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Is There a Case for More Managed Exchange Rates?

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The remarkable appreciation of the U.S. dollar after 1980 has been viewed by many observers as a failure of the floating exchange rate system, and has been a major stimulus to calls for a return to a more managed global exchange rate system. Critics of the current international monetary arrangements argue that tighter international "rules of the game" in macroeconomic policymaking would reduce the large swings in exchange rates and in global economic activity that have been experienced since the breakdown of fixed exchange rates in 1973. These critics also suggest that better policy coordination and tighter rules of behavior will be necessary for a smooth adjustment to the immediate problem of a grossly overvalued dollar. Policy recommendations of these critics run across a wide spectrum, ranging from incremental measures such as enhanced consultations among the major economies, and enhanced International Monetary Fund surveillance, to dramatic changes such as a return to fixed exchange rates among the major industrial countries.

This paper looks at the case for a return to tighter international rules of behavior for exchange rates among the industrial economies. Does the exchange rate experience since 1973 provide a clear indictment of floating rates, and more importantly, does the experience suggest new ground rules for a more managed system? Are the shortcomings in macroeconomic management in the global economy due to domestic policy mistakes that could be corrected by improved domestic rules of behavior, or are they mistakes involving the international incentives faced by national policymakers, in which case only a reform of the international rules of the game would suffice?

When economists have analyzed different rules of the game, and especially when they have focused on the choice between fixed and flexible exchange rates, the arguments have centered on two issues. The first issue is how policymakers react to alternative external constraints. For example, do floating rates permit the manipulation of exchange rates by national mone-

tary authorities (the so-called beggar-thy-neighbor issue?) Do fixed exchange rates provide a useful discipline on the inflationary tendencies of politicians? The second issue is how the world economy responds to exogenous shocks, other than those caused by the policymakers themselves. For example, do floating rates help to protect countries from unexpected shifts in demand for the domestic currency? The relative merits of alternative rules of the game clearly depend on both types of issues, the "policy" dimension and the "shock" dimension.

The recent arguments for more managed rates have tended to focus on the policy dimension, with advocates of tighter rules of the game generally making their case along some or all of the following lines'. First, it is argued that macroeconomic policymaking is made difficult today because of the inability of each country's policymakers to predict the actions of policymakers in other countries. Rules of the game would increase predictability, and would thereby enhance global stability. Second, the case is made that floating exchange rates can be manipulated by national authorities to enhance national economic goals at the expense of other countries. International rules of the game would put an end to such beggar-thy-neighbor behavior. Third, some analysts have argued that tighter rules of the game would reduce the ability of national policymakers to misuse macroeconomic instruments for domestic political ends. International pressures would be a sanction against the domestic political business cycle.

Supporters of the current "non-system" of floating rates make several rejoinders. Most importantly, many worry that a global system would merely bring to the international level all of the glaring defects of policy management that are now evident on the national level. They worry that global rules of the game would have forced all countries to opt either for Reaganomics or Mitterandism in recent years, and they take solace in the thought that the unlikelihood of such a policy consensus stands in the way of global rules. Policy coordination would bring greater predictability, but at the risk of all countries simultaneously choosing the wrong set of policies. In other words, the current international environment invites major mistakes at the national level, but it also allows individual countries to pursue sensible policies even when most others do not.

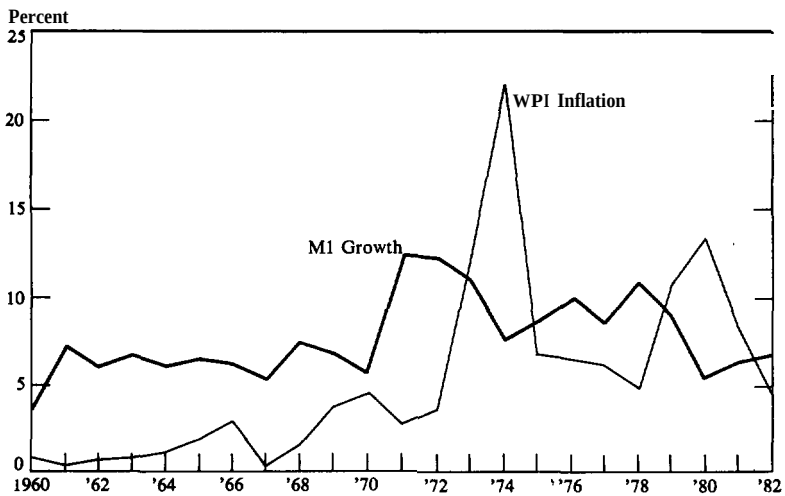
The first half of the paper focuses on the policy-based arguments for managed exchange rates, while the second half of this paper examines how shocks to the world economy are absorbed under alternative rules of exchange rate management. The first section reviews some evidence showing that monetary instability has been a major factor in the global business cycle since 1971. The second section discusses the argument that the floating rate system has had an important role in generating that instability. The third section discusses a new methodology for studying the operating characteristics of alternative exchange rate rules. A simulation model is introduced, in

which key behavioral relations are subject to exogenous shocks. Using some techniques introduced later, we are able to measure the fluctuations to output, inflation, etc., that can be expected to arise under different rules for monetary management. Would a fixed rate system of the sort advocated by McKinnon do a good job in stabilizing the world economy? Would a managed float based on monetary targeting at the national level be superior? The answers to these questions depend, we shall see, on the types of shocks hitting the world economy.

One limitation of this paper should be noted at the beginning. This paper focuses on longer-term aspects of the world monetary system, and thus does not discuss in detail the pressing problem of the large fiscal and trade deficits in the U.S. These current problems are indicative of the general shortcomings in the current world system, in which the center country feels free to take actions which greatly destabilize the world economy. In thinking about longer-term reform of the system, however, it is not useful or necessary to dwell on the short-term aberration of U.S. fiscal policy. At some point in the future, more responsible fiscal policy will prevail, and the older and more fundamental problems of monetary coordination will still remain.

FIGURE 1

Global Money Growth and WPI Inflation



Source: McKinnon (1984)

World monetary instability in the floating rate period

In several important papers, Ronald McKinnon (1982, 1983, 1984) has underlined the fact that the large cyclical fluctuations in the world economy since 1971 have had a crucial monetary component. Specifically, McKinnon is persuasive on the following empirical points:

1. The large swings in global activity since 1971 have all involved synchronized shifts in the money supplies of the major countries. Thus the boom of 1972-74, the deep recession of 1974-75, the boom of 1977-79, and the deep recession of 1980-82, all were characterized by large and synchronous shifts in money in the large OECD economies. To summarize these shifts, McKinnon has constructed a "world money stock" measure, which is a weighted average of money supply changes in several OECD economies. As can be seen in Figure 1, changes in the world money stock measure are a good leading indicator of changes in average OECD inflation rates. The two large inflation peaks, of 1973 and 1979, are clearly preceded by jumps in money growth, in 1971-72 and 1977-78. The monetary changes have also been ti good leading indicator of the global swings in real economic activity.

2. The two oil shocks, in 1973 and 1979, can in large part be attributed to preceding bursts of money supplies in the OECD. Partial evidence for this proposition is that almost all primary commodity prices boomed in 1973 and (to a lesser degree) in 1979. The role of OPEC, and particularly of Saudi Arabia, was not to raise prices, but to keep them high even after the money shock was reversed.

3. A major reason for the swings in money supplies in the non-U.S. OECD economies was the reaction in those countries to changes in the exchange value of the U.S. dollar. Thus, in 1971-72, countries intervened in huge amounts to keep the dollar from depreciating, with the result that huge increases in foreign exchange reserves and in national money stocks were recorded. This happened again in 1977-78, when the dollar was again depreciating under the Blumenthal policy of "talking the dollar down." Then, in 1980-81, with the dollar rising, other countries intervened in support of their own currencies, and thus sharply reduced their money stocks.

4. The global implications of the swings in world money were not widely appreciated at the time that they occurred in any of the three episodes. The global booms in 1972-74 and in 1978-79 were severely underestimated by contemporary observers, while the depth of the contraction after 1980 was also not predicted. In general, the problem is that global models and country forecasters have failed to account for the interactive and multiplier effects that occur when several countries all turn their monetary policy in the same direction.

It should be noted that some economists have challenged McKinnon's

claim that "world" money has played a role additional to U.S. money in determining the U.S. inflation rate. In particular, Goldstein and Haynes (1984) have shown that in a reduced-form inflation equation for the U.S., in which U.S. inflation is explained by lagged U.S. money growth, world energy price changes, and lagged world money growth, the last variable does not reach statistical significance. That result is hardly a convincing refutation, however, since it dubiously treats all of the OPEC price increases as exogenous, rather than caused in large part by the preceding growth of world liquidity.

McKinnon's monetary analysis does not help to account for the divergent cyclical experience of the U.S. and the rest of the OECD after 1982, which has been based more on differing fiscal policies than on differences in monetary policy. Nonetheless, we shall argue that some of the factors that contributed to the excessive swings in world money also help to account for recent movements in U.S. fiscal policy.

Reducing monetary instability through managed exchange rates

Assuming that the above empirical analysis is correct, the crucial issue is how best to prevent further excessive, synchronized shifts in the world money stock, while at the same time preserving enough flexibility in monetary management to avoid unnecessary economic instability in individual countries. Much of the answer to this question depends on one's diagnosis as to why the large monetary swings occurred in the first place. McKinnon has stressed one reason, though several additional reasons must also be acknowledged. Each of these differing explanations for monetary instability suggests a different emphasis for reform of the system. (As with most complicated problems, however, probably all of the factors described below played some part in the process.) This section takes up some of these possible causes of monetary instability, and introduces some of the possible cures. The next session analyzes these policy proposals more rigorously.

Currency substitution as a factor in monetary instability

According to McKinnon, each swing in global money has resulted from an autonomous and unobserved shift in private sector portfolio preferences to or away from U.S. dollar holdings. The mechanism, according to McKinnon, is as follows. In 1971 and 1977, wealth holders in the world economy decided autonomously to move away from U.S. money, and towards the monies of other countries. In both cases the dollar tended to weaken, but the Fed ignored the exchange rate signal and failed to reduce the supply of dollars through foreign exchange intervention or open-market operations. Other countries found the demands for their national currencies

to be increasing, with consequent upward pressure on their exchange rates. These countries intervened in the exchange market, basically by selling national monies in exchange for U.S. non-money assets (such as Treasury bills or Eurodollar accounts). Thus the foreign intervention increased the supply of the foreign currencies, but did not decrease the supplies of U.S. money. The overall effect, then, was that the rise in demand for foreign currencies was accommodated, but the fall in demand for U.S. money was not accommodated (i.e. the U.S. money stock was not adequately reduced). In the end, the drop in demand for U.S. money translated directly into an excess supply of U.S. money, with resulting inflationary consequences. According to McKinnon, the same mechanism, in reverse, transpired in 1980-81, when world portfolio holders shifted into U.S. dollars. Since the Fed did not accommodate this shift, while foreign central banks did, the overall global monetary position turned into one of excess demand.

If this mechanism is accurate, then the remedy is straightforward, as McKinnon observes. Portfolio s h i i across national monies should simply be accommodated by both central banks. If demand for dollars falls at the expense of Deutsche marks, then the Fed should contract and the Bundesbank should expand. "Global" money, the average of U.S. and German money stocks, would remain unchanged, as would the dollar-DM exchange rate. One operational way to implement this package is to fix the exchange rate and fix the weighted average stock of world money.

The problem with McKinnon's explanation of the global money shifts is that in each case the shifts were less inadvertent than he portrays. In 1971-72 and 1977-78, for example, monetary policy in the U.S. was expansionary by design. Similarly, the tight monetary policy of the early Volcker era was also part of an explicit anti-inflation program. The dollar shifted in each case, not because of an autonomous portfolio adjustment, but because of the public's accurate perception that U.S. monetary policy had substantially changed. McKinnon is surely correct that the global ramifications of those changes were underestimated, but there is little doubt in each case that the Fed desired a strong movement in the direction that in fact occurred.

Insularity of U.S. monetarypolicy as a cause of monetary instability

The foregoing observations suggest that it has been swings in U.S. monetary policy, more than swings in private sector portfolio behavior, that stand behind the global fluctuations in money. U.S. monetary policy has long been characterized by lack of attention to international variables, including the exchange rate. Even during the gold-exchange standard of the Bretton Woods era, when concern about U.S. gold stocks should have provided a constraint on monetary actions, the influence of diminishing gold stocks on the rate of growth of money is hard to discern. One plausible reading of the

monetary mistakes in the 1970s is that U.S. inattention to world variables proved devastating precisely because monetary policies abroad paralleled and unduly amplified the swings in U.S. monetary policy. The interesting question is why the policy of "benign neglect" of international factors, that worked so well in the 1950s and 1960s suddenly proved so inadequate in the 1970s.

One answer appears to be that the U.S. fell victim to two conflicting trends in world trade and finance. Throughout the 1960s and 1970s the U.S. share of world trade and income declined, and the U.S. became more open (and vulnerable) to foreign trade. On the other hand, and a bit paradoxically, the dollar remained preeminent in international finance, perhaps even increasing its role after 1970 (see Kenen (1983) for a perspective analysis of the continued strong role of the dollar in international finance.) These conflicting trends had the following powerful results: even as the U.S. role in world commodity markets declined, the U.S. power to influence world financial conditions remained dominant. Shifts in U.S. monetary policy brought immediate echoing responses in monetary policy in Europe and Japan. Ironically, since the U.S. monetary authorities paid little attention to movements in foreign money stocks or in the exchange rate, the U.S. found itself surprised and overwhelmed by the size of the foreign monetary response. When the Fed eased in 1971-72, other OECD economies eased even more, mainly to avoid an appreciation of their currencies. As a result, the U.S. ended up importing the inflation in world commodity prices in 1973-74. Once again, in 1977-78, we were overwhelmed by the echo of our own policy change, as Europe and Japan expanded in line with the U.S. And then in 1981-82, the recession in the U.S. and the rest of the OECD was far deeper than expected, in part because of the simultaneous tightening in OECD money supplies following Volcker's shift to tight money at the end of 1979. In sum, the U.S. has constantly underestimated both the extent to which foreign monetary authorities are led to mimic U.S. policy actions, and the extent to which those parallel foreign actions are likely to amplify the effects of our own policies.

One possible response, therefore, for U.S. monetary policy would be to anticipate the policy reactions of other governments when major changes in our own monetary policy are contemplated, as well as to account for the global macroeconomic implications of simultaneous policy changes in several major economies. This increased sensitivity to the effects of our monetary policy choices on other countries would not require anything as drastic as a return to fixed exchange rates.

A second, and very different, response would be to take measure to decouple foreign monetary policies from our own, by reducing the international role of the dollar. Through such a strategy, U.S. monetary authorities could then continue to focus mainly on the U.S. economy, without having to

TABLE 1

Correlation of Money Growth Rates in the United States, Germany, and Japan

	United States	Germany	Japan
1965-76			
United States	1.0	—	—
Germany	0.3	1.0	—
Japan	0.6	0.1	1.0
1977-84			
United States	1.0	—	
Germany	0.7	1.0	—
Japan	0.1	0.6	1.0

Source: Correlation matrix of annual (year-over-year) growth rates of M1. Data are from the International Financial Statistics of the International Monetary Fund.

worry as much about the policy reactions abroad. This process of decoupling is already evident in the case of Japan. With the emergence of the yen as a *bona fide* international reserve currency, and with the failures of Japanese monetary policy during the early 1970s, monetary policy in Japan has become less and less centered on U.S. financial conditions. In Europe, on the contrary, national monetary policies are still centered squarely on financial conditions in the U.S. financial markets (and in the Eurodollar market). Table 1 gives some evidence of the relatively greater independence now exercised by Japanese monetary policy. Movements in the Japanese money supply since 1977 have been almost uncorrelated with movements in the U.S. money supply, in contrast with the close correlation between the two money supplies in the period 1965-1976. The German money stock, on the other hand, continues to show a very high correlation with the U.S. money stock.

The European Monetary System (EMS) was created, at least in part, to allow the European countries to dissociate their currencies from the dollar. While the operation of the EMS has been relatively successful in stabilizing intra-European exchange rates, and (to a lesser extent) in encouraging the harmonization of macroeconomic policies; the EMS has not yet really served to diminish the importance of the dollar for the monetary policies of the individual European economies. Most importantly, since there is no common EMS policy for the exchange rate of the ECU vis-a-vis the dollar, the ECU dollar exchange rate is still determined implicitly by the separate actions of the leading central banks in the EMS. Moreover, the ECU has not

yet become an intervention currency or a store of value (it remains mainly a unit of account for official transactions in the EMS). An enhanced role for the ECU could go a long way in breaking the dependence of European financial policies on corresponding U.S. policies.

Beggar-thy-neighbor policies as a source of monetary instability

The two explanations just examined of the recent fluctuations in world money supplies assume that policymakers were making conceptual mistakes in the implementation of monetary policy. The third and fourth explanations to which we now turn assume, on the other hand, that the policymakers know what they are doing, but that they operate under inappropriate incentives. It has been argued, for example, that the current system, with its absence of clear rule of the game, encourages beggar-thy-neighbor monetary policies that contribute to overly expansionary or overly contractionary policies on the global level. A growing economics literature, beginning with Hamada, and including studies by Canzoneri and Gray, Oudiz and Sachs, and others, describes this possibility.

A simple illustration of how inappropriate incentives can make monetary policy too contractionary is as follows. Consider a group of countries, linked by floating rates, that are all attempting to reduce a high level of inflation (as in the OECD during 1980-82). Policymakers in each country decide on the degree of monetary restraint to pursue in the disinflation process. If the economies were closed economies, each monetary authority would presumably consider the short-run tradeoff of inflation and unemployment in deciding how tight the monetary policy should be. In an open economy, however, there seems—from the point of view of each policymaker—to be another dimension to the problem. Each central bank knows that by having a tighter monetary policy than abroad, the domestic currency will strengthen in value, thereby reducing import prices and domestic inflation. The other countries, of course, will suffer higher inflation on the same account. From the vantage point of each individual central bank, a strong exchange rate seems to be an added anti-inflation "bonus" that comes from tight monetary policy.

Each central bank is therefore led to tighten its monetary policy in the attempt to strengthen its currency, as a way to reduce domestic inflation. However, from a global perspective, it is not possible that each currency appreciates vis-a-vis the others. The tight money policies that each central bank pursues simply cancel each other out, so that nobody's exchange rate ends up appreciating in equilibrium. No country achieves the anti-inflation benefits of lower import prices, but all of the countries suffer from exceedingly tight monetary policies.

When put in the language of game theory, we see that the temptation to

appreciate the exchange rate in order to fight inflation is just like the temptation to confess in the classic prisoners' dilemma. In the prisoners' dilemma, each prisoner is induced to confess to a crime even though both prisoners would be better off by both refusing to confess. In the case of anti-inflation policy, each country can be led to pursue an excessively tight monetary policy even though both countries would be better off if the policies were not so tight.

TABLE 2

Monetary Policy and Social Loss

		Country 2: Loose Money	Country 2: Tight Money
Country 1: Loose Money		$C_1 = 11$ $C_2 = 11$	$C_1 = 14$ $C_2 = 6$
Country 1: Tight Money		$C_1 = 6$ $C_2 = 14$	$C_1 = 12$ $C_2 = 12$

Explanation: See text. C_1 is loss for Country 1; C_2 is loss for Country 2.

A simple numerical illustration of this problem is shown in Table 2. Suppose that each country has two options: tight money or loose money. If both pursue tight money, they deliver a deep recession, with unemployment equal to ten percent, and low inflation, with price increases of two percent. If both pursue loose money, there is no recession, so that unemployment remains at five percent, but inflation remains high at six percent. If one country pursues tight money while the other pursues loose money, the loose-money country has a sharp currency depreciation, and thereby suffers a large jump in inflation, while the tight-money country enjoys the anti-inflation benefits of a currency appreciation. Suppose that the loose-money country ends up with ten percent inflation and four percent unemployment, while the tight-money country ends up with zero inflation, and six percent unemployment. Finally, suppose that the "loss" function of each country's policymaker is the Okun Misery Index, equal to the sum of unemployment and inflation. Under these assumptions, the social losses if both pursue tight money are 12 in each country (= 10 + 2); the social losses if both pursue loose money are 11 (= 5 + 6); the social loss from loose money if the other

pursues tight money is 14 (= 4 + 10); and the social loss from tight money if the other pursues loose money is 6 (= 6 + 0). These payoffs are shown in the matrix in Table 2.

Consider, now, the strategic interactions of the two central banks. Suppose first that the central banks can observe each others' actions, but that they do not directly coordinate their policies. From the point of view of the home-country, it is always better (in terms of minimizing the social losses) to pursue tight money, no matter what the other central bank does. If the other central bank also pursues a tight-money policy, then the loss from a tight money policy at home is 12, while the loss from a loose-money policy would be 14. Similarly, if the other country pursues a loose-money policy, then the loss from a tight-money policy at home is six, while the loss from a loose-money policy would be 11. For this reason, both central banks are led to pursue a tight-money policy, and both countries end up with a loss of 12.

It is easy to see that the combination of tight policies is inefficient. If both countries simply loosened up their monetary policy, they would each end up with smaller losses of 11. But in the absence of policy coordination, or adequate rules of the game, each country is induced to be overly restrictive in its monetary policy. How could better rules of the game help here? Suppose that the countries were linked by a fixed exchange rate, with a common monetary policy being set by agreement. Then it would be easy for both countries to assent to the loose-monetary policy, because each country would be confident that its currency would not depreciate relative to its partner's.

The prisoners' dilemma problem is rife in monetary and fiscal management in the global economy. Almost whenever large countries interact with each other in a non-cooperative way, the resulting equilibrium is likely to be "inefficient," in the sense that all countries could potentially be made better off by increased policy coordination (a theorem to the effect is demonstrated in Oudiz and Sachs, 1984, pp. 26-29.) However, it is one thing to establish the general principal that policy coordination or improved rules of the game are desirable, and quite another to identify the specific areas where gains can be achieved.

In earlier studies I have noted two particular ways in which non-cooperative policymaking is likely to be inefficient. One possibility has just been noted: in a floating rate regime, countries attempting disinflation will pursue overly contractionary monetary policy, as each country attempts to maintain a strong currency. Second, and for similar reasons, the policy mix in each country will be biased towards fiscal expansion cum monetary contraction. For any given output target, the policy authorities will attempt to hit the output level with a policy mix that keeps the exchange rate strong, so as not to import inflation from a currency depreciation. Since a tight money, loose-fiscal policy will keep a currency stronger than would the reverse mix, each

country will tilt towards monetary contraction and fiscal expansion. In the aggregate, of course, not all countries will be able to keep their currencies strong relative to the others, so the mutual attempt will largely cancel out, but all of the countries will be left with large budget deficits. The global equilibrium will be characterized by excessive budget deficits, excessively tight money, and excessively high world interest rates.

In Sachs (1985), I have quantified the gains, from the U.S. point of view alone, of disinflating in recent years through a combination of tight money and expansionary fiscal policy. If the U.S. had maintained the same path of unemployment as during 1981-84, but had done so through more expansionary monetary policy combined with tighter fiscal policy, the result would have been higher inflation in 1984. For example, if the policy mix had been such as to keep the dollar exchange rate constant after 1980 (instead of appreciating by more than 40 percent), inflation in 1984 would have been between two and three percentage points higher in 1984. Each OECD country has faced a similar tradeoff in its policy mix, and so each country has been induced for this reason to tilt in the direction of fiscal expansion and monetary contraction. Of course other factors also affect each country's decision over the extent of fiscal expansion (and indeed fiscal policy has been fairly tight in Japan and Germany in the recent past). Generally speaking, the exchange rate non-system has probably contributed to the global pattern of large fiscal deficits, tight money, and high world interest rates.

In another paper, Warwick McKibbin and I attempted to measure the size of this bias towards fiscal expansion cum monetary contraction. Our methodology was as follows. A dynamic simulation model of the global economy is specified, and the OECD region is divided into the U.S. and ROECD (rest of OECD). The dollar-ROECD exchange rate fluctuates freely in the model, subject to the assumption that the exchange market is efficient (i.e. that the market is competitive, and that all market participants have rational expectations). Policymakers in the U.S. and the ROECD deploy monetary and fiscal policy instruments to minimize an intertemporal loss function. Basically, the policymakers in each region aim for four targets: full employment, zero inflation, current account balance, and domestic budget balance. The policy instruments are tax policy and open market operations.

We assume that both countries inherit an inflation rate of ten percentage points per year, due to past shocks or policy mistakes. The policymakers then attempt to bring that inflation rate down to zero at minimum social cost (as measured by the loss function). Under "non-cooperative" policymaking, policymakers in the U.S. and the ROECD are assumed to choose policy rules that have the following "equilibrium" property: the selected rules are optimal for the given region (i.e. the rule minimizes the loss function), taking as given the rules that the other region is following. The equilibrium is non-cooperative in that each side chooses its macroeconomic strategy sepa-

rately, taking as given the strategy that the other region is pursuing. This leads to a set of rules with the property that I have already described. Each region finds it optimal to fight inflation with over-tight monetary policy, and over-loose fiscal policy.

In the "cooperative" equilibrium, some global rules of behavior are established for monetary and fiscal policy in the two OECD regions. These cooperative rules are selected in order to minimize a weighted average of the social losses of the U.S. and the ROECD. By construction, the cooperative rules of the game take into account the basic fact that it is futile for each country to try to appreciate its currency vis-a-vis the other. Therefore, both regions are led to fight inflation in a more balanced way, with monetary and fiscal policies pointing in the same direction. Naturally, the cooperative equilibrium yields world interest rates that are much lower than in the non-cooperative case.

The model is calibrated to yield magnitudes roughly in line with the actual economies of the OECD. The path of U.S. nominal short-term interest rates under the two types of disinflation are shown below:

Year of Disinflation Policy	1	2	3	4
Non-cooperative Policies	**21.1**	**16.7**	14.5	**12.7**
Cooperative Policies	**15.4**	**13.6**	**11.9**	**10.6**

In both types of equilibria, the process of disinflation requires a period of high nominal interest rates, until the momentum of inflation is eliminated. But in the non-cooperative equilibrium, the interest rates are much higher, for much longer. This is because the non-cooperative case is characterized by high fiscal deficits in the U.S. and the ROECD, while under optimal cooperative rules of the game, fiscal deficits stay near zero in both countries.

Who are the big losers from the failure to cooperate in the disinflation process? First, the U.S. and the ROECD suffer by choosing to implement over-expansionary fiscal policies. These countries are caught in the prisoners' dilemma. But "third parties" are also victims of the absence of adequate rules of the game. In this case, the LDC debtor countries turn out to be big victims, since they are forced to pay extraordinarily high interest rates on their outstanding debts. We calculated that the LDC savings on interest charges that would result from a move to cooperative policies would be several billion dollars per year.

Political incentives and monetary instability

A fourth explanation of the failures of monetary policy stresses the incentives that face politicians when implementing monetary policy. The phases of over-expansionary monetary policy are blamed, at least in part, on the shortcomings of the political system. Two separate types of political shortcomings have been noted. The first is the so-called time consistency problem, which argues that policymakers are unable to persevere with sensible economic policies because the incentives to persevere change adversely over time. A great burst of monetary expansion, following pronouncements of stable and tight monetary policy, is seen to be the result of this problem. The second is the political business cycle, in which policymakers manipulate the economy for short-run political gain, but at a longer-term economic cost. In both cases, some analysts have seen international rules of the game as a way to restrict the "anti-social" tendencies of domestic politicians. However, many other economists fear that international policy coordination would merely elevate to the global level the shortcomings that are now apparent at the domestic level.

An influential view of the politics of inflation, set forth by Barro and Gordon (1983), holds that the timing of policy decisions imparts an inflationary bias to the economy. Consider the following illustration. Wage setters are assumed to set next year's nominal wage in contracts negotiated at the end of the current year. After the wage is set, it is assumed to be fixed throughout the following year, until the next wage round. The current nominal wage is set in order to guarantee an expected real wage the next year. Thus, the wage is set in constant proportion to the expected price level of the next period. Next year's price in turn depends on next year's monetary policy. Thus, the monetary authority has an incentive to announce that next year's monetary policy will be very restrictive, in order to convince workers that the price level will be low, so that the workers will agree to small nominal wage increases.

The time consistency problem arises because once the wage is fixed by contract, the monetary authority no longer has a strong incentive to pursue the tight monetary policy that it promised. In fact, with a fixed nominal wage, it may have a strong incentive to expand the money supply, to try to get a good short-run expansion of the economy. After a while, wage setters will catch on to the monetary authority's game, and will no longer credit policy pronouncements of tight future monetary policy, knowing that the policymaker has an ex-post incentive to renege on its promise. Wage contracts will be based on high expected inflation, since wage setters will recognize the monetary authority's incentive to inflate the economy after each wage contract is determined. This basic argument has been used as a justification for establishing firm rules for monetary policy, as opposed to relying on the

discretion of the monetary authority.

The argument has then been extended to the international arena, by arguing that international rules of the game will be easier to enforce than national rules. An international gold standard, for example, would completely eliminate national discretion from domestic authorities, and so would eliminate the inflationary bias in domestic economy. Theoretical arguments along these lines may be found in Horn and Persson (1984), though the argument that fixed exchange rate arrangements impose discipline on domestic authorities has a long and venerable tradition.

Skeptics of this line of reasoning argue that international rules are unlikely to restrain domestic policymakers, or even worse, that new international arrangements could actually weaken, rather than strengthen, domestic political will. In his classic defense of flexible exchange rates, Friedman (1953) expressed doubt that the stern rules of a fixed exchange rate system such as the classical gold standard could once again be re-established.

> Governments of "advanced" countries are no longer willing to submit to the harsh discipline of the gold standard or any other standard involving rigid exchange rates. They will evade its discipline by direct controls over trade if that will suffice and will change exchange rates before they will surrender control over domestic monetary policy. Perhaps a few modem inflations will establish a climate in which such behavior does not qualify as "advanced"; in the meantime we had best recognize the necessity of allowing exchange rates to adjust to internal policies rather than the reverse (p. 180).

Perhaps the "few modern inflations" have in fact now established the correct climate for fixed rates. In any event, the assumption that strong international rules would actually be observed remains debatable.

Other authors have argued that fixed rates and greater international cooperation could actually make matters worse with respect to the inflationary bias. This argument, made by Vaubel (1983), and formalized independently in an ingenious paper by Rogoff (1983), runs something like this. Under the current non-system of floating rates, a monetary authority that chooses to expand the money supply faces the inflationary consequences of a currency depreciation. The fear of depreciation weighs against unilateral monetary expansion, and thus helps to mitigate the inflationary bias arising from the time consistency problem. If a group of countries decided instead to coordinate their monetary policies, they might well be emboldened to undertake a joint expansion, because the common action would eliminate the fear that any particular currency would depreciate relative to the others. Thus, the joint action of the various central banks might be to approve a monetary expansion that each individually would be unwilling to undertake. Put sim-

ply, the problem of time consistency imparts an inflationary bias to each country, while the fear of currency depreciation helps keep that bias in check. One result of enhanced policy coordination might be an elimination of the fear of a unilateral depreciation, rather than a reduction in the inflationary bias. For this reason, Vaubel and others have argued that "currency competition" rather than "currency cooperation" is the best check against over-inflationary politicians.

The Vaubel and Rogoff point of view can be related to our discussion of the prisoners' dilemma. Referring back to Table 2, remember that the fear of depreciation imparted a deflationary bias to the system (both countries choose to have tight money, even though both would be better off with a common policy of loose money.) According to Vaubel and Rogoff, that kind of deflationary bias is exactly what is needed in the world economy in order to offset the inflationary bias that comes from the time consistency problem.

The political business cycle arguments are closely related to the time consistency arguments. To the extent that politicians manipulate the economy for electoral purposes, international rules of behavior could help to keep such proclivities in check. However, to the extent that the resulting global rules can be manipulated jointly by all of the politicians of the monetary area, the problem of the political business cycle might be exacerbated rather than diminished. (However, at least one point is relevant here in favor of international rules, and that is that national elections in the major industrial countries are staggered, so that global manipulation for electoral purposes becomes more difficult if not impossible.)

Designing new rules for exchange rate management

Any reforms of the international monetary system must confront the sources of monetary instability that we have just outlined. An improved system should enhance predictability, by allowing the policy authorities in each country to have a better understanding of the likely policy reactions in other countries. Next, the system should recognize the possibilities for beggar-thy-neighbor behavior, and therefore try to establish clear rules for "good citizenship" in monetary and fiscal management. Third, the system should be designed to be operated by real, live politicians, who will have incentives to try to bend the rules for short-run political purposes. Fourth, the system should also help to accomodate the major exogenous (non-policy) shocks that the system is likely to experience, whether they are of the portfolio-switching sort emphasized by McKinnon, or of other sorts, as introduced below.

It is a truism of policy analysis that rules which seem appropriate for certain types of shocks to the economic system are less well suited to other

types of shocks. McKinnon's proposal for a fixed exchange rate and a fixed growth of a global money aggregate, is ideal for the portfolio shift disturbances that McKinnon stresses, but is less appropriate if the dominant disturbances are shifts in demand for goods between countries. (The linking of alternative systems to alternative types of shocks goes back to the optimal currency area debate, to which McKinnon (1963) was a pioneering contributor.)

A few general points can be made about the relationship of rules and exogenous shocks. Fixed exchange rates typically allow financial shocks in one country to be "dissipated" widely in the world financial system. Thus, a rise in money demand in one economy, that is not otherwise accommodated, causes all other countries to supply a small amount of the increased money demand to the country in question. All of the countries in the fixed exchange rate union therefore experience a small amount of monetary contraction, and probably a small decline in GNP. The same type of shock under flexible rates has very different implications: the country whose money demand increases experiences a large contraction (if the money demand shock is unaccommodated), while the others experience little change. If the financial shocks across countries are negatively correlated, as in the McKinnon example, fixed exchange rates are even better. Financial shocks across countries then basically cancel each other out, without causing fluctuations in the real economy. On the other hand, flexible rates are generally better at dissipating shifts in demand in the goods markets. A rise in demand for U.S. goods at the expense of European goods will be satisfied by an appreciation of the dollar, without significant fluctuations in employment. Under fixed rates, however, such a shift will cause a boom in the U.S. and a recession in Europe.

Most discussions of fixed versus flexible rates stop at this point; their goal is to check how alternative currency arrangements handle particular exogenous shocks. We have seen however that another major source of disturbances may be the policymakers themselves. While fixed rates help to distribute any country's exogenous financial shocks throughout the world economy, fixed rates also distribute any mistakes in monetary management throughout the world. Under floating rates, if one country is too expansionary it suffers inflation. If, on the other hand, monetary policy is too inflationary under fixed rates, all countries suffer inflation. It should be remembered, for example, that the burst of liquidity in 1971-72 occurred under the fixed exchange rate rules of the Smithsonian Agreement of December 1971. All countries paid for that mistake in monetary management. Similarly, the Great Depression occurred under the rules of the (collapsing) gold standard; the insufficient supply of gold in the world economy in the 1920s and 1930s was transmitted in the form of deep economic contraction to all countries.

Thus, the recommendation of fixed exchange rates makes sense only if

one is confident that exogenous financial shocks will be more important than policy mistakes as sources of instability in the world economy. Fixed rates provide diversification for exogenous shocks, but provide the opposite with respect to policy mistakes.

I now turn to a formal analysis of how exogenous shocks and exchange rate rules are likely to interact. The basic idea is as follows. A large-scale, five-region model of the world economy is used to compare the operating properties of several alternative rules. The model is a dynamic model of trade and financial interactions among the U.S., Japan, the rest of the OECD (ROECD), OPEC, and the non-oil LDCs. A complete description of the model can be found in Sachs and McKibbin (1984), with further applications in Sachs (1985) and Ishii, McKibbin, and Sachs (1985). The U.S., Japan, and the ROECD economies are managed by monetary and fiscal policies in each of the three regions. The model allows for capital mobility among all five regions, and a floating exchange rate among the three OECD areas. The model has two properties that make it particularly appealing for policy analysis. First, all relevant stock-flow relations are observed in the model. That is, budget deficits cumulate into public debt, and current account deficits cumulate into net foreign external debt. Governments and countries are thereby bound by intertemporal budget constraints. Government deficits today must be serviced by increased taxes or reduced expenditures in the future. Second, the asset markets, and particularly the exchange market is governed by rational expectations among wealth holders. When policy rules change, private sector agents understand that the dynamic behavior of the exchange rate will change accordingly..

Using this framework, we inspect the operating properties of four rules. These rules are, respectively: (1) a pure float, with no changes in domestic money supplies or in fiscal policy, in reaction to shocks in the system; (2) the McKinnon rules, in which the exchange rates among the U.S., Japan, and the ROECD are fixed in expected value (the exchange rate will be allowed to change within each period because of unexpected shocks that occur after the policy instruments are set for the period), with the weighted average of the money stocks in the three regions also fixed; (3) a system of nominal GDP targeting within each country, with the exchange rate among the countries allowed to float freely; and (4) a modified McKinnon plan, in which the exchange rates are fixed in expected value, but in which the weighted average of the world money stocks is allowed to change in order to stabilize a measure of world nominal GDP. This last policy choice is like a rule for global GDP targeting.

The specific methodology for comparing the properties of these alternative rules is described briefly in the Appendix, and is described in full technical detail in McKibbin and Sachs (1986). Here I will merely describe the main idea behind the procedure. Once a rule is selected, the dynamic prop-

erties of the world economy can be described compactly by a set of first-order stochastic difference equations, of the form:

$$(1)\ X_{t+1} = AX_t + DS_t$$

The X vector here is the vector of state variables of the system, i.e., the vector of variables whose current levels are determined by the past historical evolution of the economy. Variables contained in the X vector include: the levels of public debt in each of the economies, the price levels in the economies, the levels of foreign indebtedness, etc. In total, the X vector has 37 elements. The vector S is a set of random shocks that are assumed to buffet the world economy. These shocks are assumed to hit several different parts of the global economy. In particular, we allow for random disturbances in the money demand equations of each OECD region (i.e., velocity can rise or fall for purely random reasons), in the price levels in each country (these shocks can be considered as country-specific supply shocks or wage shocks), in the world price of oil, and in the level of aggregate demand in each country (such shocks are akin to investment shifts due to "animal spirits".)

Using numerical techniques described in the Appendix and in the technical paper, it is possible to transform Equation (1) in order to calculate the steady-state variances and covariances of the variables in the X vector. In other words, for a given policy rule, it is possible to know how much the price level in each country will fluctuate, on average, over time. This is very valuable information, since another equation exists which links the macroeconomic targets to the values of the state variables and the values of the random shocks:

$$(2)\ T^i_t = KX_t + MS_t$$

In this equation, T^i is the vector of the target variables (inflation, GDP gap, current account, budget deficit) in country i (i = U.S., Japan, or ROECD.) Once the variances of the X's are known, it is possible to use Equation (2) to calculate the variances of the target variables. But such variances are exactly what we would like to know about each rule: does the rule help to stabilize output, inflation, etc., or does it contribute to increased instability? For a given loss function that is a quadratic function of the targets, it is possible to measure the steady-state welfare that each rule delivers for each country, since the steady-state welfare depends only on the variances of the target variables.

Certain key aspects of the simulation exercise and of the rules must be explained in more detail. In the model in Equation (1), the stochastic shocks

are assumed to occur each period only *after* the rules of monetary and fiscal policy are set. In the cases studied here, therefore, the control rules for country i take the form

$$(3)\ U^i_t = \Gamma X_t$$

where U^i is a vector of the policy instruments (usually monetary and fiscal policy) of each country. The key point of Equation (3) is that the policy instruments at time t are not functions of the random shocks at time t. For the McKinnon rule, for example, monetary policies are set so that the bilateral exchange rate in fact varies within the period since money stocks are not readjusted within the period. All market participants, however, hold the rational expectation that the exchange rate will revert to its normal level in the next period. Because of these expectations, actual deviations of the current exchange rate from the target level will tend to be small. In sum, our version of the McKinnon rule is really a "target zone" system rather than a strict fixed exchange rate system.

Consider how the different rules perform with and without exogenous shocks. In the McKinnon plan, the exchange rate is perfectly fixed if no shocks occur, while as just explained, actual exchange rates fluctuate in response to the exogenous disturbances. In the modified McKinnon plan, the exchange rates and global nominal GDP are fixed each period, as long as no exogenous shocks occur. Finally, in national GDP targeting, each country's nominal GDP is fixed in expectation each period, while the exchange rates are allowed to change. Actual GDP's fluctuate, of course, because of the exogenous disturbances.

It is worth spending a moment on the difference of the McKinnon plan, in which the global money stock is fixed, and the modified McKinnon plan, in which the global money stock is allowed to vary in order to fix the expected value of global nominal GDP. The operational differences of the two rules can best be understood with respect to particular shocks.

Suppose a pure velocity shock occurs in the U.S., which reduces the demand for U.S. money for several periods. In the McKinnon plan, the world stock of money would remain constant, but the U.S. money stock would decline while the money supplies in the rest of the OECD would increase. On balance, an excess supply of money, at initial interest rates and prices, will develop in the world economy. The result will be an increase in output and eventually in prices. Under the nominal GDP targeting plan, however, the fall in U.S. money demand will be fully compensated by a fall in the U.S. money supply after one period. There will be no need for a sustained period of higher output or prices. The key distinction is that the GDP targeting rule does not require that the global money stock remain fixed.

The relative performance of these arrangements depends crucially on the

relative importance of the random shocks buffeting the economic system. An exhaustive analysis of the different rules would require a detailed analysis of a large array of random shocks. We have indeed experimented with several types of shocks, but for brevity and simplicity here, I will report the implications of only a few of these disturbances. Specifically, the following table shows the effects of six types of shocks: random shifts in national prices levels (with one shock each in the price equations of the U.S., Japan, and the ROECD), and random shifts in the money demand equations of the three regions. All six types of disturbances *are* assumed to be independent across countries, and independent over time. However, even though the shock to prices is serially uncorrelated, in effect the shock is persistent because the model builds in the assumption that price shocks enter a wage-price spiral of the standard Phillips curve variety. Similarly, money demand shocks have persistent effects since money demand is specified with a lagged adjustment process, so that money demand in period $t+1$ is a function of the level of real money balances in period t.

Using the numerical and analytical techniques described in the Appendix, it is possible to calculate the standard deviations of key target variables (e.g., output gap, inflation, etc.) as a function of the standard deviations of the underlying shocks and the policy rules that are being pursued. In this way, it can be asked which rules *are* best for stabilizing which types of disturbances to the global economic system. The results of such calculations are shown in Table 3. The table is read as follows. For each type of shock across the top line of the table, we can ask how a one percent standard deviation of the shock affects the steady-state standard deviations of the key variables listed down the side of the table. The standard deviations depend on the particular rule being followed, as shown in the table. For example, a one percent standard deviation in the shock to the U.S. price level causes a a 6.6 percent standard deviation in U.S. real output if the McKinnon rule is being followed; a 3.1 percent standard deviation in real output if the nominal GDP targeting is employed; etc. The standard deviations resulting from the other disturbances may also be read off of the table.

The results of the table show that for domestic price shocks, floating rates (pure float or nominal income targeting) are superior to global, fixed exchange rate rules (McKinnon, global nominal income targeting.) Thus, for example, a one percent standard deviation shock to U.S. prices induces a steady-state standard deviation in U.S. output of 6.6 percent under the McKinnon rule, but only 3.1 percent under national GDP targeting. Among the global rules, the world nominal GDP targeting is superior to the McKinnon rule in this model. The reason is as follows. An output price shock starts a damped wage-price spiral in the model. Under the McKinnon rule, U.S. output falls for several periods after a U.S. price shock, while the U.S. price level rises for several periods. Eventually, the prolonged U.S. recession

TABLE 3

Variance of Targets Under Alternative Rules

Target/Rule	Source of Shock: U.S. Price	ROECD Price	Japan Price	U.S. Money Demand	ROECD Money Demand	Japan Money Demand
U.S. Output						
McKinnon	6.641	2.330	6.359	1.761	0.363	0.571
Global Nominal GDP	3.342	0.815	0.569	1.71	0.268	0.195
Nominal GDP (country by country)	3.078	0.752	0.31	1.685	0.534	0.0
Flexible	2.723	0.664	0.223	1.628	0.292	0.071
U.S. Inflation						
McKinnon	3.558	1.021	3.912	0.672	0.122	0.392
Global Nominal GDP	1.537	0.308	0.219	0.559	0.141	0.063
Nominal GDP (country by country)	1.323	0.385	0.128	0.531	0.118	0.032
Flexible	1.229	0.417	0.161	0.505	0.114	0.032
U.S. Current Account						
McKinnon	1.101	0.586	1.157	0.225	0.077	0.077
Global Nominal GDP	0.526	0.138	0.063	0.192	0.063	0.0
Nominal GDP (country by country)	0.462	0.141	0.055	0.179	0.077	0.0
Flexible	0.377	0.148	0.063	0.161	0.071	0.0

starts to decrease the U.S. price level, and given the dynamics of the model, the price level eventually falls to the point where a U.S. output boom begins. In fact, the overall world economy actually follows a damped oscillation between boom and bust for several years. With the McKinnon rule, the global money stock is not allowed to adjust to stabilize these fluctuations, while under the global nominal GDP targeting, the global money supply is adjusted for this exact purpose. Put simply, given the tendency of the underlying real economy to cycle, it is important that rules contain an "error-correction mechanism" to dampen the inherent fluctuations that result from exogenous shocks.

The fixed exchange rate system appear to be about equivalent to the floating rate systems with respect to money shocks. Here, however, we may have stacked the deck a bit against the fixed-rate systems. The standard

deviations are all based on the assumption that the six types of shocks are statistically independent. McKinnon, of course, has argued (with little direct evidence) that the exogenous shocks in the money equations tend to be negatively correlated. I suspect that with negative correlations in the disturbances, the fixed rate rules would look even better, since under the fixed rate system, negatively correlated money shocks would tend to cancel themselves out, while this is not necessarily the case under floating rates. In a subsequent analysis, McKinnon and I plan to extend the analysis to alternative covariance relationships for the disturbances.

Some key limitations of this analysis should be kept in mind. The computer simulation assumes that the private portfolio holders understand the rules being pursued by monetary authorities, and perhaps more importantly, that the monetary authorities understand the rules being pursued by their counterparts in other countries. Clearly, these are assumptions to be taken with some skepticism! Moreover, the specific rules (e.g., to fix the expected value of nominal GDP) are often complex and might be difficult to implement. Also, the computer simulation cannot adequately treat the issues of the political business cycle and the time consistency issue, so that the exercise does not really answer the question of whether fixed rates would help to provide political discipline against inflationary politicians. Finally, I have made no formal attempt *to* answer the question as to which of the various possible shocks are the ones that a new system should regard as most empirically relevant. The exercise shows only that certain rules are better in some contexts than others, but not which contexts are most likely to be faced.

Conclusions and future analysis

This paper has taken up the classic issue of the appropriate design of the world monetary system. Dissatisfaction with the experience under floating in the past dozen years has led many observers to advocate a return to more managed rates. As we have noted, the arguments for new "rules of the game" are many and varied. Some analysts argue that key random shocks to the world economy would be better handled by an automatic fixed rate system; others argue that the U.S. monetary policy has been inappropriate for floating rates; many analysts have suggested that rules of the game are necessary to forestall beggar-thy-neighbor attempts at exchange rate manipulation; and still others suggest that rules of the game can help restrain the inflationary proclivities of domestic politicians.

In any event, any concrete proposals for monetary reform must be tested for "robustness" to the variety of shocks that may hit the world economy. Rules which are good for financial shocks might not be particularly salutary for real shocks of various sorts. With this problem in mind; the second part of the paper introduces the result of a large-scale simulation exercise in

which alternative rules are put through the paces. Not surprisingly, it turns out that fixed exchange rate rules are not very adept at handling domestic price shocks; the comparative advantage of such fixed-rate rules is clearly for monetary disturbances of the sort emphasized by McKinnon. In the absence of a satisfactory demonstration that domestic price shocks are unimportant, or that they would go away in a stable fixed-rate system, the results must give pause to those advocating a return to fixed exchange rates. The next round of analysis should focus on realistic national rules in the context of a continued managed float.

Appendix

The McKibbin-Sachs global (MSG) simulation model of the world economy was developed in Sachs and McKibbin (1985). The reader is also referred to recent papers by Ishii, McKibbin and Sachs (1985) and Sachs (1985) for several applications. In the MSG model, the world economy is modelled as five regions consisting of the U.S., Japan; the rest of the OECD (hereafter ROECD), OPEC and the developing countries. Each region is linked via flows of goods and assets. Stock-flow relationships and intertemporal budget constraints are carefully observed. Budget deficits cumulate into a stock of government debt which must eventually be financed, while current account deficits cumulate into a stock of foreign debt. Asset markets are forward looking so the exchange rate and long-term interest rate are conditioned by the entire future path of policy.

There are equations for the internal macroeconomic structure of the three industrialized regions of the U.S., ROECD, and Japan although the OPEC and developing country regions have only their foreign trade and financial structures incorporated. Each region produces a good which is an imperfect substitute in the consumption basket of each other region, where the consumption of each good depends on income and relative prices. Private absorption depends on wealth, disposable income and long and short interest rates along conventional lines. Wages are predetermined in each period where the nominal wage change is a function of consumer price inflation, the output gap and the change in the output gap. With the assumption that the GDP deflator is a fixed markup over wages, we derive a standard Phillips curve. All asset stocks are defined in real terms. Residents in different countries hold their own countries assets as well as foreign assets (except foreign money) based on the relative expected rates of return. Money demand is determined by transactions demand.

The model is parameterized using actual 1983 trade shares and assets

stocks. Behavioral parameters are chosen to be equal to what we consider as an average of the values found in the empirical literature.

The non-linear and linear versions of the model are simulated using numerical techniques which take into account the forward looking variables in the model. The linearized version of the model is amenable to policy optimization exercises and has been used to consider the gains to policy coordination using dynamic game theory techniques [see Sachs and McKibbin (1985)].

In this paper I have examined the stochastic steady state properties of various rules using techniques derived in McKibbin and Sachs (1986, forthcoming). The procedures are quite complex, however, so that this section will give only a simplified description of the key steps.

We incorporate stochastic shocks to demand, prices, velocity of money, and portfolio preferences in the U.S., Japan, and ROECD as well as to OPEC prices. We assume that policy is set before the shock is observed in each period. This enables us to appeal to certainty equivalence in some of the derivations below. The system can be summarized conveniently as follows:

$$(A1)\ X(t+1) = A\,X(t) + B\,U(t) + C\,e(t) + D\,S(t)$$

$$(A2)\ e(t+1) = E\,X(t) + F\,U(t) + G\,e(t) + J\,S(t)$$

$$(A3)\ T(t) = K\,X(t) + L\,U(t) + M\,e(t) + N\,S(t)$$

where X is the vector of state variables, U is a vector of policy instruments (or control variables), e is the vector of forward looking variables (or jumping variables), S is the vector of shocks and T is the vector of target variables.

Using dynamic programming we can solve equations A1 and A2 backwards (required because of the forward looking variables in the model) for a rule for setting the control variables as a function of the state variables in the model and a rule which links the forward looking variables jumping variables to the state variables. In the case where a rule is given for control variable we only need to solve backwards for the jumping variable rule. The rules are in the form:

$$(A4)\ U(t) = \Gamma\,X(t)$$

$$(A5)\ E_t[e(t+1)] = H\,X(t+1)$$

With the rule for control variables (A4) and for jumping variables (A5),

we have a system of equations which link the state variables to their previous values and to the stochastic shocks. Using Equations (A4) and (A5) in Equation (A1), we can then find the variance/covariance matrix for the state variables as a function of the variance/covariance matrix of the shocks. Given that we also have a relation between the target variables and the states we can derive the variance/covariance matrix for the targets.

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