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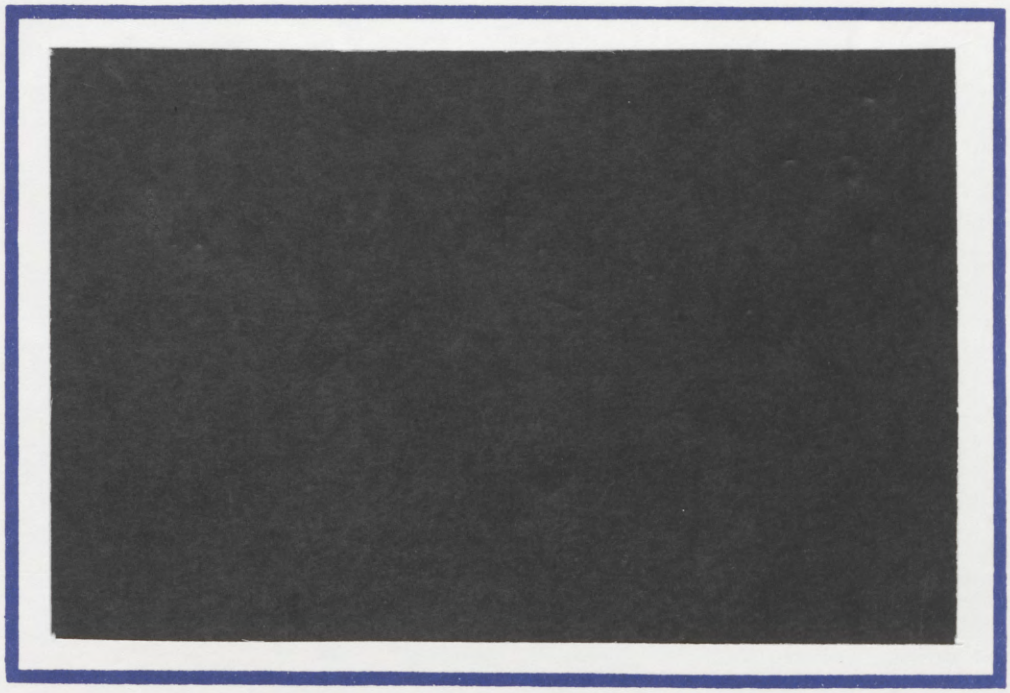

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EXCHANGE RATE SYSTEMS: NEW PERSPECTIVES

by

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[1]The original version of this paper was completed in December 1989. For the purpose of the current revision we have not updated the literature, as is particularly evident from section IV dealing with exchange rate bands. We will deal with exchange rate bands in more detail in a forthcoming paper. We thank the Israeli International Institute for supporting our research project on exchange rate systems.

I. INTRODUCTION

An ideal evaluation of exchange rate systems would proceed along the lines of standard welfare economics. It would compare regimes in terms of costs and benefits, and derive net welfare gains for every country. Exchange rate systems would than be ranked according to Pareto's criterion in order to see which fare best. This procedure is unlikely to lead to a unique best choice, however, because more than one regime is expected to top the list. Regimes differ in their distributional implications, with some favoring one set of counties while others favoring a different set.

At this stage it would make sense to examine cooperative rules of conduct that exploit the available surplus in a way that benefits all parties. If the implementation of side payments that compensate losing countries from the adoption of a more efficient system is judged to be out of reach, one would seek a cooperative regime that has a built in mechanism for the sharing of benefits.

This selection procedure is rooted in standard economic thinking. It represents an approach that has been widely used in theory and practice. Examples include the evaluation of public utilities, the tunnel beneath the English channel, and the debate about socialism between Lange, Lerner and von Misses. It has, however, played only a limited role in discussions of exchange rate regimes. Why?

One reason is that the study of exchange rates has become part of macroeconomics when the latter evolved into as a separate field of inquiry. Initially macroeconomics addressed a new set of issues that did not fit in well with mainstream economics of the time. This gave it strength, and it has become an important area. Unfortunately, macroeconomics also developed its own terminology, models, evaluation

criteria, and the like, and resisted integration with mainstream economics for many years to come. The letter proved to be detrimental. These developments affected the ways in which economists have been thinking about exchange rates, postponing for many years the natural approach outlined at the beginning of this section.

Second, the study of exchange rates involves considerations of international trade, pricing policies, financial markets, international capital flows, interest rates, monetary and fiscal policy, and more. In short, exchange rates are relative prices of the utmost importance. They affect many facets of economic activity on the one hand, and they are affected by many structural features of national economies and the international system on the other. Consequently, their proper understanding requires knowledge of different areas of economics and the ability to integrate their complex interactions. This is a difficult task to the best of economists, exchange rate theorists and practitioners not withstanding.

The treatment of complex problems involves compromises in research strategies, often in the form of short cuts in the formulation of problems. In retrospect some short cuts prove to be well chosen, in the sense that their implications survive more elaborate analyses. Others, however, prove to be far fetched. The study of exchange rates is no exception.

A major compromise consists of the evaluation of exchange rate regimes by means of criteria that are only loosely related to acceptable

welfare measures. Proper welfare analyses of exchange rate systems are hardly available (see, for example, the Handbook of International Economics, edited by Ronald W. Jones and Peter B. Kenen). Attention has been focused instead on the performance of exchange rate regimes in terms of the variability of output, variability of the price level, and the like. One may argue that these criteria are important, and that they are related to the ultimate measures of welfare, as indeed they are. This is a good reason to explore their behavior under alternative exchange rate systems. But to draw from such studies firm conclusions about the desirability of alternative exchange rate systems is a different matter altogether.

The degree of confidence one has in the use of these proxies as welfare measures is a matter of judgment; there exist no objective way to form an opinion on this isssue. Occasionally the pendulum of confidence tilts in a particular direction as a result of a new theoretical development or empirical finding, subsequently it changes course. This point is demonstrated by the current debate on the desired international monetary system, that reveals again lack of common ground in the desired approach and in the use of evaluation criteria. On the face of it, the current debate resembles similar debates in the fifties and sixties. There exist, however, important differences. These have to do with methodological innovations as well as with the nature of the debated proposals. Moreover, available evidence from empirical studies is now broader and more reliable than ever before.

The old debates have been documented and reviewed extensively in the literature. For this reason we focus on recent theoretical and empirical developments that shed new light on the main issues. In Section II we review the literature that uses proper welfare criteria in comparisons of exchange rate systems. This approach is still underdeveloped. So far technical reasons and other difficulties have prevented it from dealing with a number of central problems in the choice of an exchange rate systems. Consequently, simple performance measures have been used instead, such as the variabilities of output, the price level, consumption, and the real exchange rate (for early theoretical explorations along this lines see Mundell (1973) and Fischer (1977)). We report in Section III empirical evidence on the variability of real exchange rates and other macroeconomic variables under alternative systems. We elaborate on possible explanations for the major finding that real exchange rates are more volatile under flexible rates.

The next section addresses issues related to the viability of exchange rate pegs. We pay particular attention to dynamic processes that arise in the presence of expectations of a change in regime. Such expectations develop in response to monetary and fiscal policies that are inconsistent with the announced exchange rate policy. We show how the theory has been used to explain important empirical regularities and we describe empirical studies of the collapsing exchange rate pegs. In Section IV we review studies of exchange rate bands. This system has

become particularly topical with the evolution of the European Monetary System. Our conclusions are presented in Section V.

II. WELFARE COMPARISONS

A number of studies have examined welfare properties of exchange rate systems by comparing utility levels across regimes (see Helpman and Razin (1979), Kareken and Wallace (1981), Helpman (1981), and Lucas (1982)). They brought out two main points. First, proper comparisons require careful formulation of the problem in order to avoid building in asymmetries that are not inherent in the systems per-se. This came out particularly forcefully in the treatment of international capital mobility. While it was common to restrict capital mobility in flexible exchange rate regimes, formulations of fixed exchange rates implicitly allowed for international capital movements through the flow of international reserves (see, for example, Mundell (1973)). Naturally, this approach biased the outcome in favor of fixed exchange rates, despite the fact that international financial integration can be part of a flexible exchange rate system. Second, these studies identified conditions under which fixed and flexible exchange rates have the same welfare implications.

The employment of explicit models with utility maximizing agents involves much more complexity than the use of simple reduced form macroeconomic models. The strength of the maximizing approach lies in its explicitness. It requires, for example, a clear statement of the

economic mechanisms that drive and interline transactions. As of now, however, the weakness of this approach lies in its inability to accommodate elaborate monetary mechanisms and realistic structures of financial markets. This shortcoming is important, because the structure of financial intermediation, the monetary mechanism, and the behavior of monetary authorities are central to the understanding of exchange rate systems. This is not to say that alternative approaches fare better on these accounts. It only makes clear the point that explicitness in an approach makes these shortcomings rather visible, while in some alternative formulations the emperor seems to wear clothes when in fact he does not.

Contrary to some evaluations, the explicit approach is not a narrow brand of the new classical macroeconomics. And contrary to those evaluations (see, for example, Dornbusch and Frankel (1988)) it has been designed to deal with frictions. Moreover, one of its main tasks is to explicitly model frictions in order to evaluate the comparative advantage of exchange rate regimes to overcome them. Thus, for example, it has been found that certain forms of financial markets ensure the irrelevance of frictions that result from cash in advance constraints in the use of money in both fixed and flexible exchange rate regimes (see Helpman (1981) and Lucas (1982), and the exception reported in Ashauer and Greenwood (1984)). On the other hand, incompleteness of financial markets (that limits risk sharing opportunities) has important affects on the ranking of exchange rate systems. For example, market

incompleteness of the form studied by Helpman and Razin (1982) -- that results from the need to commit to a portfolio of assets before one observes commodity prices -- was shown to favor flexible rates.

If anything, the explicit approach should be criticized for not going far enough in its designated direction. Occasionally interesting frictions have been introduced in these models, but their welfare implications have not been studied (e.g., Svensson (1985) and Grilli and Roubini (1989)). The roles of other frictions need to be studied, frictions related to informational problems, financial intermediation, agents heterogeneity, and the like. And the cash in advance monetary mechanism employed in much of this line of work should be modified to better fit reality.

III. MACROECONOMIC STABILITY

A recent interesting line of empirical research compares the statistical properties of key macroeconomic variables across fixed and floating exchange rate regimes. An attempt is made to detect whether means, variances, and other moments of output, real exchange rates, consumption, and other variables, have changed in moving from one exchange rate system to another.

The behavior of real exchange rates in a fixed and floating exchange rate system was empirically studied by Mussa (1986). He compared the experiences of sixteen of the more advanced industrial countries since 1957. For pairs of countries with similar moderate

rates of inflation, Mussa has detected the following regularities. First, real exchange rates typically show much greater short term variability in a floating than in a fixed rate regime. Stockman (1983) reached a similar conclusion based on estimation of a fixed-effects variance-components model in which a measure of the variability of the real exchange rate was regressed on a fixed country effect, on a fixed year effect, and on a dummy variable that indicates the exchange rate regime. Second, the increased variability in a floating rate regime is largely accounted for by the increased variability of nominal exchange rates, with little contribution from changes in the variability of ratios of national price levels or the covariances between movements in nominal exchange rates and movements in relative prices. Third, changes in real exchange rates under floating rates exhibit relatively high persistence, similar to the persistence of nominal exchange rate movements. On the other hand, the degree of persistence of changes in ratios of national price levels does not appear to change from one regime to another.

In interpreting these empirical regularities, Mussa indicates that they provide strong evidence against models that embody the property of "nominal exchange rate neutrality." According to simple versions of these models, the behavior of real exchange rates should not be affected systematically by the nominal exchange rate regime. According to Mussa, the regularities conform with models that assume sluggishness in the adjustment of nominal price levels relative to the speed of adjustment

of nominal exchange rates (in a floating rate regime). These models imply that real exchange rates would move more slowly under fixed than under flexible rates, and this implication seems to be in line with the sample information.

The paper by Baxter and Stockman (1989) investigates differences in time series behavior of major macroeconomic aggregates. They study the Bretton Woods system that broke down between 1971 and 1973, and the flexible rate regime during the 1973-1986 period. Since most of the time series they investigate are nonstationary, they filter the data in order to achieve stationarity before they compute statistics such as means and variances. They employ two common filters: (i) removal of a linear trend fitted to the log of a given variable; and (ii) computing first differences of the log of a variable. They use a sample of postwar data for 49 countries that consists of industrial production, consumption, trade flows, government consumption spending, and real exchange rates.

Their main conclusion is that there is no evidence to support the view that the cyclical behavior of real macroeconomic aggregates (as reflected in the standard deviations of the filtered variables), such as industrial production, private consumption, and real trade flows, depends systematically on the exchange rate regime. The only exception is the real exchange rate, which exhibits higher volatility under flexible than under fixed rates. These conclusions were reinforced by the results of two episodes in which countries changed their exchange

rate regime at times other than the breakdown of Bretton Woods. The episodes are the switch of Ireland from a peg to sterling before 1979 to the DM (via the EMS) after 1979, and the Canadian float against the U.S. dollar from 1951-62 (that was resumed in 1970).

On the other hand, Grilli and Kaminsky (1988) argue that Mussa's (1986) finding that variances of the real exchange rates of the major countries are eight to eighty times higher during the floating than during the fixed rate period, holds only for samples of post WWII data. They investigate the time series properties of the dollar/pound real exchange rate between January 1885 and December 1986. Their chronology suggests the following exchange rate regimes for the dollar/pound rate:

1. The Gold Standard Period, January 1879 - June 1914.
2. Transition to Wartime Markets, July 1914 - November 1914.
3. Controlled Floating, December 1914 - June 1919.
4. Floating Back to the Gold Standard, July 1919 - March 1925.
5. Gold Exchange Standard, April 1925 - August 1931.
6. Abandonment of Fixed Exchange Rates, Sept. 1931 - August 1939.
7. Wartime Foreign Exchange Controls, Sept. 1939 - Sept. 1949.
8. Fixed Exchange Rates (Bretton Woods), Sept. 1949 - Feb. 1973.
9. Floating Exchange Rates, March 1973 - present.

These authors first provide a preliminary analysis of real exchange rate behavior by means of summary statistics. Second, they perform a nonparametric test of whether the observations from different exchange rate periods belong to one sample. Third, they test this hypothesis

using a simple fixed-effects variance-components model also used by Stockman (1983).

Their main findings are that: (i) real exchange rates behaved differently in the postwar (WWII) than the prewar period; and (ii) large differences in the volatility of real exchange rates between fixed and flexible regimes are present only in the postwar period. In particular, the Bretton Woods period appears extremely stable when compared not only to flexible rate periods but also to other fixed rate periods. They conclude that the real exchange rate is more a function of the specific historical episodes than of the nominal exchange rate system.

In order to examine how well Israel fits into the broader evidence, we have used monthly data on the rate of inflation and the rate of depreciation of the domestic currency relative to the U.S. dollar to perform calculations similar to Mussa's. There are three exchange rate systems that we considered: a crawling peg (from July 1975 to September 1977), a float (from February 1978 to July 1985), and a quasi-fixed exchange rate that was adopted as part of the 1985 stabilization program. Our variables consist of DE, the rate of change of the exchange rate relative to the dollar (monthly average); DP, the rate of inflation; and DRE (= DE-DP), the rate of change of the real exchange rate. (To simplify matters, we abstracted from foreign inflation).

Table 1 contains the results. It shows that the variability of the real exchange rate was highest during the floating rate period. In fact, in recent years -- with disinflation and a quasi fixed exchange

rate -- the variance of the rate of change of the real exchange rate equals about 50 percent of the previous variance. Similarly, under the crawling peg there was lower real exchange rate variability than under the float. These observations support the view that real exchange rates are more volatile under floating than under fixed exchange rates.

Next we examine whether increased real exchange rate volatility under the Israeli float can be attributed, as in Mussa, to increased volatility of nominal exchange rate changes. Interestingly, here our findings differ. In particular, comparing the floating rate period with the recent quasi-fixed rate period indicates that both inflation and nominal exchange rate variances have substantially decreased in the recent period. Specifically, the variance of inflation fluctuations in the most recent period (of a quasi-fixed exchange rate) equals about 4 percent its level in the preceding period, and the variance of nominal exchange rate fluctuations equals about 16 percent of its previous level. In addition, the covariance between movements in inflation and nominal depreciation has decreased; the correlation is 0.239 in the later period whereas it was about 0.835 in the preceding period. Similar results hold for comparisons of the crawling peg and floating rate periods. Thus, there are marked changes in the variance of inflation along with changes in the variance of the nominal exchange rate, and one cannot attribute (in a statistical sense) the fluctuations in the real exchange rate mostly to fluctuations in the nominal exchange rate. In our view, this evidence does not conform with the implications

of the sticky price models discussed by Mussa. This may well be a reflection of the fact that the sluggishness in prices for which Mussa found support is not particularly relevant for high inflation economies such as Israel (recall that Mussa's sample consisted of industrial countries with relatively low inflation rates).

So far we have discussed evidence for real exchange rate volatility. What about the behavior of other macroeconomic variables? A partial answer to this question can be obtained from a recent investigation by Leiderman and Liviatan (1989), who quantitatively compared the behavior of macroeconomic variables before and after disinflation in Israel. From this comparison one learns that the shift to lower exchange rate flexibility was accompanied by a decrease in the variability of real exchange rate movements, yet no major change has been observed for the variabilities of changes in real output,

TABLE 1 - NOMINAL AND REAL EXCHANGE RATE VARIABILITY IN ISRAEL

Statistic	Crawling Peg (75:7-77:9)	Float (78:2-85:7)	Quasi Fixed (85:9-89:10)
Mean DE	1.937	8.046	0.624
Mean DP	2.396	8.429	1.493
Mean DRE	-0.459	-0.384	-0.870
Var DE	3.108	32.429	5.206
Var DP	2.992	27.413	1.148
Var DRE	3.380	10.058	5.184
Corr (DE,DP)	0.446	0.835	0.239

Note: DE is the rate of change of the nominal exchange rate for the dollar (monthly average); DP is the rate of inflation; and DRE = DE - DP. All data are monthly and taken from the data base of the Bank of Israel.

employment, consumption, and the trade deficit. This result conforms remarkably well with the findings of Baxter and Stockman.

The approach underlying these quantitative comparisons has several limitations, however, some of which have been explicitly discussed by the authors. The first and most important limitation results from the fact that in these studies it is difficult to control for the contribution of other factors to the variability of the macroeconomic variables. Consequently there exists great uncertainty as to whether the observed changes in the statistical behavior of these variables can be attributed to the change in the exchange rate regime per-se. Government policies, the nature of disturbances, structural parameters, and the like may have changed during the sample period independently of the change in the exchange rate regime. This difficulty is especially evident in the case of Israel, where the shift to quasi-fixed exchange rates in 1985 was part of a broader policy switch that consisted of major changes in monetary and fiscal policy.

Can we conclude from the evidence about higher real exchange rate volatility in a floating rate regime that fixed exchange rates are preferable ? This central question has no simple answer. Naturally, there exists a relationship between welfare and uncertainty in important economic variables, but this relationship is involved, especially with regard to endogenous variables, such as the real exchange rate. Fluctuations of endogenous variables result from the interaction of market forces and fluctuations of fundamentals, as has been observed by

Friedman (1953) long ago. For this reason it is essential to identify changes in fundamentals when moving from fixed to floating exchange rates in order to interpret these empirical findings. On the other hand, Friedman's argument was based on the notion that speculation is stabilizing. That is to say, the presence of potential exchange rate variability per-se cannot bring about actual exchange rate variability, because speculation is stabilizing. The last argument is incorrect, however. Recent research has demonstrated that rational bubbles and noisy traders in asset markets may generate substantial variability (e.g., Blanchard and Fischer (1989, chapter 5) and De Long et al. (1990)). The presence of these factors can induce fluctuations beyond and above fundamentals that Friedman had in mind. On the other hand, the welfare implications of these factors are yet unclear. Future research should provide better answers to these important questions.

IV. VIABILITY OF EXCHANGE RATE PEGS

Since exchange rates are relative prices of monies and governments have the power to issue money, there exist cooperative arrangements between governments that can sustain fixed exchange rates. Experience suggests, however, that even in potentially viable systems it can be difficult to secure the needed cooperation when some countries impose serious strain on the system. We will come back to this issue in the next section. Here we consider the difficulty facing a single country that attempts to peg its exchange rate without help from other countries. The following discussion applies to single currency pegs as well as to pegs to currency baskets.

A country that pegs its exchange rate can always support it with suitable monetary and fiscal policies. If it is free and willing to adjust these policies it can forever maintain its exchange rate peg. In practice, however, difficulties in maintaining fixed parities abound. They typically result from difficulties to adjust other policies. Such situations lead to the loss of reserves and increasing foreign debts. Eventually the exchange rate peg is abandoned or the parity adjusted. Occasionally other policies are altered in the framework of a stabilization program.

Several interesting features have been observed about such adjustments. First, countries suffer international reserve losses long before a collapse of the peg, with a run on reserves preceding the collapse. Second, prior to the policy change there is an increase in nominal interest rates and premia emerge in forward and black markets for foreign exchange, despite the observed constancy of the spot exchange rate (this has been termed "the Peso Problem"). Third, a one-time (jump) depreciation of the exchange rate follows policy adjustments. These regularities have been observed in a number of episodes, including the following (see Penati and Penacchi (1989)): (i) The collapse of the French franc in March 1983, when the currency was devalued by 8 percent relative to the D-mark. After the collapse the country went back to a fixed exchange rate regime. (ii) The collapse of the Italian lira on January 1976, that resulted in a depreciation of about 16 percent relative to the D-mark and a shift to a

freely floating regime until the establishment of the EMS in 1979. (iii) The collapse of the Mexican peso in February 1982, that resulted in a 28 percent devaluation relative to the U.S. dollar. (iv) The collapse of the Chilean peso in June 1982. After more than three years with a fixed exchange rate of 39 pesos per dollar, Chile adopted a system of pre announced monthly exchange rate devaluations.

In what follows we discuss these issues in two parts. We begin with a description of the theory that has been developed to explain them. In the second part we describe empirical studies.

A. Theory

Theoretical explanations of these regularities have been provided in a number of studies (see Krugman (1979), Lizondo (1983), Flood and Garber (1984), Obstfeld (1986), Drazen and Helpman (1987, 1988), van Wijnbergen (1988) and Penati and Penacchi (1989)). The abrupt large loss of reserves has been originally explained by Krugman (1979), for the case in which at a known date a fixed exchange rate is replaced by a free float. His fundamental insight is explained first.

Consider a situation of free international capital mobility, and a peg to a foreign currency with a constant foreign interest rate. Before the peg is abandoned the exchange rate remains constant and its instantaneous expected rate of change equals zero. Therefore arbitrage between domestic and foreign interest bearing assets ensures that the domestic interest rate equals the foreign interest rate. With a

constant domestic interest rate the demand for real balances remains constant (other factors that affect the demand for money are assumed constant).

Now, at a predetermined date the exchange rate peg is abandoned and replaced with a free float. Assume that from that moment on the money supply grows at a positive rate, at least for some time (in order to, say, finance the budget deficit). Then at the moment of policy switch the demand for real balances drops discretely, because the interest rate rises discretely as a result of the uncovered interest parity condition (that ensures the absence of arbitrage opportunities between domestic and foreign currency denominated assets). It rises from the foreign level to a level that exceeds the foreign level by the correctly forecasted rate of inflation. After the policy switch inflation results from money growth. Since the exchange rate cannot jump in an anticipated fashion at the time of the policy switch (because this would produce unbounded arbitrage opportunities between domestic and foreign assets), the lower demand for real balances is accommodated by a lower money supply. The lower money supply is attained by a run on reserves a moment before the policy switch.

The timing of the run on reserves can in fact be determined endogenously from the central bank's monetary policy. If the central bank expands domestic credit during the fixed exchange rate period, every unit of additional credit finds its way back to the central bank in exchange for foreign currency. This results from the fact that

during this time interval the demand for real balances remains constant and so does the price level (due to the peg). When the value of reserves exceeds the smallest permissible level by an amount just equal to the contraction of the money supply that is required by a switch to a free float, a run on reserves takes place exactly in this amount. As a result of the run reserves drop to the minimum level, and the authorities abandon the exchange rate peg.

This story is very powerful, because it identifies a mechanism that has broader applications than the particular policy experiment. Once it is understood, one can ask, for example, how will the adjustment differ if instead of abandoning the exchange rate peg and resorting to inflationary finance the authorities were to maintain a fixed exchange rate and raise taxes instead, or cut expenditure on traded goods, or cut expenditure on nontraded goods. Drazen and Helpman (1987) have shown, for instance, that only the last alternative leads to a run on reserves while the first two do not (with taxes being lump-sum). They also showed that the anticipation of different policies for dealing with the loss of reserve problem have different implications for the trade and current account. For example, when the foreign interest rate equals the subjective discount rate, the use of taxes is preceded by a balanced current account while the use of budget cuts on traded goods is preceded by a deficit on current account. In all cases, however, real balances remain constant prior to the policy switch. The last finding is disturbing, because often one observes declines in real balances in

anticipation of a policy change even when the exchange rate remains constant.

To remedy this difficulty one can introduce uncertainty about the timing of the policy switch (see Drazen and Helpman (1988)). This added feature also helps to explain (a) domestic interest rates that exceed the foreign interest rate during the peg; (b) premia on forward and black markets for foreign exchange during the peg (the Peso Problem); (c) declining real balances during the peg; and (d) discrete devaluations as part of the policy switch.

Consider a situation in which the exchange rate is pegged but the public expects a devaluation. In this case uncovered interest parity requires the domestic interest rate to exceed the foreign interest rate at least by the expected rate of devaluation (in the absence of risk aversion the interest rate differential just equals the expected rate of devaluation). These expectations are also reflected in a higher exchange rate in the forward market and a higher premium on the black market for foreign exchange (see Lizondo (1983)).

The larger the expected rate of devaluation, the larger is the interest rate differential, the higher is the exchange rate in the forward market, and the larger is the premium on the black market. A larger expected rate of devaluation may result from expectations of a larger devaluation or a larger probability of devaluation. If the probability of a devaluation rises over time or the required exchange rate adjustment rises over time, they will be reflected in rising

nominal interest rates, rising exchange rates in the forward market, and rising premia on the black market, as one typically observes.

The point of departure of our preceding discussion was the presence of an expected devaluation. But one may ask what are the circumstances in which a required policy adjustment leads to a rationally expected devaluation? To begin with, the imbalance in the monetary-fiscal policy mix that leads to reserve losses can be corrected without recourse to the abandoning an exchange rate peg. Consider, for example, a situation in which the government is expected to raise taxes, cut spending on traded goods, or cut spending on nontraded goods in order to balance the budget. In such cases there is no money growth after the policy switch and therefore the exchange rate remains constant after the policy switch even if the exchange rate peg is abandoned. When the budget is balanced with lump-sum taxes or spending cuts on traded goods the expected rate of devaluation equals zero at each point in time, and indeed there is no change in the exchange rate at the policy switch date. Consequently real balances remain constant and no run on reserves takes place (see Drazen and Helpman (1988)).

When the authorities are expected to balance the budget with an expenditure cut on nontraded goods, however, it matters whether the public expects the exchange rate peg to prevail after the policy switch (in fact it matters whether the peg prevails only a short while after the policy switch). If the exchange rate peg is expected to prevail a while after the policy switch the public expects no devaluation, and

money balances remain constant until the policy switch takes place (despite the fact that the timing of a policy switch is uncertain). At the moment of the budget cut the real exchange rate depreciates as a result of a decline in the nominal price of nontraded goods and the nominal exchange rate remains constant (assuming full price flexibility). The decline in demand for real balances as a result of the real depreciation is satisfied by means of a run on reserves (see Drazen and Helpman (1988)). This run on reserves is possible only if the authorities do not abandon the peg following the budget cut.

On the other hand, if the peg is abandoned with the budget cut on nontraded goods, the decline in demand for real balances that results from the real depreciation cannot be satisfied by an asset swap. Consequently a nominal devaluation has to follow the policy switch. This leads to expectations of a devaluation prior to a policy switch with the expected rate rising over time as long as the policy switch does not take place. The observed result will be rising interest rates, rising exchange rates on forward markets, and a rising premium on the black market (see Drazen and Helpman (1988)).

Finally, the presence of timing uncertainty of a policy switch that consists of the abandoning of a peg and recourse to money-financed budget deficits, leads to expectations of a devaluation prior to the policy switch. The expected rate of devaluation rises over time because the probability of a policy switch rises (as long as this probability rises with the degree of imbalance) and because the required exchange

rate adjustment is larger the more time elapses without a policy change. The latter point can be seen from the observation that the longer the authorities maintain the imbalance, the larger the accumulated government debt, and therefore the larger the budget deficit that has to be financed with an inflation tax. Consequently the more time elapses, the larger the post policy switch rate of money growth and the higher the post policy switch nominal interest rate. This implies that the demand for real balances drops more the later the policy adjustment takes place, and therefore the larger the required devaluation. The result is that real balances, the nominal interest rate, the forward rate and the black market rate, behave similarly to the case of a budget cut on nontraded goods with an abandoning of the peg.

We have thus seen that expectations of policy adjustments that rely on the abandoning of exchange rate management and either a budget cut on nontraded goods or inflationary finance lead to (a) rising nominal interest rates; (b) rising forward exchange rates; (c) rising premia on the black market; (d) declining real balances; and (e) discrete devaluations at the time of the policy switch. These are realistic features that help to explain many observed episodes (see, for example, Helpman and Leiderman (1988)).

B. Estimation and Evidence

Several studies have empirically examined exchange rate dynamics in environments in which economic agents assign a non negligible

probability to the event of a change in regime. Research on speculative attacks, on collapsing exchange rate systems, and on the Peso Problem fall squarely into this category. We first discuss studies of speculative attacks and collapsing regimes. Next, we turn to studies of the impact on exchange rate dynamics and forecast errors of gradual learning about changes in the stochastic processes that drive the exchange rate.

A good example of the first area is the paper by Blanco and Garber (1986). They develop an empirical method for predicting the timing and magnitude of devaluations forced by speculative attacks on fixed exchange rate systems. The method is applied to the Mexican experience during 1973-82. After more than 20 years with a fixed exchange rate, Mexico devalued the peso in August 1976, and in February and August of 1982.

The Blanco-Garber devaluation model has the following ingredients. First, they focus on equilibrium in the money market. Domestic credit creation is exogenous, possibly reflecting needs to partially finance the government's budget deficit. Money demand takes a standard form and depends on output and the domestic interest rate. The latter is related to the foreign interest rate and to expected devaluations through the assumption of uncovered interest parity. The domestic price level satisfies a stochastic version of Purchasing Power Parity. Under a fixed exchange rate, movements in international reserves are the equilibrating factor in the money market. These features can be fit

into the theoretical models of sub-section A above.

The next building block consists of the devaluation policy. When the domestic credit requirements and money market conditions impose extreme pressure on the central bank's reserves at the prevailing exchange rate, the exchange rate peg is relinquished. Namely, given a fixed exchange rate $\bar{e}$ the central bank stops intervening in the foreign exchange market when net reserves reach a critical level R.

The authors provide expressions for the probability of devaluation at time t+1 based on information available at time t. Using this probability they calculate conditional and unconditional expected (forecasted) future exchange rates. When applied to the Mexican experience, the model's probabilities of devaluation reach relatively high values prior to actual devaluations, and the expected exchange rates conditional on devaluation are close to the values that prevailed in those episodes.

Among the limitations of their analysis we point out the following. First, the minimum level of reserves R is taken to be time invariant, given with certainty, and taken from outside the model. Second, the model postulates a fixed exchange rate with recurrent devaluations. It excludes by assumption a post attack free float as well as other alternatives. Finally, the government is assumed not to impose foreign exchange controls in the face of a speculative attack. Though these assumptions may fit well the Mexican case ex-post, they are rather limiting and prove less useful for other countries.

Cumby and van Wijnbergen (1989) apply a similar model and a similar methodology to the Argentine experiment with a crawling peg between December 1978 and February 1981. Their analysis contains an important extension; they allow for uncertainty about the level of reserves that will trigger abandonment of the crawling peg regime. In other words, agents cannot calculate with certainty the critical level of domestic credit that will result in a discrete devaluation. A key assumption in their work is that, to the extent that the crawling peg proves to be unsustainable, the authorities will shift to a free floating exchange rate. These changes affect the estimates of collapse probabilities.

The authors assume a uniform distribution with a finite support for the public's beliefs about the central bank's critical value of international reserves. They also assume that the upper limit is the current level of reserves and the lower limit equals minus the central bank's current gross foreign liabilities. Under these assumptions, Cumby and van Wijnbergen calculate the probability as of the end of period t that a collapse will occur at the end of period t+1, which is the probability that reserves will fall below the critical level. They find that credit expansion in the second quarter of 1980 undermined the credibility of the crawling peg. Eventually, credibility was lost almost completely, and the one-month-ahead probability of collapse rose to 77 percent immediately before the abandonment of the crawling peg.

The foregoing discussion was confined to collapsing exchange rate systems. Peso Problems may arise not only in these cases but also when

economic agents gradually learn and revise their beliefs about changes in the stochastic process followed by fundamentals, without necessarily implying that there is a switch in the exchange rate regime. In a recent paper, Lewis (1989) develops and estimates a model designed to account for what appears to be a systematic under prediction by market participants of the strength of the U.S. dollar in the early 1980s. Her model shows how systematic forecast errors may arise during a period in which the market gradually learns about a change in fundamentals (using Bayesian updating). The model is applied to U.S. data so as to empirically investigate the impact upon dollar forecast errors of learning about the increase in U.S. money demand that occurred in the early 1980s. The expansion of money demand is interpreted as a one-time shift in the drift term that characterizes the stationary first-difference process of fundamentals. Lewis' learning model results in systematic under-prediction of the dollar's strength by about one-half the levels suggested by the forward exchange rate. It represents progress in attempting to account for the observed forecast errors. Contrary to the implications of the model, however, the systematic nature of the forecast errors -- as implied, for instance, by the forward rate -- does not appear to die out over time. Thus, in addition to the learning process emphasized by Lewis, anticipations of future policy changes and fluctuations in risk premiums may account for these persistent errors.

Kaminsky (1988) studied the Peso Problem for the U.S. dollar/pound

exchange rate during 1976-87 (assuming rational learning by investors). In one case investors are assumed to forecast the future path of the exchange rate conditional on past observations of the exchange rate and on the Federal Reserve officials' announcements about current and future monetary policy (as published in the media). These announcements were assumed to provide only imperfect information about the exchange rate process. The assumptions of the model yield a solution for the rate of currency depreciation at time t,

$$d_t = \delta_i + \epsilon_t ,$$

where d is the rate of depreciation, δ_i is the value of the drift term in regime i, and ϵ is white noise (δ_i does not change over time). Regimes are classified by different values of δ_i. Changes in these values can be thought of as arising from shifts in the drift term of the domestic money supply process. Kaminsky provides evidence indicating that exchange rate depreciation can indeed be described by an uncorrelated shock around a drifting mean, that was negative in 1981-84 and positive in the 1970s and late 1980s. Her model is also consistent with a Peso Problem, in that investors anticipated an appreciation of only .24 percent per month during the 1981:2-1985:2 period when in fact the dollar appreciated at an average of 1.6 percent per month.

An important shortcoming of Kaminsky's and Lewis' work is that regime changes that are captured by shifts in their drift parameters are

not linked to changes in fiscal and monetary policy. In principle, it would be possible to link their models to the theoretical models of collapsing exchange rate regimes. One could stipulate, for example, that δ_i is set by the authorities according to the state of, say, inflation. Thus, the higher the rate of inflation, the higher the probability that low values of δ_i will be chosen by the authorities (thus reflecting contractionary monetary policy). As it stands, however, the models contain a very simple formulation of regimes and the role of macroeconomic factors in endogenizing the choice of regime. These issues, as well as the processes that drive fundamentals, need to be studied in more detail.

V. EXCHANGE RATE BANDS

So far we have dealt with rigid exchange rate pegs. The fact is, however, that even fixed exchange rate regimes provide some flexibility for exchange rate movements within pre specified narrow bands, the Bretton Woods system being a prime example (its band was 1%). The interest in exchange rate bands has significantly increased in recent years, because many countries have adopted exchange rate bands as an explicit policy (such as Norway, Sweden and Israel), with the most prominent example of this regime provided by the European Monetary System (EMS). There also exist proposals for an application of bands to the major currencies (see Williamson (1983) and Williamson and Miller (1988)).

The existence of bands rather than fixed parities raises a number of questions, the first being how do exchange rates behave within pre-specified bands. Do they fluctuate in the interior of a band as they would if they were freely floating? Do bands eliminate the danger of balance of payments crises of the type discussed in the previous section? How do they affect interest rates as compared to fixed parities or a free float? These questions have been recently investigated and the answers have turned out to be very interesting (see Krugman (1987), Krugman and Rotemberg (1990), Flood and Garber (1989), Froot and Obstfeld (1989), Svensson (1989) and Buiter and Grilli (1989)).

It proves useful to begin with a simple case in which the authorities choose an upper bound on the exchange rate. The meaning of the upper bound is that whenever the exchange rate reaches that ceiling, the central bank stands ready to sell foreign exchange as much as required, as long as the stock of reserves remains above a predetermined minimum level. For current purposes we assume that whenever the reserves that have been allotted to defend the exchange rate are exhausted, the exchange rate ceiling is abandoned and replaced with a free float. It should be clear at this point that alternative scenarios are also possible, such as the defense of the ceiling with fiscal instruments as described in the previous section.

The most interesting cases of exchange rate bands arise when there exist random elements that drive the exchange rate. Since empirically

proportional changes in exchange rates are reasonably well approximated by a random walk process (i.e., a process whose increments are independently distributed), suppose that proportional shifts in money demand follow a continuous time random walk without drift (a Wiener process) and thereby induce fluctuations in exchange rates (the addition of a drift does not change the arguments in any substantial way). There is no domestic credit expansion and the money supply remains constant. Using a simple monetary model of exchange rate determination this specification implies that the unrestricted free floating exchange rate possesses the random walk property and the natural logarithm of the exchange rate e is linearly related to the logarithm of the proportional shocks to money demand v, as depicted by curve FF in figure 1. Hence, the larger v (the lower the demand for money) the higher the exchange rate (i.e., the weaker the domestic currency). In the absence of intervention in the foreign exchange market fluctuations in v induce fluctuations in e along FF (see Krugman and Rotemberg (1990)).

Next suppose the authorities announce a ceiling $\bar{e}$ on the exchange rate, which will be defended with existing reserves (see figure). Will now the exchange rate follow FF in response to shifts in money demand, at least for values of v below $\bar{v}$? The answer is no. For suppose v is below $\bar{v}$ but very close to it. At this point the public expects increases in v to the same extent that it expects decreases (the random walk property). In the absence of a ceiling it expects

symmetrical increases and decreases in the exchange rate, so that the expected rate of devaluation equals zero and the domestic interest rate equals the foreign interest rate. In the presence of the ceiling some upward increases in the exchange rate in response to increases in v will not materialize, because the central bank will intervene in order to prevent the exchange rate from crossing the ceiling. Consequently the expected rate of devaluation is negative and the foreign interest rate exceeds the domestic interest rate. As a result of the interest rates differential the demand for real balances is lower in the presence of a ceiling. It follows that the supply of real balances has to be higher in the presence of a ceiling. Observe, however, that the nominal stock of money remains constant as long as the exchange rate ceiling has not been reached. Under these circumstances the exchange rate has to be lower in the presence of an exchange rate ceiling in order raise real balances to its equilibrium level.

In fact, the relationship between e and v is now along a lower curve, such as CC in figure 1. The larger v, the larger the deviation of the exchange rate from FF. Thus, the existence of an exchange rate ceiling reduces the exchange rate's sensitivity to velocity shocks (see Krugman and Rotemberg (1990)). This result is central to the understanding of exchange rate bands. Evidently, the behavior of an exchange rate in the interior of a band differs from a free float (the current case can be considered as a band with an unbounded lower limit).

Available reserves determine the critical value of v_c at which CC reaches the ceiling. If available reserves are small, v_c is close to $\bar{v}$, and once v_c is attained there will be a run on reserves that will wipe out the entire available stock. This will reduce the stock of nominal money balances and shift to the right the free floating curve FF (this curve is higher the higher the stock of money). Since the exchange rate cannot jump in an anticipated fashion (because it would provide unbounded arbitrage opportunities), the free floating exchange rate just after the run on reserves has to equal $\bar{e}$. Given the required stock of reserves, that determines the rightward shift of the FF curve in case of a run on reserves that depletes them to the postulated minimum, this condition determines v_c and the end point of the CC curve.

We have thus described a situation in which the exchange rate floats below a pre-specified ceiling, responding to velocity shocks less elastically than in an unrestricted float, and a run on reserves takes place the moment it hits the ceiling. As mentioned above, this situation applies when reserves are low. Figure 2 describes a situation with a large amount of foreign exchange reserves (see Krugman and Rotemberg (1990)). The corresponding CC curve lies below FF as before, except that this time it reaches a peak at the ceiling.

Suppose the initial value of v is lower than v_c. Fluctuations in v that remain below v_c lead to corresponding exchange rate fluctuations along CC. If, however, v_c is reached and the exchange

rate hits the ceiling, this time there is no run on reserves. Instead the central bank defends the ceiling by selling foreign currency. The required interventions are small and deplete only gradually the stock of reserves. Each time the exchange rate hits the ceiling sales of reserves reduce nominal money balances and the FF and CC curves shift to the right. This process continues as long as the central bank has reserves. The exchange rate fluctuates on CC below the ceiling for some time, hits the ceiling, thereby inducing a shift to the right of the CC curve, and fluctuates on the new CC curve until the next time it hits the ceiling. When the entire stock of available reserves gets exhausted the central bank abandons the ceiling and changes its exchange rate policy to a free float. In this case no run on reserves precedes the abandonment of the ceiling.

An important feature of the above described exchange rate movements is the positive association between v and e. Namely, declines in money demand lead to exchange rate depreciations independently of whether the exchange rate floats freely or is restricted by a ceiling. This results from the fact that a policy that defends the ceiling with infinitesimal interventions prevents the exchange rate from following the downward slopping portion of the CC curve in figure 2 (to the right of v_c). As pointed out by Flood and Garber (1989), however, a different intervention strategy leads to very different consequences.

Thus, suppose that instead of intervening in a minimal fashion in order to defend the ceiling (as described above) the central bank uses a

pre announced finite amount of reserves each time it intervenes in the foreign exchange market. In this case the downward slopping part of CC will also be followed by the exchange rate. In figure 2 intervention will take place only when v_f is reached. The finite size intervention will bring about a decline in money balances, FF and CC will shift to the right, and the new CC curve will pass through point 1 (this is how v_f is determined for a pre-determined size of the intervention). The crossing of the new CC curve with the old one at point 1 prevents an anticipated jump in the exchange rate in response to the intervention. As a result of this intervention rule one observes periods during which declines in money demand are associated with exchange rate appreciations. Such "paradoxical" co movements necessarily precede the central bank's intervention.

It follows from this discussion that in the presence of a band there does not exist a simple relation between fundamentals and the exchange rate. This complexity has a bearing on empirical tests of exchange rate theories. For example, many studies of the simple monetary approach have regressed the log of the exchange rate on the log of relative money supplies (and on other variables) and have tested for a coefficient of unity on this explanatory variable. It is evident from our discussion that this test is not suitable in the presence of a band.

We have so far discussed exchange rate ceilings. It is now straightforward to see what happens when there also exists a lower bound on the exchange rate; i.e., when there exists an exchange rate band.

Figure 3 describes a band $[\underline{e},\bar{e}]$ that is defended with a large stock of reserves. Suppose that the central bank engages in minimal interventions at the limits of the band. A free floating exchange rate would fluctuate along FF while in the presence of a band it fluctuates along CC as long as v remains in $(\underline{v}_c,\bar{v}_c)$. If the exchange rate hits the lower limit (v hits $\underline{v}_c$) the central bank buys foreign currency and increases its reserves. The money supply increases and our curves shift to the left. When the exchange rate hits the upper limit the central bank sells foreign currency and depletes its reserves. The money supply declines and our curves shift to the right.

Since there exists no limit on the feasible accumulation of reserves (from the point of view of a single country), the band can be maintained as long as the upper ceiling can be defended. It cannot be defended, however, for prolonged periods of time when the exchange rate hits the ceiling very often. This happens when v has a strong positive drift. Namely, when there exists a strong secular decline in the demand for money. Or alternatively, when domestic credit grows fast.

These models contain an inherent relation between the variability of the interest rate and the width of the band. Naturally, they also contain an inherent relation between exchange rate variability and the width of the band; the wider the band the more volatile the exchange rate (for given fundamentals). Svensson (1989) has shown that interest rate variability rises with the width of the band for narrow bands and

declines with wide bands. It follows that for narrow bands the widening of the band raises the volatility of both the interest rate and the exchange rate. For wide bands, however, widening the band gives rise to a trade-off, in that it raises volatility of the exchange rate but reduces volatility of the interest rate. These consideration are of major concern to central banks who determine the size of their band. As argued in section III, volatility in nominal exchange rates can result in real exchange rate volatility, which is often thought to be detrimental. Similarly, nominal interest rate volatility may affect the volatility of real interest rates, which are important relative prices. In addition, the behavior of nominal interest rates may affect the functioning of financial markets, which are in the responsibility domain of central banks.

At this stage the theory of exchange rate bands has not reached the same stage of development as the theory of collapsing exchange rate regimes. The two are, of course, related, as is evident from our discussion. We need further extensions of the band theory in order to better understand the relationship between interventions at pre-announced or uncertain limits of exchange rate movements and monetary and fiscal policy. In view of the theory of collapsing exchange rate regimes one can see immediately that it may make a major difference whether the defense of a band limit is carried out by means of foreign exchange intervention, open market operations, adjustments in government spending or taxes. Here one may distinguish short-term

responses from long-term responses, where in the short term the major burden of defense is assigned to monetary policy and foreign exchange intervention while in the long-run fiscal policy carries the burden. These important issues, as well as the welfare implications of alternative policies, remain to be explored.

Many useful empirical implications of the band models have not yet been fully articulated. As pointed out by Froot and Obstfeld (1989), for example, bands imply nonlinear exchange rate equations. They also imply stationarity for the log of the exchange rate, thereby contradicting the random walk theory that has served as the null hypothesis in recent years. Thus, commonly used empirical models are miss specified when dealing with data from countries with exchange rate bands. Another example concerns volatility tests that can be used to examine band theories. As pointed out above, different band sizes have different implications for the co movement of volatility measures of interest rates and exchange rates. These implications could be tested with cross country data.

VI. CONCLUDING REMARKS

In these remarks we briefly elaborate on a number of additional important issues related to the choice of the exchange rate regime which have not been discussed in the foregoing analysis. First is the issue of hysteresis. Conventional analysis of floating exchange rates uses some version of Purchasing Power Parity whereby, assuming that foreign

prices are given, domestic prices move in line with exchange rate movements. Recent evidence on domestic prices of imported goods and services in the U.S. fails to support this hypothesis (see, for example, Krugman and Baldwin (1987)). That is, prices of imported goods in the U.S. have not moved in unison with movements in dollar exchange rates and have exhibited an important degree of sluggishness. A number of authors have constructed theoretical models to explain this phenomenon (see Baldwin and Krugman (1989) and Dixit (1989)).

The main line of work has built on the notion that exporting firms face entry (exit) costs that become sunk costs after the event of entry (exit). These costs are denominated in the currency of the export market while manufacturing costs are denominated in the firms' domestic currency. The implication is that there exists a range of exchange rate movements within which an incumbent firm does not leave the export market while a new firm does not enter it. This range depends on structural features as well as on the drift and variability of the exchange rate. Hence, the process of exchange rate movements affects the degree of sluggishness in the response of supply to the export market. This is an important point that has a bearing on the ranking of alternative exchange rate arrangements that we have not discussed in detail. (Froot and Klemperer (1989) provide an alternative explanation).

Second is the issue of disinflation. Two branches of research have converged into the hypothesis that moving toward fixed exchange rates

helps achieve disinflation through a more rapid and less costly transition than under alternative exchange rate systems. It has been argued that for countries such as France and Italy joining the EMS enhanced credibility, discipline, and commitment, that are necessary to generate a fast downward adjustment of inflationary expectations. And this adjustment, in turn, played a key role in generating the observed convergence in rates of inflation toward the rate prevailing in Germany. Another line of research has dealt with disinflation in high inflation countries, such as Argentina, Brazil and Israel. There the argument has been that in the presence of the required adjustments in monetary and fiscal fundamentals, fixing the exchange rate can help break existing inflationary inertia. Moreover, examples have been constructed showing that using the exchange rate as a nominal anchor may disinflate the economy with lower sacrifice ratios than using monetary targets; see Fischer (1988).

Although the argument that, during disinflation a fixed exchange rate serves as a useful anchor of nominal values, has its merits, its empirical validity has not been definitively established. Some evidence indicates that in the early to mid 80s the EMS countries performed poorer than other OECD countries, in the form of higher unemployment rates and lower growth rates of output and employment (see De Grauwe (1989)). Similarly, the relatively slow downward adjustment of actual and expected inflation in countries such as France and Italy in the 80s indicates that credibility problems may have well persisted despite the

fact that both countries joined the EMS (see Collins (1989) and Giavazzi and Giovannini (1989, ch. 5)). In addition, the quantitative importance of fixing the exchange rate in producing low rates of inflation in previously high-inflation economies has not yet been determined. In order to meaningfully determine this quantitative importance it is required to provide estimates that control for the effects of other changes, such as monetary and fiscal adjustments, changes in wage indexation rules, price controls, etc., whose precise empirical specification is as yet unknown (see Helpman and Leiderman (1988)).

Third, there exists the issue of policy coordination. The choice of an exchange rate regime is important in an imperfect world where markets are incomplete, there exist informational problems, and other market failures (see section II). In such cases markets do not allocate resources efficiently. These inefficiencies are not restricted to national boundaries but also impinge on the international economy. For these reasons there exists an a-priori case for policy coordination. In addition, many exchange rate systems, such as Bretton Woods and the EMS, inherently build on a specific form of policy coordination.

The literature on policy coordination in a world of strategic behavior has shown that coordination may or may not be desirable (see Oudiz and Sachs (1984) and Rogoff (1985)). Distortions that result from competitive policies may be worse than distortions that result from market failures. These findings imply that detailed analysis of cooperative exchange rate arrangements is required in order to form an

opinion about their merits and shortcomings. The success of an exchange rate regime depends not only on the form of cooperation in exchange rate arrangements but also on the form of cooperation of fiscal policies. For monetary policies, for example, the creation of a European Central Bank would be an important ingredient in a general policy package. There exists an extensive literature on these problems that we have not reviewed.

Are there new answers to the old questions? Our review shows clearly that during the many years that have passed since the publication of Friedman's (1953) defense of floating exchange rates the debate has shifted from the narrow comparison of fixed vs. floating exchange rates to debates on much richer menus of choice. This outcome has resulted from the wide recognition that neither one of these polar regimes is perfect and that the best solution lies in an intermediate system. For this reason much of the research and practical policy debate has been redirected to the identification of a good intermediate case. It is, therefore, not surprising to find that we now face many new questions and have to deal with many new issues that were not considered in earlier debates. For example, the emphasis of recent research on the response of the private sector to the possibility of a regime switch had no place in discussions of pure floats or pure fixed exchange rate regimes. In addition, the wealth of empirical evidence that has accumulated over the years sheds new light on the functioning of alternative exchange rate systems, and no practical policy debate or

theoretical argument can ignore it. Although the issue of the best exchange rate regime is yet unsettled, we may safely conclude that we have learned a great deal from recent research.

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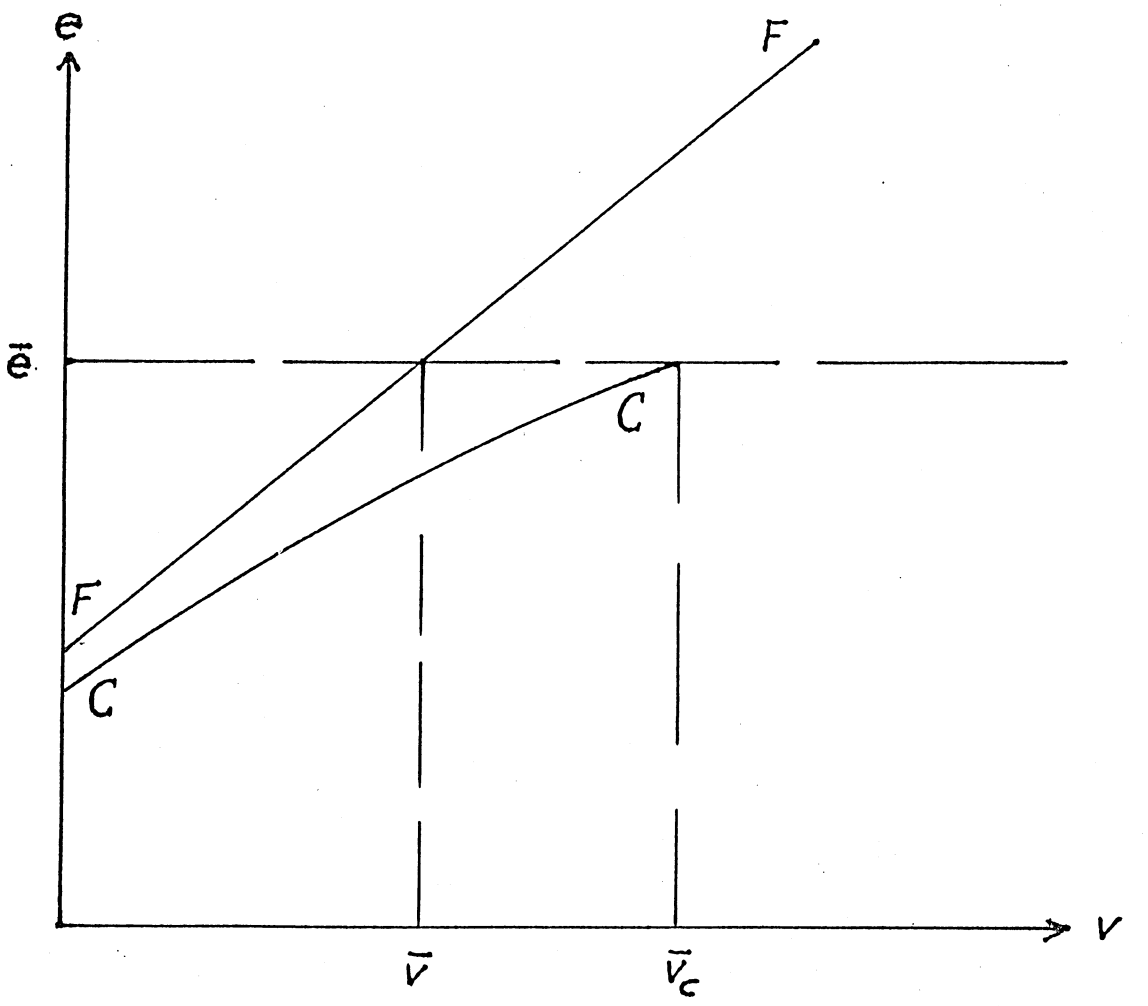

Figure 1

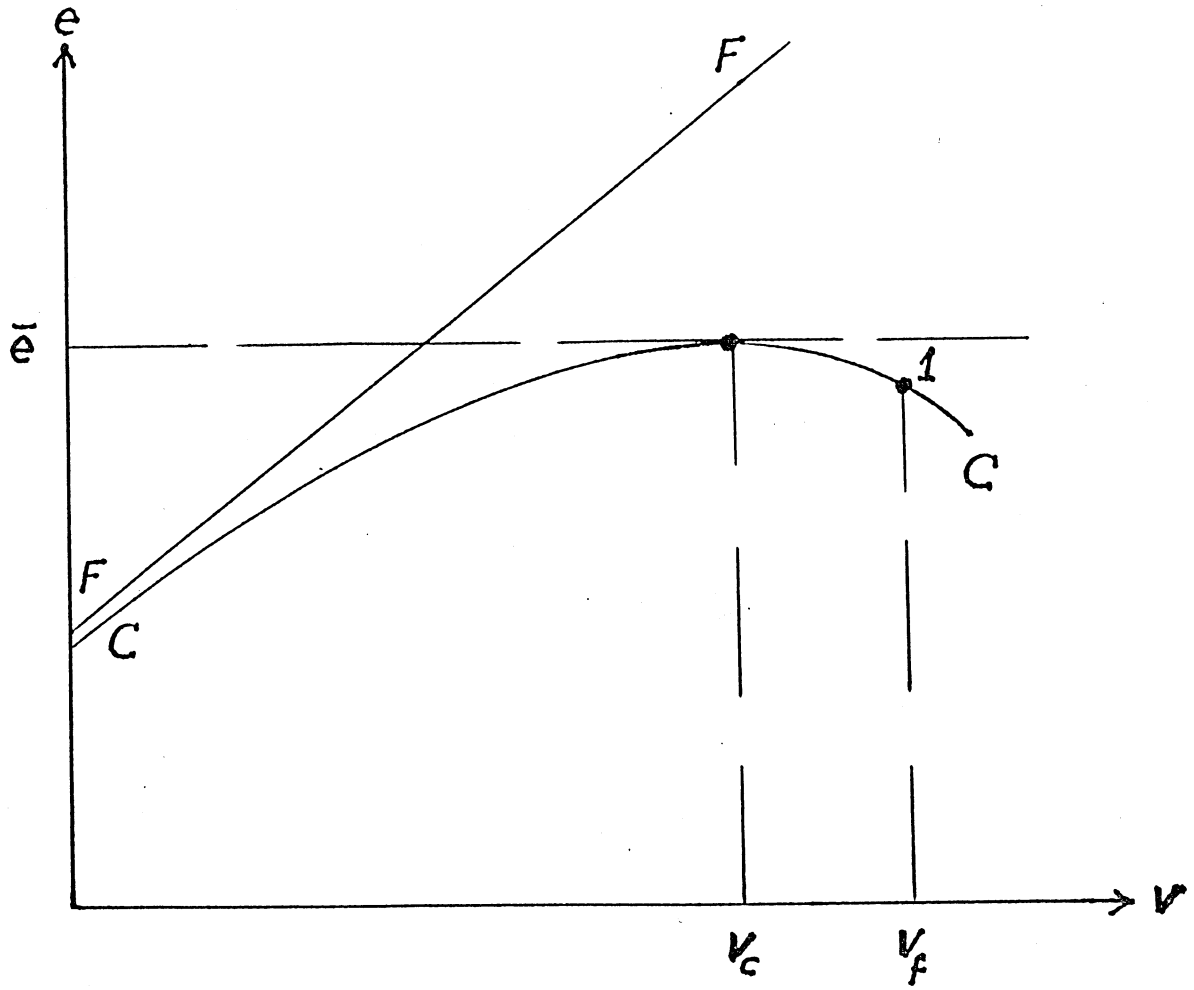

Figure 2

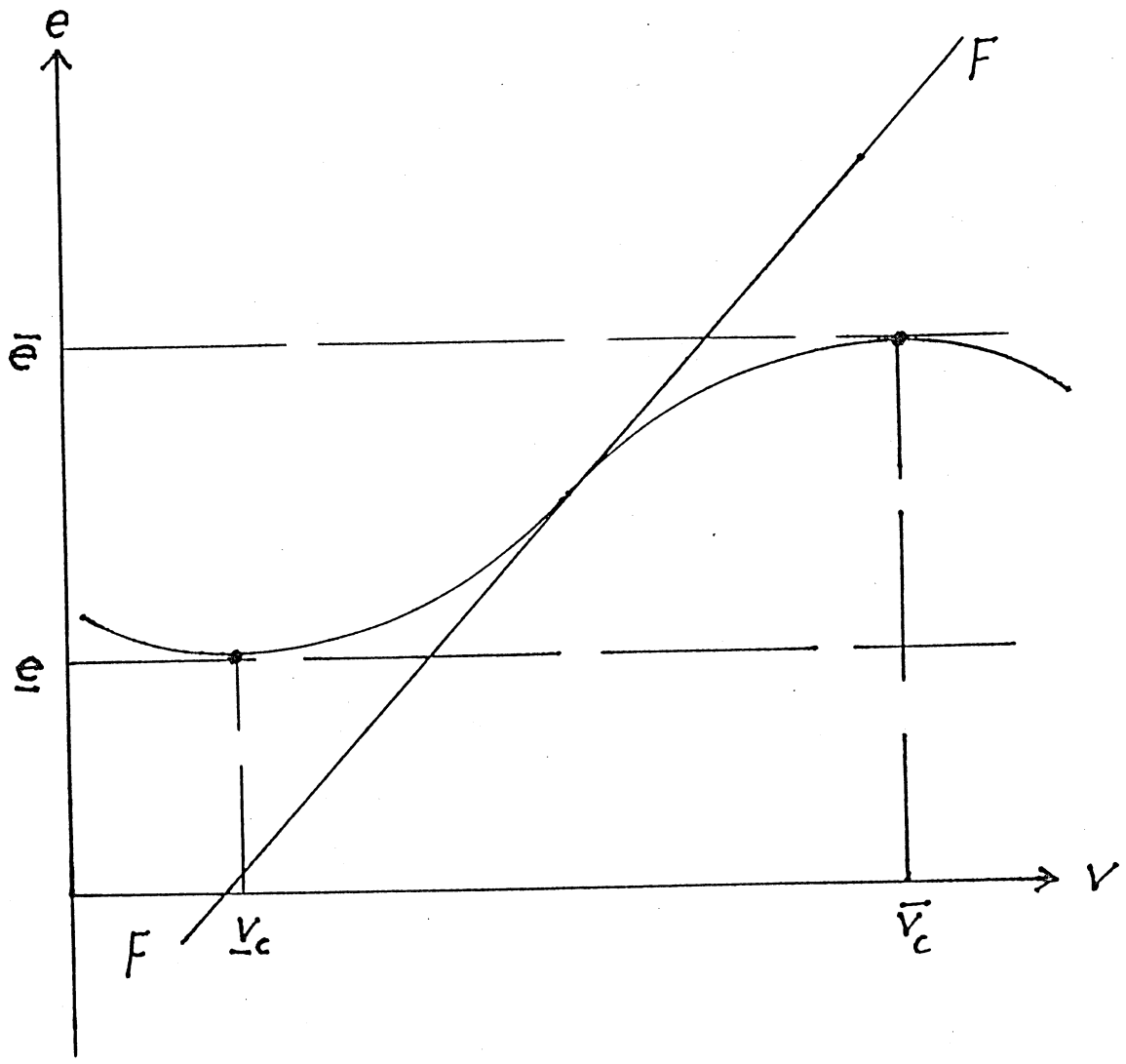

Figure 3