0.034	−0.266	0.5
Japan	−0.043	−0.035	−0.125	−0.007	−0.610	−0.041	−0.453	0.5
U.K.	−0.029	−0.038	−0.134	−0.006	−0.010	−0.877	−0.229	0.5
U.S.	−0.066	−0.048	−0.169	−0.009	−0.025	−0.051	−0.896	0.5
Canada	−2.327	−0.081	−0.573	−0.010	−0.027	−0.074	−0.712	0.9
France	−0.036	−2.623	−0.876	−0.012	−0.010	−0.046	−0.235	0.9
Germany	−0.006	−0.020	−2.893	−0.001	−0.001	−0.006	−0.035	0.9
Italy	−0.074	−0.171	−0.900	−0.913	−0.029	−0.093	−0.661	0.9
Japan	−0.124	−0.105	−0.622	−0.017	−0.886	−0.111	−1.109	0.9
U.K.	−0.086	−0.114	−0.669	−0.015	−0.028	−1.997	−0.641	0.9
U.S.	−0.190	−0.144	−0.839	−0.023	−0.061	−0.142	−1.998	0.9
Canada	−0.929	−0.029	−0.527	−0.003	−0.010	−0.026	−0.253	0.5
France	−0.013	−0.963	−0.770	−0.004	−0.004	−0.016	−0.086	0.5
Germany	−0.006	−0.017	−2.918	−0.001	−0.001	−0.006	−0.034	0.9
Italy	−0.023	−0.056	−0.852	+0.284	−0.008	−0.028	−0.194	0.1
Japan	−0.044	−0.038	−0.597	−0.005	−0.610	−0.042	−0.458	0.5
U.K.	−0.030	−0.041	−0.631	−0.004	−0.011	−0.878	−0.234	0.5
U.S.	−0.067	−0.052	−0.801	−0.007	−0.025	−0.052	−0.903	0.5

Table 5

Macroeconomic performance: Non-cooperative multicountry policy rules.

Country	Variance ($\times 10^{-4}$) σ_π^2	Variance ($\times 10^{-4}$) σ_y^2	Loss ($\times 10^{-4}$) $\lambda\sigma_\pi^2+(1-\lambda)\sigma_y^2$	Percent standard deviation σ_π	Percent standard deviation σ_y	Weight on inflation
Canada	55.9	7.2	12.0	7.5	2.7	0.1
France	13.6	5.6	9.4	6.6	2.4	0.1
Germany	202.1	1.2	21.3	14.2	1.1	0.1
Italy	6.3	1.4	2.0	2.6	1.2	0.1
Japan	27.0	3.5	5.8	5.2	1.9	0.1
U.K.	168.9	20.5	35.4	13.0	4.5	0.1
U.S.	13.3	2.7	3.6	3.6	1.6	0.1
World macro performance			89.7			
Canada	20.8	24.7	22.8	4.6	5.0	0.5
France	15.3	23.8	19.6	3.9	4.9	0.5
Germany	146.5	51.5	99.0	12.1	7.2	0.5
Italy	3.8	9.6	6.7	1.9	3.1	0.5
Japan	15.6	12.9	14.3	4.0	3.6	0.5
U.K.	67.0	65.7	66.3	8.2	8.1	0.5
U.S.	5.2	13.6	9.4	2.3	3.7	0.5
World macro performance			247.1			
Canada	9.5	88.5	17.4	3.1	9.4	0.9
France	5.9	107.3	16.1	2.4	10.4	0.9
Germany	53.5	448.2	92.9	7.3	21.2	0.9
Italy	3.2	58.5	8.7	1.8	7.7	0.9
Japan	13.6	48.4	17.1	3.7	7.0	0.9
U.K.	35.4	208.0	52.6	5.9	14.4	0.9
U.S.	2.8	69.1	9.4	1.7	8.3	0.9
World macro performance			214.2			
Canada	21.3	47.3	34.3	4.6	6.9	0.5
France	17.5	71.9	44.7	4.2	8.5	0.5
Germany	52.7	452.2	92.7	7.3	21.3	0.9
Italy	10.6	51.7	47.6	3.3	7.2	0.1
Japan	15.7	37.0	26.4	4.0	6.1	0.5
U.K.	67.3	98.1	82.7	8.2	9.9	0.5
U.S.	5.5	55.2	30.4	2.4	7.4	0.5
World macro performance			358.8			

The optimal policy rules and resulting welfare loss for each country and for the group as a whole are presented in tables 4 through 7. The g-parameters of the non-cooperative rules are given in table 4 with the resulting welfare in table 5, and g-parameters of the cooperative rules are given in table 6 with the resulting welfare in table 7. The policy rules were computed for three different weights on inflation in the welfare function (0.1,

Table 6

Cooperative multicountry policy rules.

	Accommodation parameters (g_{ij})							Weight on inflation
	Canada	France	Germany	Italy	Japan	U.K.	U.S.	
Canada	−0.315	0.007	−0.007	0.005	0.006	0.006	−0.042	0.1
France	0.008	−0.314	−0.009	−0.013	0.004	0.009	0.008	0.1
Germany	0.037	0.085	−0.058	0.056	0.019	0.047	0.127	0.1
Italy	0.016	−0.009	−0.015	−0.267	0.015	0.013	−0.044	0.1
Japan	0.018	0.011	−0.009	0.017	−0.254	0.015	−0.108	0.1
U.K.	0.009	−0.008	−0.009	0.009	0.008	−0.309	−0.032	0.1
U.S.	0.047	0.021	−0.010	0.056	0.093	0.046	−0.260	0.1
Canada	−0.886	0.020	−0.076	0.013	0.016	0.017	−0.134	0.5
France	0.022	−0.917	−0.115	0.027	0.010	0.025	0.017	0.5
Germany	0.106	0.242	−0.443	0.124	0.047	0.132	0.348	0.5
Italy	0.046	0.023	−0.131	−0.576	0.036	0.034	−0.132	0.5
Japan	0.048	0.031	−0.085	0.043	−0.538	0.040	−0.319	0.5
U.K.	0.026	0.022	−0.093	0.022	0.020	−0.837	−0.112	0.5
U.S.	0.110	0.054	−0.112	0.103	0.159	0.104	−0.689	0.5
Canada	−2.200	0.049	−0.448	0.026	0.025	0.035	−0.443	0.9
France	0.060	−2.498	−0.688	0.040	0.020	−0.054	0.002	0.9
Germany	0.295	0.638	−2.364	0.191	0.101	0.325	0.817	0.9
Italy	0.098	0.048	−0.723	−0.840	0.011	0.064	−0.330	0.9
Japan	0.080	0.068	−0.489	0.054	−0.791	0.056	−0.795	0.9
U.K.	0.059	0.049	−0.529	0.035	0.029	−1.888	−0.362	0.9
U.S.	0.152	0.107	−0.653	0.095	0.111	0.135	−1.517	0.9
Canada	−0.875	0.045	−0.228	0.020	0.019	0.027	−0.108	0.5
France	0.037	−0.884	−0.340	0.031	0.013	0.037	0.050	0.5
Germany	0.267	0.621	−1.419	0.345	0.165	0.398	1.078	0.9
Italy	0.061	0.089	−0.392	−0.233	−0.027	0.057	0.014	0.1
Japan	0.069	0.075	−0.263	0.050	−0.529	0.063	−0.256	0.5
U.K.	0.046	0.064	−0.281	0.035	0.027	−0.817	−0.058	0.5
U.S.	0.135	0.107	−0.344	0.082	0.169	0.131	−0.624	0.5

0.5 and 0.9). For three calculations we assumed that all countries had the same preferences, and for one we assumed a mix of different preferences. For the mixed case Germany was assumed to have a high weight on inflation and Italy was assumed to have a low weight on inflation with the other countries falling in between. As one would expect the policy rule becomes less accommodative to inflation as the weight on inflation in the welfare function increases.

A comparison of tables 4 and 6 clearly indicates that the cooperative policies are more accommodative to inflation than the non-cooperative policies, much as in the symmetric two-country example. For all values of the loss function and for all countries, the diagonal elements ($i=j$) are smaller in absolute value in the cooperative case. Hence, an increase in domestic

Table 7

Macroeconomic performance: Cooperative multicountry policy rules.

Country	Variance ($\times 10^{-4}$) σ_π^2	σ_y^2	Loss ($\times 10^{-4}$) $\lambda\sigma_\pi^2+(1-\lambda)\sigma_y^2$	Percent standard deviation σ_π	σ_y	Weight on inflation
Canada	50.7	5.5	10.0	7.1	2.3	0.1
France	39.0	3.5	7.0	6.2	1.9	0.1
Germany	213.2	3.2	24.1	14.6	1.8	0.1
Italy	6.1	0.5	1.0	2.5	0.7	0.1
Japan	24.6	2.0	4.3	5.0	1.4	0.1
U.K.	161.1	16.4	30.9	12.7	4.1	0.1
U.S.	33.5	10.0	4.2	5.8	10.0	0.1
World macro performance			81.5			
Canada	19.2	18.4	18.8	4.4	4.3	0.5
France	13.9	14.6	14.3	3.7	3.8	0.5
Germany	169.3	33.9	101.6	13.0	5.8	0.5
Italy	3.6	4.3	4.0	1.9	2.1	0.5
Japan	15.1	7.4	11.3	3.9	2.7	0.5
U.K.	64.5	51.8	58.1	8.0	7.2	0.5
U.S.	11.9	5.9	8.9	3.5	2.4	0.5
World macro performance			217.0			
Canada	9.1	68.3	15.0	3.0	8.3	0.9
France	5.2	76.9	12.6	2.3	8.8	0.9
Germany	68.0	359.9	97.2	8.2	19.0	0.9
Italy	3.2	39.9	6.9	1.8	6.3	0.9
Japan	13.6	32.3	15.5	3.7	5.7	0.9
U.K.	34.8	165.7	47.9	5.9	12.9	0.9
U.S.	4.7	42.7	8.5	2.2	6.5	0.9
World macro performance			203.6			
Canada	18.6	23.8	21.2	4.3	4.9	0.5
France	11.6	27.1	19.4	3.4	5.2	0.5
Germany	112.8	195.1	121.0	10.6	14.0	0.9
Italy	6.0	17.1	16.0	2.5	4.1	0.1
Japan	15.1	14.2	14.6	3.9	3.8	0.5
U.K.	62.2	55.3	58.8	7.9	7.4	0.5
U.S.	8.6	17.5	13.0	2.9	4.2	0.5
World macro performance			264.0			

inflation calls for a smaller decline in output relative to trend when countries are cooperating in their choice of rules than when they are in a non-cooperative equilibrium.

The off-diagonal elements ($i>j$) or ($i<j$) are all negative in the non-cooperative case: an increase in foreign inflation brings about a decline in output at home for each country. In the cooperative case, however, the off-

diagonal accommodation parameters are usually positive or at least less strongly negative. There are three exceptions: compared to the non-cooperative equilibrium, (1) with a 0.1 weight on inflation for all countries, France contracts output more strongly in response to an increase in inflation in Italy in the cooperative case, (2) with a 0.9 weight on inflation in all countries, France contracts output more strongly in response to an increase in inflation in the U.K. in the cooperative case, and (3) with the mix of welfare weights Italy contracts output more strongly in response to an increase in inflation in Japan in the cooperative case. These results are therefore slightly different from the two-country symmetric model considered previously where all the off-diagonal parameters were positive in the cooperative case.

The values of the loss function shown in tables 5 and 7 indicate how welfare would change as a result of a shift from a non-cooperative equilibrium to cooperation. The cooperative policy rule minimizes the simple sum of the loss functions in each country. Hence, it is not surprising that the sum of the loss functions — an indicator of world macroeconomic performance — is smaller in the cooperative case. The improvement is proportionately larger when countries have a mixture of preferences for price stability over output stability.

Note that the size of the improvement differs accross the countries according to this calculation. Welfare is actually reduced for Germany in all the cases that we consider; and it is reduced for the U.S. as well when the weight on inflation is small (0.1). There are offsetting gains in welfare for Canada, France, Japan, Italy and the U.K. In order for the change from non-cooperation to this particular cooperative policy rule to be Pareto improving — at least one country better off and no country worse off — some compensating payments would be necessary to make this cooperative policy an improvement to Germany (and the U.S. if the weight on inflation is small). More formally we could adjust the weights in the sum of the loss functions — placing a heavier weight on Germany and the U.S. — and recompute the cooperative policy. If this new cooperative policy resulted in a reduction in welfare for some country, then the weights could be adjusted further until a Pareto improving cooperative policy was found. This calculation would then constitute a formal proof that the cooperative policy results in a Pareto improvement in world welfare.

It would also be reasonable to adjust the relative weights on inflation and output in the individual country welfare functions when calculating the cooperative policies. For example, when the weight on inflation is 0.9 in all countries, the improvement in welfare for Japan, the U.S. and the U.K. shows up entirely in a reduction in output variances. By adjusting the relative costs of inflation and output fluctuations, some of the gain could be placed in a reduction in inflation fluctuations as well.

It is worth noting that there is no particular normative reason to weight each *country* the same in the world welfare function. Perhaps a more utilitarian approach would be to weight each country's welfare in proportion to its population; this would be similar to weighting each *person* the same when computing world welfare.

6. Summary and concluding remarks

The main objective of this paper has been to examine some of the international issues that arise in designing macroeconomic policy rules. A theoretical two-country rational expectations model was used to illustrate the effects of monetary and fiscal policy in an international economy. In brief summary the following effects were noted: A stimulative monetary policy has positive real output effects abroad whether exchange rates are fixed or flexible, though the foreign effects are much larger with fixed rates. A stimulative fiscal policy has positive short-run effects on output abroad when exchange rates are flexible and negative effects when the exchange rate is fixed. An expansionary fiscal policy eventually raises real interest rates abroad, but there is initially a decline when exchange rates are flexible, and an overshooting when exchange rates are fixed. Regardless of whether exchange rates are fixed or flexible domestic monetary and fiscal policy are effective aggregate demand instruments at home even though capital is perfectly mobile. The international effects of demand shocks are completely eliminated if monetary policy is used for LM curve shocks and fiscal policy is used for IS curve shocks.

The two-country model suggests a simple but attractive class of policy rules in which monetary policy is used to offset velocity shocks and to determine the appropriate amount of accommodation to inflation, while fiscal policy is used to deal with aggregate spending shocks. Exchange rates need to be flexible for this class of policy rules because each country has an independent monetary policy. We noted that there is a potentially important international externality in the choice of how accommodative monetary policy should be when exchange rates are flexible. The underlying reason is the effect of exchange rate on inflation.

The latter feature of the theoretical two-country model was highlighted in a simpler n-country model that was used to examine policy in the seven summit countries. A comparison of cooperative and non-cooperative optimal macro policy rules for these seven countries indicated that the cooperative policy rule is in fact more accommodative, regardless of the preference in each country.

Finally, from a technical viewpoint these results indicate how some of the new policy evaluation techniques recently applied to closed economy models might be applied in an international context. The model used in this paper is still too aggregative to address many of the important questions about international monetary and macro policy reform, but the results are sufficiently promising to indicate that the general econometric approach could be extended to deal with many important international reform issues.

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