Variability of Prices, Output and Money Under Fixed and Fluctuating Exchange Rates: An Empirical Study of Monetary Regimes in Japan and the United States

ALLAN H. MELTZER*

I. Introduction

The closing of the gold window at the U.S. Treasury, announced in mid-August 1971, formally ended the Bretton Woods system of fixed but adjustable exchange rates. In Japan, the shift in regime and measures accompanying the shift are known as the "Nixon shock." The shock initially increased uncertainty in Japan, and elsewhere. Negotiations to reestablish fixed exchange rates at new parities eventually produced a new agreement that soon collapsed. In March 1973, major countries abandoned efforts to restore a fixed exchange rate regime.

The shift from fixed to fluctuating exchange rate changes the rules and procedures for issuing and withdrawing money, so it is a change in monetary regime. Changes in monetary regime change the ways in which shocks are transmitted through the economy and, to a degree, the type of shocks that occur. As is well-known, a system of fluctuating exchange rates can transfer the effect of monetary shocks, coming from abroad, from the domestic money stock and the prices of

* The paper reports on a study completed while the author was a Visiting Scholar from Abroad at the Bank of Japan during the winter of 1984-5. The author is grateful to Dr. Yoshio Suzuki of the Institute for Monetary and Economic Studies and the Bank for their hospitality; Yoshiaki Shikano for providing cheerful assistance and helpful suggestions; and other helpful comments received from Kazumi Asako, Fumio Hayashi, Akiyoshi Horiuchi, Thomas Mayer, Charles Plosser, Juro Teranishi and Toshihisa Toyoda. The author is also grateful to the cooperation of Edward Bomhoff and Clemens Kool of Erasmus University, Rotterdam. Earlier versions were presented at the Bank of Japan and at Kobe, Hitotsubashi and Tokyo Universities. The final draft reflects the comments and suggestions of many participants at these seminars.

domestic goods to the exchange rate. Fluctuating exchange rates give greater freedom to countries wishing to pursue independent monetary policies and provide more opportunity to control money. This freedom may be used to increase the stability of domestic prices, but it has been used also to produce relatively high and variable rates of money growth and inflation.

Theoretical analysis of fixed and fluctuating exchange rates considers the opportunities under each system. The classic statement of the benefits of fluctuating exchange rates is Friedman (1953). Critics of fluctuating rates usually allege that exchange rate fluctuations increase risk and inhibit trade. The classic statement of this case is Keynes's *Tract* (1971, pp. 87-94), although he limited the argument to seasonal fluctuations. A more recent statement by Kindleberger (1969) is less restricted. Kindleberger takes for granted that uncertainty about exchange rates increases uncertainty about prices and output and inhibits trade. See also McKinnon (1984).

A central issue in these discussions is the degree to which institutional arrangements — specifically the choice of monetary rules or regimes — damps or perhaps augments fluctuations. Analysis of the comparative merits of fixed and fluctuating exchange rates shows that the choice depends on such features as the relative size of the economy or the share of imports in consumption. Many early studies used a deterministic framework. Later work, allowing for some unforeseen shocks, has not yielded firmer or less conditional conclusions. Fischer (1977), and Flood (1979) list factors such as the slope of the Phillips curve, the response of spending to interest rates, the size of real balance effects and other factors that are likely to differ between countries. Further, the choice of an optimal monetary rule depends on the type of shocks that occur. For example, if there are frequent shocks to the growth rate of real output, a rule seeking price stability cannot be implemented successfully by keeping expected money growth constant. On the other hand, constant expected money growth is more appropriate if most shocks are a result of unanticipated changes in money.

Recent theoretical work carried out in the framework of the so-called Lucas supply function presumes that the dominant cause of fluctuations in output and prices is a monetary shock to aggregate demand. Initially, people misperceive the shock as a change in relative demand. The confusion of aggregative and relative demand does not persist. As soon as people learn that the stock of money has changed, output and prices (or rates of inflation) return to the expected values. In the language of this paper, the shock is a transitory shock to the level of output.

Little is known currently about the persistence of shocks. Recent studies by Bomhoff (1982, 1983) separate shocks empirically according to expected persistence and effects on levels or growth rates. Meltzer (1984), using Bomhoff's procedure to compare the persistence of shocks to money, prices and output experienced under different monetary regimes, found substantial differences between the types of shocks and the variability of output, prices and money during different monetary regimes in the United States during this century. In the six regimes of the past century, transitory shocks were found to be less important than permanent shocks as a cause of disturbances.

Shocks differ by source as well as persistence. Analysis of the source of shocks and the interrelation between shocks to output, prices and money contributes to the discussion of the causes of fluctuations in economic activity and prices. Two alternative positions are well-known. One emphasizes the role of sudden changes in money or its growth rate as a main cause of fluctuations. The other assigns greater weight to real shocks affecting tastes, productivity or the degree of optimism and pessimism. Recent work by Kydland and Prescott (1983) and by Long and Plosser (1983) has revived interest in real theories of the business cycle. Work by Nelson and Plosser (1982) and by Stulz and Wasserfallen (1985) has revived interest in the view that postwar business cycles are mainly the result of random shocks — in their analyses, changes in the stochastic trend of output. The present paper attempts to contribute to these discussions in two ways. First, the paper presents measures of the size and degree of persistence of shocks to levels and growth rates obtained from univariate time series analysis. Then the paper considers the interrelations between shocks by estimating the effect of past real and nominal shocks on current shocks and by considering the extent to which current, unanticipated changes are unexplained and apparently unrelated to past shocks.

In a fixed exchange rate regime, current shocks to money are, at least partly, the result of current and past changes in prices and output at home and abroad. Current and past changes in prices and output reflect current and past changes in technology but also reflect current and past changes in money. This interacting set of relations is complicated further by the presence of anticipations about future monetary (or other) policies and about future effects of past changes in money and technology. A change in monetary regime to fluctuating exchange rates alters these relations, in principle, by eliminating the commitment to allow the money stock, or its growth rate, to be influenced by past real and monetary shocks. Anticipations about the future money stock and its influence on prices and output are revised, the extent of the revision depending on the degree to which the announced change in regime is followed by a change in the behavior of the central bank.

One cannot expect to resolve the long-standing issues about the comparative merits of monetary standards by considering a single country or a few countries during a short period of time. Previous work, Meltzer (1984), documents the substantial decline in variability of actual and forecast values of output, prices and money in the United States after the Second World War and shows that the variance of forecast errors declined more than proportionally to the decline in measured variability.[1]

This study narrows the time period to the postwar years but extends my earlier study in two ways. First, by using data for the U.S. and Japan, we can begin to overcome one major issue about empirical studies — the extent to which the results are applicable beyond a particular sample. Second, the use of two major countries permits analysis of the degree to which shocks are interrelated and, also, the way in which the interrelations changed following the shift in regime from fixed to fluctuating exchange rates in 1971.

Section 2 orients the study by considering issues about the choice of monetary regime and the relation of this choice to the type of shocks and their consequences for the economy. Section 3 discusses the procedure used to separate shocks, the choice of data and some related issues. Section 4 compares the variability of output, prices and money and the distribution of variability by type of shocks in Japan and the United States under fixed and fluctuating exchange rates. Section 5 considers the interrelation of shocks. A conclusion completes the paper by summarizing main findings.

II. The Choice of Monetary Standard

Choice of the monetary standard affects both the way in which a country receives and responds to shocks or impulses and the social cost of maintaining a payments system. Commodity money increases storage cost, but, according to proponents, commodity money reduces costs of monitoring, reduces the private and social costs of variable inflation and contributes to long-term price stability. Different monetary standards also change the type of risks that an economy bears and the ways in which they are borne.

Proper choice of the monetary standard can reduce cost and risk. From the perspective of the typical risk averse consumer who seeks to maximize the utility of consumption, the optimal choice of a standard reduces these costs to their minimum. The minimum risk in any society is the risk inherent in nature, trading and (other) institutional arrangements. Monetary arrangements cannot prevent real shocks to productivity or prevent changes in the policies of other countries or changes in non-monetary policies. But monetary arrangements can dampen (or not amplify) the domestic effects of shocks or impulses by preventing or reducing the monetary consequences of real shocks; policies of exchange rate control will differ from policies of money stock control in this respect.[2] Further, monetary arrangements can affect the

1. Forecasting methods are described in Bomhoff (1983) and are discussed below. DeLong and Summers (1984) also document the decline in variability and discuss reasons for the decline.
2. The difference in the policies of the Bank of Japan preceding and following the first and second oil shocks of the 1970s provides an example of the ways in which different policy rules or procedures augment or reduce the impact of unavoidable shocks to the domestic economy.

confidence the public has in the stability of future nominal values and, thus, work to stabilize the demand for money.

Shocks affect expectations and thus affect the size of future shocks to the same or other variables. One reason is that people may misperceive the persistence of shocks. Suppose a transitory shock is believed to be permanent, or conversely. Expected values will reflect the belief, and errors of forecast will reflect the misperception. Gradually, people correct the error or misperception and adjust their forecasts. The speed of learning depends on the amount of noise in the system, so if noise is relatively high, forecasts based on all available information can make errors in the same direction. Also, expectations are interrelated. An increase in expected money growth has implications for the expected exchange rate, the expected rate of inflation and other variables. A change in monetary regime affects the expected response to an unanticipated change in money growth or an unanticipated change in productivity.

A risk averse consumer is concerned about the choice of monetary regime. Greater stability of international values encourages diversification over a wider mix of assets and lowers risk and lowers the cost of hedging risks. Greater long-term stability of expected domestic and international prices lowers the risk that savings held in nominal assets will depreciate or appreciate over time. Unanticipated appreciation means that people, looking back, could have consumed more earlier without reducing consumption during retirement. Unanticipated currency depreciation lowers the real value of pensions and bequests denominated in the depreciating currency. In practice, risk of loss from currency appreciation or depreciation are not — and possibly cannot be — fully diversified, so concern for losses of this kind may lead risk averse consumers to reduce consumption during working years, lowering utility. The effect of hyperinflations on the real value of pensions in Germany and elsewhere during the twenties is well-known. Other less dramatic examples have occurred in countries experiencing high rates of inflation in the recent and more distant past. Greater uncertainty about future values also imposes an excess burden by raising the equilibrium rate of return to capital, reducing the capital stock and future consumption. Losses of this kind cannot be eliminated, but losses can be reduced by choosing a monetary regime that increases stability.

Some of the issues involved in the choice of monetary regime can be summarized by considering the case for a world money. A single currency, available for the world or for major trading countries, issued under conditions that maintained expected price stability over long periods of time, would reduce costs arising from internal and external price fluctuations and different rates of inflation. This is the key insight of the proponents of a world central bank or a world money. A problem with most proposals for a world money is that they often give little regard to the risks of future inflation or deflation. A world money reduces the cost of exchanging currencies and the cost of acquiring information about the monetary policies of many countries. General use of a single world currency restricts opportunities for societies to avoid the costs of inflation or deflation. To capture the gain to society from a world money, the public may be required to accept the social costs of inflation and variable nominal values.

Considerations of a world money brings out the societal gain from the introduction of a common medium of exchange and the social costs arising from fluctuations in the standard of value.[3] The nature of these costs can be developed by supposing that all countries adopt compatible monetary arrangements of the type recommended on several occasions, for example, Meltzer (1985). Under the proposed arrangement, each country commits its monetary authority to a path for money growth that adapts gradually to changes in the growth of real output and the growth of monetary velocity by setting the growth of money equal to the difference between the three year moving average rates of growth of real output and velocity. On average, a policy of this kind limits the size of price fluctuations and contributes to expectations of domestic price stability. The international character of the policy — the fact that it is adopted by several large countries — contributes to the stability of exchange rates. Thus, the proposal contributes to the stability of prices of domestic and internationally traded goods in a way that cannot be achieved either by a single country, acting alone, that seeks domestic price stability or by a group of countries acting together to fix exchange rates. A single country can, at best, reduce fluctuations in domestic prices and thus limit the effects of these fluctuations on real variables. A fixed exchange rate can, at best, stabilize exchange rates. The proposed agreement to seek price stability can achieve as much domestic price stability as a single country acting alone and, in addition, can remove one source of fluctuations in exchange rates.

Unanticipated changes in technology, changes in the age composition of the population and other real shocks would continue to produce fluctuations in prices, output and exchange rates. Under the proposed arrangement, or others, fluctuations cannot be eliminated entirely. The choice of monetary regime or monetary standard can, at most, reduce the cost of such shocks by damping rather than augmenting the initial effects and by reducing errors in anticipations.

In principle, activist policies — including activist rules for policy as described by McCallum (1984) — do not minimize the cost of fluctuations if policymakers and the public cannot distinguish promptly between transitory and permanent changes or between changes in level and changes in growth rate. Transitory changes in level are self-reversing. If transitory changes are unanticipated, monetary policy can do noth-

3. Some of these issues are treated more explicitly in Brunner and Meltzer (1971), but that analysis does not consider the choice of monetary regimes.

ing to prevent or offset these changes.

The choice of monetary standard can, however, affect the cost of unforeseen changes by reducing the frequency of monetary changes or by limiting their size. Some argue that the central bank can use monetary changes to offset some effects of real shocks or changes in anticipations. Many economists urged discretionary changes in money at the time of the 1970s oil shocks. They reasoned that the permanent increase in the price level lowered aggregate demand by reducing real money balances, so they called for an increase in money to restore the level of real balances and reduce the social cost of adjusting to the shock. Costs may be raised, not lowered, if the one-time change in money is perceived by the public as a change in the rate of money growth. If the public believes that money growth is higher, they shift from money to real assets and, in other ways, anticipate a change in the rate of inflation.

Examples of this kind bring out some of the issues in the choice of monetary standards or monetary regimes. There are, as always, two types of errors that we can describe as excessive activism and excessive passivity. The former occurs when a policy regime introduces more variability than it removes. The latter occurs when a policy regime fails to reduce variability that can be offset. Examples of excessive activism are the use of monetary or interest rate changes to offset transitory changes and the effect on expectations if people perceive changes in level as changes in rates of change. An example of excessive passivity is a failure to adjust the growth rate of money when a change in the growth rate of output has been identified. The Bretton Woods system encouraged excessive passivity by countries outside the United States. By failing to adjust their exchange rates or change the monetary regime, they paid the cost of higher and more variable inflation and, later, the costs of disinflating.

This section emphasizes that the choice of a policy regime that reduces risk or uncertainty depends on the type of shocks that occur. Shocks may be real or nominal, permanent or transitory, changes in level or in growth rate. The choice of monetary regime and other institutional arrangements is a way of affecting the distribution between the categories and the level of risk that society bears.

III. Empirical Procedures

The statistical procedure used in the paper has two parts. The first computes the size of shocks — unanticipated changes — in each of a series of variables treated separately. Shocks are measured by taking deviations from forecasts made using the multi-state Kalman filter developed by Harrison and Stevens (1976) and implemented by Kool (1983) and Bomhoff (1983). The second procedure analyzes the relationship between shocks using vector autoregressions, VAR.

The multi-state Kalman filter uses a set of filter models to analyze data and a

Bayesian learning process to revise the weights on the different models.[4] There are, in fact, two learning processes. Estimates of the underlying variability change as errors of forecast rise and fall. Each period, the program revises the conditional variance of the forecast for the next period. In addition, the program revises the probabilities assigned to the types of errors that occur. These revisions change the weights assigned to the types of errors that are anticipated: permanent and transitory errors in the level of the series and permanent changes in the growth rate of the series. (Permanent changes in level are transitory changes in growth rate.) Changes in weights affect the length of the lag in response and the weight that is placed on recent observations relative to data from the more distant past. The greater the probability assigned to transitory changes, the more weight is assigned to observations in the distant past and the slower is the optimal adjustment to new information. As more weight is assigned to permanent changes in level, or permanent changes in rates of change, optimal forecasts rely more on recent observations. In the limit, if all variability is transitory, the optimal response to an error is not to adjust, whereas if all variability is perceived as permanent, complete adjustment of expectations to new information is optimal.

In practice, weights on the particular components are adjusted according to the general success of the forecasting scheme in the recent past and its reliability in the two most recent quarters. Two quarters are the minimum period required to decide that a particular change is not entirely transitory, but the lag in adjustment increases when a permanent change occurs after a long series of transistory changes.

The forecasting model used in the study consists of equations (1) to (3) where ε_t, γ_t and ρ_t are, respectively, transitory shocks to the level of a series, permanent shocks to the level and permanent shocks to the growth rate.

$$X_t = \bar{X}_t + \varepsilon_t \qquad \varepsilon_t \sim N(0, \sigma_\varepsilon^2) \tag{1}$$

$$\bar{X}_t = \bar{X}_{t-1} + \hat{X}_t + \gamma_t \qquad \gamma_t \sim N(0, \sigma_\gamma^2) \tag{2}$$

$$\hat{X}_t = \hat{X}_{t-1} + \rho_t \qquad \rho_t \sim N(0, \sigma_\rho^2) \tag{3}$$

Combining the three equations, we have

$$X_t = \bar{X}_t = \hat{X}_{t-1} + X_{t-1} + \varepsilon_t + \gamma_t + \rho_t \tag{4}$$

where X is the logarithm of the observed value of output, price level or money stock. The expected value of X_t at the start of period t, denoted EX_t, is

4. A more complete discussion is in Bomhoff (1983, Chapter 4) and Kool (1983). The author relies on their discussions.

$$EX_t = \bar{X}_{t-1} + \hat{X}_{t-1} \tag{5}$$

The shocks, ε_t, γ_t, ρ_t are serially uncorrelated, mutually independent disturbance terms with zero means and the variances σ^2 shown in each equation.

People do not know the underlying level, $\bar{X}_t$, or the permanent growth rate $\hat{X}_t$. They observe only X_t and use the model to infer these values from the information on X_t available at the time forecasts are made. Shocks cannot be observed separately so, as shown in (5), the expected value and hence the forecast of X_t depends on beliefs about the underlying level and permanent growth rate of X. Consequently, the forecast for k periods in the future, made at the beginning of period t, is

$$_tEX_{t+k} = \bar{X}_{t-1} + k\hat{X}_{t-1}$$

Relatively high variance of the permanent growth rate indicates that values in the distant future are relatively uncertain. Relatively high transitory variance implies that uncertainty about values in the distant future is not much greater than uncertainty about near-term values.

Following Kool (1983), we can exploit the equivalence between equations (1) to (3) and the familiar ARIMA (0,2,2), shown in (6).

$$\begin{aligned} \Delta^2 X_t &= (1 - Q_1 B - Q_2 B^2)\, a_t \\ a_t &\sim N(0, \sigma^2_a) \end{aligned} \tag{6}$$

Differences in the values of Q_1 and Q_2 place different weights on transitory changes in level, permanent changes in level and permanent changes in rate of change. For example $Q_1 = Q_2 = 0$ implies that $\Delta^2 X_t$ depends only on the permanent rate of growth estimated from the last two values of X.

One advantage of the multi-state Kalman filter is that it adjusts to changes in the underlying stochastic process, if such changes occur. A change in monetary regime from control of money to fixed exchange rates may change the underlying stochastic process from one in which most errors are transitory changes in level (ε) — that arise from imperfect control — to processes in which either money growth or the level of the money stock is a random walk. The Kalman filter can decide, based on the quality of forecasts, that the process is dominated by white noise; in this case most weight is given to ε. Or, if the lowest forecast errors are obtained on the assumption that the process is a random walk in the level or growth rate of the series, most weight is placed on γ or ρ.

In the actual data analysis, the weights on the transitory and permanent components adjust each period, based on Bayesian learning. The program computes prior probabilities for each type of shock each period. Shocks are divided into normal and outlier observations, with the sum of the three normal shocks taking 95% of the prior probabilities. Initially, one-third of the weight is assigned to ε , γ and ρ respectively, so the initial priors are 31-1/3% for each normal shock and 1-2/3% for each outlier.

The data are also used to revise the variance of the forecast error. The assumptions used for these computations and for the computations of the weights assigned to each type of shock are more fully described in Kool (1983).

An indication of the comparative forecasting accuracy of the multi-state Kalman filter is given by the data in Table 1. All series are natural logarithms of variables. Comparisons are to forecasts using a random walk.

The mean absolute errors and the standard errors of estimate for the Kalman filters are typically lower than the forecast errors from the random walk model. The principal exceptions are the velocity measures where the multi-state Kalman filter is

Table 1 Forecast Accuracy

Series	Period Quarterly	Kalman Filter		Random Walk	
		Mean Absolute Error (x100)	Standard Error of Estimate (x100)	Mean Absolute Error (x100)	Standard Error of Estimate (x100)
Japan					
Nominal GDP	1957/1-83/4	1.18	1.62	2.95	3.38
Deflator	1957/1-83/4	0.68	0.94	1.35	1.74
Real GDP	1957/1-83/4	1.07	1.47	1.79	2.24
M_1	1957/1-83/4	1.52	1.95	3.41	3.91
V_1	1957/1-83/4	2.07	2.58	1.82	2.38
United States					
Nominal GNP	1890/1-84/2	2.59	4.15	3.06	4.09
Monetary Base	1947/1-84/2	0.36	0.47	1.31	1.51
Base Velocity	1947/1-84/2	0.97	1.26	0.96	1.24

not more accurate than the random walk. The Kalman filter uses only data for periods prior to the forecast, however, so forecasts are closer to "true" forecasts than the forecasts from the random walk.[5]

Although the forecasts using the Kalman filters compare favorably to forecasts obtained by alternative methods, they are not fully efficient. A multi-variate version of the multi-state Kalman filter is not available, so information in related series is neglected. To take account of this inefficiency, and to investigate the interdependence of shocks, forecast errors obtained using the multi-state Kalman filter are analyzed using vector autoregressions (VAR). The VAR relate the shocks estimated from the univariate Kalman filters, so they suggest the degree to which the measured shocks are either interdependent or dependent on past shocks to other variables. The VAR are estimated using the program developed by Doan and Litterman (1981). In this program, each shock (forecast error) in period t, $X_{1t} - {}_{t\text{-}1}EX_{1t}$, depends on lagged value of specified shocks, where expected values are formed at the start of the period. The procedure is equivalent to a series of linear regressions that investigates first (say) the dependence of forecast errors for the money stock on lagged forecast errors for money, prices and output, then the dependence of forecast errors for prices on prior forecast errors for money, prices and output and, finally, the dependence of forecast errors for output on lagged forecast errors for the three variables. By estimating the relation between lagged shocks and current shocks, the VAR take into account some of the information in the quantity equation that is ignored in the univariate estimates.[6] Specifically, let m_t, y_t, and p_t be forecast errors for logs of money, real output and prices, computed as the difference between the (log) measured value for period t and the expected value for t constructed at the start of the period using the Kalman filter. Then the VAR system consists of three equations of the form.

$$m_t = b_0 + b_{1i}m\,(L)_{t-i} + b_{2i}y\,(L)_{t-i} + b_{3i}p\,(L)_{t-i} + u_t$$

where $Z(L)_{t\text{-}i}$ is the vector of lagged values and the b_{ji} are coefficients.

Standard data sources are used for Japan. These are seasonally adjusted quarter-

5. The Kalman filter forecasts differ from true forecasts because they do not make allowance for the lag in compiling and publishing data.
6. The VAR do not completely exploit the restriction in the quantity equation, however. In general, if the errors are m_t, v_t, y_t and p_t, $m_t + v_t$ will differ from $y_t + p_t$. The reason is that there is no way to restrict the sums. Each of the measured errors of forecast consists of a "true" shock and the misperception of the shock (measurement error) by the Kalman filter. If "true" shocks, could be measured, estimates would be consistent with the quantity equation, and measurement error would be zero. The auther is grateful to Kazumi Asako for insisting on this point.

ly data for nominal and real gross domestic product (GDP), the price deflator, the consumer price index and the stock of money as reported by the International Monetary Fund. Monetary velocity is computed as the ratio of nominal GDP to money. M_1 is used throughout. The Bank of Japan projects M_2 + CDs and assigns greater importance to this measure of money. See Suzuki (1984). For the entire period, however, Ishida (1984) using Divisia estimates shows that M_1 has been less influenced by deregulation and other changes, so it is a more homogeneous product for the period as a whole.

U.S. data is from a larger project analyzing the shocks to the U.S. economy under various monetary systems since 1890. See Meltzer (1984). Quarterly data for output and prices from 1890 to 1980 are from Gordon (1982). Monetary data for early periods are from Friedman and Schwartz (1963) with the exception of data for the monetary base (adjusted for changes in required reserve ratios). These data for recent years are from the Federal Reserve Bank of St. Louis and are available as quarterly data from 1947 to middle 1984.[7] All data are seasonally adjusted. The Kalman filter estimates start at the beginning of each data series, so the forecast errors for the U.S. are based on much longer series. Initial conditions, including initial assumptions about the probability distribution of shocks, have little influence on the U.S. and greater influence on forecast errors at the start of the Japanese data. The same is true of the underlying variances of the series. Initial values of the underlying variances are based on the first 10 observations, as explained by Kool (1983). The different lengths of the U.S. and Japanese data series implies a larger influence of the initial estimates of the underlying variance for Japan during the early quarters of the fixed exchange rate period.

Comparison of fixed and fluctuating exchange rate periods requires choice of a date on which the regime changed. There are several candidates. The two most appealing are third quarter 1971, when the United States closed the gold window, and first quarter 1973, when the Smithsonian agreement broke down and the shift to fluctuating rates was recognized as a permanent change. I chose third quarter 1971 as the end of the fixed exchange rate system. Estimated variances and distributions of shocks into permanent and transitory are not very sensitive to the choice. Where interpretation depends on the choice of date, I report estimates also for fluctuating rates beginning second quarter 1973.

The multi-state Kalman filter treats the data as a continuous time series. An alternative procedure would analyze each regime separately. The alternative would remove the influence of a prior regime from the forecasts of the subsequent regime. A shift in regime would be analyzed as a break in forecast patterns, but forecasts

7. Friedman, Schwartz and Gordon use standard sources for the period analyzed here, but the models depend to some degree on earlier data.

would depend considerably more on somewhat arbitrary initial conditions assumed for the underlying variances and the probabilities assigned to particular shocks at the start of the new regime. The procedure used carries these (probability) weights from one regime to the next and revises the weights as new information arrives.

By treating the time series as a single series, a new regime affects the forecast error and its computation initially only by the immediate change in behavior. These initial effects are not negligible during the period studied. For Japan, there are large "outlier" shocks to several variables in third and fourth quarter 1971 and in first quarter 1973. The procedure allows people to acquire information about any change in variance gradually and to revise the weights assigned to particular shocks as they find that forecast errors increase. This procedure has greater intuitive appeal as a model of learning about the consequences of a change in regime than the use of new, arbitrarily chosen, values for the underlying variances and the prior probabilities with each change in regime.

IV. Forecast Errors and Types of Shocks

Popular discussion and some academic work take for granted that the shift from fixed to fluctuating exchange rates was followed by an increase in variability of prices and output. Kindleberger (1969) is a strong statement of this view, but a related view can be found in McKinnon (1984) and Fukao (1984). The basis for some of these claims appears to be the observed variability of exchange rates. Evidence that exchange rate variability or uncertainty about future exchange rates has affected output or prices is harder to find.

This section presents measures of the variance of actual values and forecast errors for Japan and the United States under fixed and fluctuating exchange rates. Under the fluctuating rate regime, many central banks announce targets or projections of future money growth. Cukierman and Meltzer (1984) show that these announcements add to the information used to form rational expectations even if the announcements are not completely credible. Since announcements affect expectations and therefore alter forecasts, I treat the period in which announcements are made as a separate sub-period of the fluctuating rate regime. There are, then, three regimes: fixed exchange rates, and fluctuating exchange rates with and without pre-announced monetary growth.

Column 1 of Table 2 shows the computed variance for the fixed and fluctuating exchange rate regimes. Forecasts are for levels of the variable, and forecast errors are computed from levels, so variances of the levels are shown for comparison. Column 2 gives the variance of forecast errors for the two regimes and for the period of announced projections. Forecasts are obtained using the multi-state Kalman filter, described above. Column 3 is the ratio of the forecast error variance to the actual

Table 2 Actual Variances and Forecast Error Variances (x100)
Japan 1957 – 1983

	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Period		Nominal GDP			Price Deflator			Real GDP	
1	40.350	.051	.13	3.673	.014	.38	19.741	.036	.18
2	12.568	.015	.12	4.517	.007	.15	2.254	.012	.53
3		.003			.004			.002	
		M_1			V_1			CPI	
1	49.627	.037	.07	0.727	.079	10.87	4.656	.010	.21
2	10.191	.046	.45	0.228	.064	28.07	7.769	.014	.18
3		.048			.056			.004	

Column (1) Variance Log Actual Value x 100
(2) Forecast Error Variance x 100
(3) Ratio of (2) to (1) x 100

Period 1 1957/2 – 1971/3
2 1971/4 – 1983/4
3 1978/3 – 1983/4

variance (times 100).

The shift from a fixed to fluctuating exchange rate regime was followed by a relatively large *decline* in the variance of real and nominal output (GDP), the variance of money and velocity. The measured variances of the two price levels rose. The decline is most striking for real output; the variance is approximately one-ninth of its previous value following the shift in monetary regime.

Variances of forecast errors also declined for most variables other than the money stock following the change in regime. One possible reason for the decline is that the change contributed to the stability and predictability of the Japanese economy. Increased stability lowered the variability of the demand for money (or velocity) and possibly the covariance of money and velocity also. Use of monetary announcements was followed by a further reduction in forecast error variance for prices, real output and velocity. The latter finding is consistent with the hypothesis that the announcements contain information useful for forecasting prices, output and the demand for money.

Alternative explanations come to mind readily. One alternative was suggested earlier. The decline in actual and forecast variances may be unrelated to the change in monetary regimes. The period may have been more stable and easier to forecast despite the change in regime. This explanation seems implausible given the two oil shocks, the international debt problem, the prolonged and deep recessions of the mid-seventies and early eighties. A second alternative is that the decline in the growth of output in Japan reduced the measured or actual variance of the level of output. This explanation is less relevant for the variance of nominal GDP and less relevant also to the variance of forecast errors. Forecast values for each period include an estimate of the maintained growth rate that is revised quarterly, as shown in equations (3) and (4).[8]

The variance of forecast errors for the money stock, M_1, did not decline following the introduction of monetary announcements and rose following the shift from fixed to fluctuating exchange rates. This suggests that variability of output and prices can be further reduced by improving monetary control to reduce variability.

The variability of money is a sufficient but not a necessary condition for variability of output or prices. The increase in measured variability of money may reflect transitory changes that the public correctly ignores. Or, the public may treat large shocks as outliers to which they assign low weight when deciding on the level of spending. In effect, the public acts on the belief that the central bank will not consistently deviate from its expected or announced growth path in one direction or another, so they assign low weight to large errors of forecast for money. In Japan, there is some evidence that credibility has been relatively high in recent years. The Bank of Japan announces projected money growth for M_2 + CDs. Deviations of growth of M_2 + CDs from projection, computed quarterly, have a mean absolute error of approximately 1.3% for the period of projections, 1978/3 to 1983/4.[9,10]

8. Errors of forecasting the growth rate declined also in Japan. Using equations (2) and (3), it is seen that the measured or actual growth rate is $\bar{X}_t - \bar{X}_{t-1} = \hat{X}_{t-1} + \gamma_t + \rho_t$, and the forecast error is the sum $\gamma_t + \rho_t$, the transitory and permanent errors in growth rate. Table 3, 4, 6 and 7 present these data for Japan and the U.S.
9. The Bank of Japan announces its target for the four quarters ending in quarter t + 1 at the end of quarter t. At the time of announcement they know complete data for growth in quarters t − 1 and t − 2. The error in their projection is measured here as the actual minus projected growth for quarters t and t +1.

The Kalman filter computes prior and posterior probabilities for the normal and outlier values of the three shocks, ε , γ , and ρ . Table 3 shows the percentage distribution of posterior probabilities by type of shock. The six columns show the normal and outlier values of transitory (ε), permanent level (γ) and permanent growth (ρ) shocks. There is considerable uniformity in the distribution of the shocks across regimes, but there are some differences also. Money and the price deflator show a relatively larger proportion of "outlier" shocks to the growth rate under the fluctuating exchange regime. Transitory shocks to velocity and real output declined following the regime change. Several variables show relatively large "outliers" in the column labeled permanent changes in level under the fluctuating rate regime. Many of these shocks occur at the time of major events. The outlier shocks to money growth are in 1971/3, 1971/4, 1972/4 and 1973/1, the times of the so-called Nixon shock, the revaluation of the yen and the end of the Smithsonian agreement. For the price deflator, there are outlier shocks to the rate of change at the time of the oil embargo, the rise in oil prices and President Carter's introduction of domestic credit controls affecting the purchase of consumer durables many of which are imported from Japan.

The so-called Lucas supply curve, Lucas (1973), is commonly used to study the relation between shocks to prices and output. This model relies on confusion between relative and absolute price levels as a source of disturbance in the economy. The reasoning is that people are unable to distinguish between relative and absolute price changes at the time they occur. If price level changes are mistaken for changes in the relative price of particular goods or services, output expands. Later, people learn and correct their error. Inflation or prices and real values return to their underlying stationary position.

Shocks in models based on Lucas (1973) have mainly transitory changes in output and inflation. Bomhoff (1983) and Brunner, Cukierman and Meltzer (1983) consider permanent as well as transitory shocks. The data in Table 3 are a measure of the relative importance of the various shocks. For real GDP, the percentage of transitory shocks declines from approximately 25% under the fixed rate regime to less than 15% in period 3, the regime of fluctuating rates and monetary announcements. Transitory shocks to the price deflator increase in relative magnitude following the shift to fluctuating rates, but the percentage of shocks to the rate of price change, relevant for the Lucas' type model, declines. This is shown in column 2 of Table 3 (or by the sum of columns 2 and 5). (Recall that permanent shocks to the price level are transitory shocks to the rate of price change.) In all periods, perma-

10. Column 3 of Table 2 is a measure of goodness of fit. One minus the ratio divided by 100 is approximately the R^2 for predicted and actual values. The increase in column (3) for real GDP similar to a decline in the correlation from .998 to .995.

Table 3 Posterior Probabilities by period (in percent)
Japan

	Normal			Outlier		
	Transitory	Level	Growth	Transitory	Level	Growth
Period			Nominal GDP			
1	21.1	47.3	28.7	0.3	1.8	0.7
2	23.3	51.9	17.7	0.1	6.8	0.1
3	15.8	57.0	19.8	a	7.3	a
			Price Deflator			
1	14.9	38.8	42.4	0.3	1.6	2.0
2	3.6	30.3	52.0	0.4	2.9	10.9
3	3.6	21.6	62.3	0.8	0.2	11.4
			Real GDP			
1	25.4	46.8	23.9	0.4	2.4	1.0
2	16.8	48.0	28.5	a	6.0	0.5
3	14.7	48.4	31.0	a	5.1	0.6
			M_1			
1	13.8	22.0	60.6	0.3	1.4	1.9
2	13.5	19.6	58.3	a	1.8	6.7
3	13.6	22.4	55.9	a	2.9	5.1
			V_1			
1	28.8	37.2	29.4	1.1	2.8	0.6
2	14.4	43.4	32.9	0.1	6.3	3.0
3	9.4	46.5	34.5	a	8.0	1.5
			CPI			
1	27.5	17.9	48.6	0.4	2.7	2.9
2	17.5	17.4	59.5	a	5.1	0.4
3	6.5	12.1	78.4	a	2.4	0.6

<u>Periods</u> 1 1957/2 – 1971/3
2 1971/4 – 1983/4
3 1978/3 – 1983/4

a = .05 or less

nent shocks to the rate of price change are most frequent. Permanent shocks to the growth rate appear to be the dominant reason for uncertainty about future values of prices and money.

The percentages in Table 3 can be used to allocate the forecast error variances in Table 2 according to the frequency with which each particular type of shock occurred under each regime. To allocate the variance of the forecast error, I multiplied the probabilities in Table 3 by the variances in column 2 of Table 2. The products shown in Table 4 are estimates of ε , γ and ρ in equations (1) to (3). Normal and outlier shocks are combined. The sum of the three columns in Table 4 is (100 times) the forecast error variance shown in column 2, of Table 2.

Table 4 shows declines in transitory and permanent error variances for prices and output following the changes in monetary regime. If we use forecast error variances as measures of uncertainty, there is no sign that the fluctuating exchange rate regime increased either short-term or long-term uncertainty about the level of prices or output in Japan or their rates of change. On the contrary, more reliable forecasts of short- and long-term levels of output and prices became available following both changes in regime. Transitory variation in the price level and GDP almost vanished. Longer-term uncertainty depends on the value of ρ. The decline in ρ under fluctuating rates — shown by the lower variance of forecast errors assigned to permanent changes in growth — is a measure of the reduced uncertainty about future levels (and rates of change) of prices and output. Since lower uncertainty increases the welfare of risk averse consumers, these data suggest that welfare increased in Japan following the change in regime.

The monetary data show less change. One possibility, considered below, is that the variability of money reflects unforeseen changes undertaken by the central bank to offset changes in velocity. A successful policy of offsetting shocks to the demand for money, or monetary velocity, is consistent with the decline in the variability of forecast error variance for nominal GDP and the reduced size of transitory fluctuations in velocity. An alternative explanation is that forecast variances for real output and prices are unaffected by the increased monetary uncertainty because output markets ignore part of the variability in monetary and financial variables.

Short-term variability of velocity forecasts declined following the deregulation of financial markets. Short-term shifts in the demand for money appear to be smaller. More stable expectations of prices or inflation have not reduced the variability of forecasts of the permanent component of velocity, however.[11]

The shift from fixed to fluctuating exchange rates and the use of monetary

11. The use of univariate procedures creates a problem here. Velocity is measured as the ratio of nominal output to money. No restrictions are imposed to keep the variance of velocity equal to the sum of the variances of M and GDP minus twice their covariance.

Table 4 Allocation of Error Variance by Period (x 10,000)
Japan

	Transitory	Level	Growth
Period		Nominal GDP	
1	1.10	2.50	1.49
2	0.34	0.87	0.26
3	0.05	0.20	0.06
		Price Deflator	
1	0.20	0.54	0.60
2	0.02	0.22	0.42
3	0.01	0.08	0.27
		Real GDP	
1	0.92	1.75	0.89
2	0.21	0.68	0.37
3	0.03	0.12	0.07
		M_1	
1	0.52	0.87	2.33
2	0.62	0.99	3.02
3	0.66	1.23	2.96
		V_1	
1	2.36	3.15	2.35
2	0.93	3.17	2.29
3	0.52	3.07	2.02
		CPI	
1	0.26	0.19	0.49
2	0.25	0.32	0.86
3	0.02	0.05	0.28

Periods
1 1957/2 – 1971/3
2 1971/4 – 1983/4
3 1978/3 – 1983/4

announcements has much less effect on forecast errors in the United States. Measured variability of money and output declined following the change in monetary regime, but errors of forecast remain about the same. The use of announcements has much less effect on forecasts of U.S. nominal output than in Japan. As a result of the greater decline in forecast error variance, Japan now has a lower variance of forecast errors for output than the U.S. For prices and money, forecast error variance remains lower in the United States, but the difference for prices is much smaller. Table 5 shows the U.S. data. Note that the time periods are not identical.[12]

Once again, we find that the actual variance of real and nominal output and the variance of money and base velocity was lower during the fluctuating rate regime. The variance of the deflator was higher in the U.S., as in Japan, in part a reflection of the oil shocks of the seventies. Variances of forecast errors remained about the same. It is difficult to find support here for the belief that fluctuating exchange rates hamper trade by increasing variability or uncertainty.

The posterior probabilities are expressed as percentages in Table 6. The table shows the proportion of the shocks in each regime classified as normal and outlier values of ϵ, γ and ρ. There are noticeable differences between the fixed and fluctuating exchange rate periods. Unlike the comparable data for Japan, shown in Table 3, the relative size of "outliers" declined for most variables. Velocities of the base and M_1 and the level of the monetary base are the exceptions. After the Federal Reserve began announcing monetary targets, there was a further increase in outlier shocks to the monetary base and base velocity. Some of these outliers occur when credit controls were introduced in the spring of 1980. Some reflect other periods of sudden change in U.S. monetary policy. The policy shifts appear to increase uncertainty about the longer-term values of money and velocity. Although the shifts eventually lowered expected inflation, increased uncertainty about monetary policy has the effect of raising the real cost of the change.

Studies by Nelson and Plosser (1982) and by Stulz and Wasserfallen (1985), using time series analysis, find that the use of stochastic trends in place of deterministic trends reduces the size of cyclical fluctuations. The fluctuations commonly called business cycles appear to be dominated by changes in stochastic trend. Cyclical components — transitory changes in the growth rate — appear to be relatively small.

The multi-state Kalman filter does not fully support these findings for the United

12. Computations for 1957-1971, using quarterly data were used to check whether results are sensitive to the choice of period. No major differences were found for the variances or the posterior probabilities for the U.S. Great weight should not be placed on these comparisons. First, the differences are typically not significantly different from zero. Second, as previously noted, the variances of M, V and GDP are measured independently, so the sums of the variances may not add to twice the covariance. Using the estimates in Tables 2 and 8 suggests, however, that the latter difference is typically not large.

Table 5 Actual and Forecast Variances (x 100)
U.S.

	(1)	(2)	(3)	(1)	(2)	(3)
Period		Nominal GNP			M_1	
1	12.3	.013	.0010	3.0	.005	.0017
2	7.2	.013	.0018	2.8	.009	.0032
2A		.014				
		Deflator			M_2	
1	2.0	.002	.0010	9.8	.003	.0003
2	3.5	.002	.0006	4.3	.004	.0009
		Real GNP			V_1	
1	4.4	.011	.0025		.014	
2	0.7	.014	.0200		.011	
		Monetary Base			Base Velocity	
1	4.1	.002	.0005	2.5	.014	0.056
2	4.5	.002	.0004	0.3	.016	0.533
2A	8.0	.003	.0000	0.6	.020	0.333
2B		.004			.024	

<u>Period</u>
1 1951/2 – 1971/3
2 1971/4 – 1980/4
2A 1971/4 – 1984/2
2B 1976/1 – 1984/2

<u>Column</u>
(1) Actual Variance Log Level x 100
(2) Variance Forecast Error x 100
(3) Ratio Forecast to Actual Variance x 100

Table 6 Posterior Probabilities by Period (in percent) U.S.

	Normal			Outlier		
	Transitory	Level	Growth	Transitory	Level	Growth
Period			Nominal GNP			
1	0.2	8.9	81.9	0.1	1.1	7.8
2A	1.9	57.1	35.2	a	4.6	1.2
			Deflator			
1	1.0	57.6	38.0	a	1.8	1.7
2	0.2	60.9	35.7	a	2.2	1.1
			Real GNP			
1	1.1	23.8	66.4	a	5.0	3.5
2	3.7	33.3	57.8	a	3.5	1.6
			M_1			
1	0.8	23.0	66.7	a	0.9	8.6
2	a	14.0	79.9	a	0.2	5.8
			V_1			
1	0.7	14.3	72.7	0.2	0.4	11.7
2	0.2	16.9	69.5	a	1.5	12.0
			Monetary Base			
1	6.7	18.6	66.6	0.2	1.6	6.3
2A	36.3	13.0	41.4	0.1	4.8	4.3
2B	36.2	12.4	39.4	0.1	6.7	5.2
			Base Velocity			
1	7.0	47.3	37.8	0.1	6.9	0.9
2A	0.9	37.1	53.0	a	7.7	1.2
2B	1.1	40.7	45.8	a	10.5	1.8

Period 1 1951/2 – 1971/3 2A 1971/4 – 1984/2
2 1971/4 – 1980/4 2B 1976/1 – 1984/2

a = .05 or less

States and Japan. Shocks to real growth, ρ, are changes in the stochastic trend, and permanent shocks to the level of output, γ, include the transitory shocks to the growth rate of output usually called business cycles. For the U.S., Table 7 shows that about one-third of all shocks to real output are normal and outlier shocks to the permanent level of output (γ) in both regimes. For Japan, Table 4 shows that more than half of the shocks to real output are normal and outlier changes in the permanent level of output. For prices, the Japanese and U.S. data differ in the opposite direction. More of the shocks in the U.S. are to the price level; more of the shocks in Japan are to the rate of price change. For money, data for both countries show that the variance of the stochastic growth rate dominates cyclical fluctuations.

Table 7 gives the details of the allocation of the shocks by type of shock for the U.S. data for the base show that the increased variance of forecast errors, shown in Table 5, is mainly an increase in the transitory component of the log level of the base, ε, but there are no offsetting declines in other components. The variance of transitory shocks to the level of the base increased much more than the variance of γ, and ρ, following the change in regimes.

The large increase in the transitory variance of the monetary base shown in Table 7 may indicate the use of monetary policy to offset fluctuations in base velocity or the demand for money. Table 8 finds little support for this interpretation. The simple correlation between contemporaneous shocks to money and velocity is typically close to zero for the U.S. and slightly higher and positive in Japan under fluctuating exchange rates. A positive value suggests that the covariance is positive. Positive covariance implies that monetary control procedures augment shocks to output or prices by increasing variability of aggregate demand.[13]

Earlier, we considered two explanations of the finding that the variance of forecast errors for nominal GDP declined without a corresponding decline in the variance of forecast errors for measures of money and velocity. One explanation is rejected if we accept as meaningful the positive or low negative covariance between errors to money and velocity. The alternative explanation is that the economy damps shocks and variability coming from the monetary system.[14] The real sector, on this explanation, works to stabilize the economy in the face of relatively large shocks and uncertainty coming from the monetary sector. This finding, if correct, does not imply that monetary variability is costless. Consumption, investment and asset allocation

13. A positive value is also found the contemporaneous correlation of shocks to the base and base velocity. The negative covariance of shocks to M_2 and V_2 suggests that monetary changes contributed to some reduction in the variance of nominal output shocks under fixed exchange rates.

14. The statement in the text should not suggest causality. The shocks coming from the monetary system may start as productivity shocks and feedback to output after affecting money. Some of these interactions are studied below.

Table 7 Allocation of Error Variance by Period (x 10,000)
U.S.

	Transitory	Level	Growth
Period		Nominal GNP	
1	a	0.13	1.19
2A	0.03	0.87	0.51
		Deflator	
1	a	0.14	0.09
2	a	0.13	0.08
		Real GNP	
1	0.01	0.32	0.78
2	0.05	0.51	0.82
		M_1	
1	a	0.12	0.37
2	a	0.12	0.74
		V_1	
1	0.11	0.42	0.92
2	0.63	0.15	0.28
		Monetary Base	
1	0.01	0.03	0.13
2A	0.11	0.05	0.13
2B	0.13	0.07	0.17
		Base Velocity	
1	0.10	0.78	0.55
2A	0.02	0.89	1.07
2B	0.03	1.24	1.15

Period				
	1	1957/1 – 1971/3	2A	1971/4 – 1984/2
	2	1971/4 – 1980/4	2B	1976/1 – 1984/2

a = .005 or less

Table 8 Correlation of Shocks

U.S.	1951/2 – 1971/3	1957/2 – 1971/3	1971/4 – 1980/4	1976/1 – 1984/2
M_1 and V_1	–.02	–.01	–.09	–.10
p and y	+.08	+.08	–.08	
M_2 and V_2	–.20	–.20	+.01	
Base and VB	+.01		+.12**	–.09
Japan		1957/2 – 1971/3	1971/4 – 1983/4	1978/3 – 1983/4
M_1 and V_1		.02	.15	.16
p and y		.04	–.37	.10
Japan and U.S.*		1957/2 – 1971/3	1971/4 – 1980/4	
real output		0	.52	
M_1		.37	0	
V_1		.03	0	
nominal output		0	.05	
deflator		0	0	

* current and two lag values of U.S. variable, correlation is square root of R^2 adjusted for degrees of freedom.

** –.07 for 1971/4 to 1984/2

Symbols p = price deflator, y = real output, M = money stock, V = monetary velocity decisions are subject to increased uncertainty and there may be costs associated with the arrangements that buffer monetary shocks.

If both expectations and actual values adjust slowly to changes in money, monetary shocks are not fully reflected as shocks to current prices and nominal output. Output and expected output (or prices) may adjust slowly to the changes in money reflected in the monetary shocks. Slow adjustment of price expectations is consistent with most studies of prices, but partial or slow adjustment of output is not. Nevertheless, the data here suggests that some of the monetary variability may be ignored. On this interpretation, some of the shocks to money or velocity would be (uncorrelated) random errors of forecast in our data. Below, we investigate this hypothesis more thoroughly.

Shocks to the price level and real output, p and y in Table 8, have low contemporaneous correlation. A strong, positive correlation would suggest the presence of a Lucas-type Phillips curve between the levels of prices and output. The strongest relation is negative, for Japan, under fluctuating exchange rates. A negative relation is also found for the U.S. during this period. A plausible explanation is that the correlation reflects the influence of the two oil shocks in the 1970s. Below, we investigate this relation in greater detail.

Table 8 also takes a first glance at the relation between shocks in the two countries. Shocks to Japanese magnitudes are assumed to depend on current and lagged values of shocks to the same variable for the U.S. as noted at the bottom of the table. The data shown are obtained from values of R^2, adjusted for degrees of freedom. When the adjusted R^2 is negative, the correlation is set to zero. The data tell nothing about the sign of the relation.

For most variables, there is no evidence of any relation between U.S. and Japanese shocks. The exceptions are the money stock under the fixed rate regime and real output under fluctuating rates. The latter may reflect, at least in part, the oil shocks common to all countries.

One relation, notable for its absence, is a relation between velocities in Japan and the United States under fluctuating exchange rates. McKinnon (1984) claims that currency substitution increases instability under fluctuating exchange rates. Currency substitution implies a relation between the demands for currencies, yen and dollars, in this case. Table 8 shows no effect of shocks to the demand for dollars, or U.S. monetary velocity, on yen velocity or conversely.

Evidence from simple correlations, or from correlations between a small number of current and lagged values is at best suggestive. The finding of very few shocks to Japan from current or past shocks to the same U.S. variables neglects more complex interactions. The following section attempts a more complete analysis.

V. Interaction Between Shocks

The variables considered in this paper are part of an interactive system in which unanticipated changes or shocks to one variable affect anticipations for the particular variable and others. Shocks to one variable may also induce shocks to another variable or to the same variable at a later date. Interaction between shocks can occur even in a fully rational world for several reasons. Two are most important here, but a third possible source of relations should be noted. First, there are costs of learning about changes in money, output, prices and other variables. Costs of learning affect the speed of adjustment of assets and output and may make price setting a rational alternative to price taking as suggested in Meltzer (1982). Second, people cannot identify shocks as permanent or transitory or as shocks to levels or rates of change at the time they occur. Shocks may be misperceived initially. While people learn, additional unanticipated changes can perturb the system as part of the adjustment to revised information. (Brunner, Cukierman and Meltzer (1983).) Third, the estimates from the univariate multi-state Kalman filters are not constrained by the quantity equation, as noted earlier. Inconsistencies from this source may distort the relations presented here.

The size of the shocks or unanticipated changes for Japan and the United States, reported in Tables 2 and 5, include both endogenous responses to current and past values of shocks to other variables and autonomous changes. Economic theory has built on these interrelations from its earliest days. The price-specie flow theory is one example of a theory that can be interpreted as a relation between current unanticipated changes in money, prices and output and prior unanticipated changes in money, prices and output. A main point of this theory is that monetary (gold) changes are induced by changes in the balance of trade or by capital flows arising from changes in opportunities or changes in anticipations about future values. The theory can be viewed as a dynamic theory relating past unanticipated changes to current anticipations and unanticipated changes. The price-specie flow theory is, of course, only one hypothesis, among many, relating current and past unanticipated changes of the variables analyzed here.

This section uses vector autoregressions (VAR) to study the relation between unanticipated changes in money, velocity, output and prices in Japan and the U.S. The study is restricted to the relation between the shocks — the degree to which a shock to one variable for one country is, at least in part, the result of unforeseen *prior* changes in the level of that variable or in the levels of other variables at home or abroad. Shocks to one variable also affect anticipations, and changes in anticipation have consequences for current and future forecasts. These influences on anticipations are ignored except as they affect errors of forecast. To the extent that anticipations are estimated correctly, forecast values correctly measure any permanent influence of lagged shocks. There are then no relations between shocks, and the procedures used here would find none. A finding of no relation between shocks does not imply that there is no effect of variability. The effect would be in the revised anticipated values but would be neglected here.

The aim of this section is to study the relation between shocks or impulses as a step toward a better understanding of the comparative effects of alternative monetary regimes (or institutional arrangements) on variability and uncertainty. Several hypotheses are tested. Four are of particular interest. First, economists have long maintained that the transmission of shocks depends on the type of monetary regime. A shift from fixed to floating exchange rates is likely to be followed by a change in the stochastic process governing the money stock and the price level. If unanticipated changes in money and prices affect output, the stochastic process governing output may change also.[15] Countries are better able to control money under fluctuating rates if they choose to exercise control, but one of the costs of increased monetary control is increased variability of the exchange rate. Second, the fluctuating rate regime reduces variability coming from abroad, particularly variability transmitted through the monetary system. The previous section shows that variability has declined in Japan. This section considers the hypothesis that the decline is a consequence of improved monetary control. Third, McKinnon (1984) argues that currency substitution between countries is a leading cause of exchange rate fluctuations. We test for a relation between velocity shocks for Japan and the U.S., for the effect of exchange rate changes on velocity, and the effect of monetary and velocity shocks on exchange rates changes. Fourth, by removing most of the influence of past foreign and domestic shocks in several different ways, we investigate the extent to which shocks to money and output appear to reach an irreducible minimum for particular periods under the policy and other institutional arrangements of that period.

All of the tables below report on results for specific lag lengths. Usually, estimates were made for 4, 6 and 8 lags and occasionally for 12 lags. Since one purpose of the investigation is to find how much variance can be reduced under particular regimes, the standard error of estimate was used as a main criterion for choice of lag length to be reported. We are interested, also, in the relation between shocks. The F-statistics and significance levels were used as a second criterion. This criterion is much less robust. A particular set of lagged shocks may pass the usual test for significance at (say) lag 4 but not at lag 6 or lag 8. For example, lagged monetary shocks may have a relatively strong effect on output shocks at lags 1 to 4, while by lag 8 the effect is attributed to shocks to foreign GNP or foreign money. One further

15. Sims (1980) pioneered in the use of VAR systems in economics and recommended the use of VAR methods for identifications. Although he divides his sample and tests for the differences between samples, he ignores the effect of regime change and most of the effect of foreign shocks on domestic variables.

caveat should be mentioned. Coefficients have different signs in some regressions at different lags. The sum of the coefficients shown in the tables may be low either because effects are small or because coefficients of opposite sign have been summed.

Table 9 shows the interrelation of domestic shocks in Japan under fixed and fluctuating exchange rates. The largest difference between the two periods is in the equation for price shocks. Following the shift to fluctuating exchange rates, past shocks to money and output have larger and more reliable effects on price shocks; past price shocks have smaller and slightly less reliable effects. There is a much weaker response of money to output shocks under fluctuating rates, and the reciprocal shock from lagged money shocks to output is smaller in magnitude. Under the fluctuating exchange regime, shocks to money appear to be independent of domestic shocks or, at least, shocks to the variables specified here. Further, shocks to real output appear to be unrelated to any of the lagged shocks under fixed exchange rates, and price shocks and output shocks have no significant interaction. Following the regime change, these shocks are more closely related through dynamic interaction. The results are qualitatively unchanged if we date the start of fluctuating exchange rates at second quarter 1973.[16]

The price shock equation under fluctuating rates has the significant positive effect of past output shocks on price shocks implied by the Phillips curve. The output equation shows a negative relation between the same variables when price shocks are the lagged variable. The coefficients have approximately the same magnitude in the two equations under fluctuating exchange rates. For 1973-84, the absolute values of both coefficients increase, but they remain approximately equal in absolute value. This suggests continuing dynamic interaction that damps gradually rather than the one-way relation specified by Phillips curves.

To investigate the effects of longer lags and, later, the interaction between U.S. and Japanese shocks, we consider a system consisting of nominal output and money. Table 10 shows the relations between shocks to nominal output and money in the U.S. and Japan under different monetary regimes at 8 and 12 lags.

At the longer lag, there is a relatively strong influence of past money shocks on nominal GDP shocks under fixed exchange rates for the U.S. and Japan and under fluctuating exchange rates for Japan. There is no evidence of any influence of lagged shocks to GDP and money on money shocks in Japan; the relation is principally one way. This finding is surprising given the controls on interest rates and the determination of the government and the Bank of Japan to keep nominal lending rates low. See Suzuki (1980). Policies of this kind typically lead the central bank to expand and contract money when there are positive and negative shocks to aggregate demand

16. Revisions of Tables 9 and 10 with fluctuating rates starting in second quarter 1973 are available from the author on request.

Table 9 Interrelation of Domestic Shocks VAR for Japan

Dependent Variable	Variable	Sum of Lag Coefficients	F-Statistic	Significance Level	$\bar{R}^2$	SEE	DW
		Fixed Exchange Regime, 4 lags 1958/2 – 1971/3					
yJ	M1J	1.00	1.70	0.17	0	1.94	2.07
	yJ	–0.34	1.02	0.40			
	pJ	–0.54	0.34	0.85			
pJ	M1J	0.26	0.64	0.63	0.18	0.96	2.22
	yJ	0.45	1.65	0.18			
	pJ	–1.27*	3.55	0.01			
M1J	M1J	–0.55	0.89	0.48	0.19	1.75	1.93
	yJ	–0.72*	2.50	0.05			
	pJ	–0.41	1.22	0.32			
		Fluctuating Exchange Regime, 4 lags 1971/4 – 1983/4					
yJ	M1J	–0.01	1.30	0.28	0.17	1.00	2.14
	yJ	–0.23	0.27	0.89			
	pJ	–0.72*	2.87	0.04			
pJ	M1J	0.17*	3.26	0.02	0.47	0.59	1.71
	yJ	0.69*	6.12	a			
	pJ	0.36**	2.27	0.08			
M1J	M1J	–0.80	1.35	0.27	0	2.24	2.03
	yJ	–0.12	0.58	0.68			
	pJ	–0.48	0.24	0.91			

All variables are shocks (unanticipated changes).

Symbols: yJ = real GDP, pJ = price deflator, M1J = money stock

* significance level .05 or less

** significance level .05 to .15

a = .005 or less

Table 10 Interrelation of Domestic Shocks VAR for Japan and U.S.

Dependent Variable	Variable	Sum of Lag Coefficients	F-Statistic	Significance Level	$\bar{R}^2$	SEE	DW
		Japan: Fixed Exchange Regime, 12 lags 1960/2 – 1971/3					
GDPJ	M1J	1.34*	2.21	0.05	0.39	1.61	1.30
	GDPJ	–0.57**	1.92	0.09			
M1J	M1J	–0.30	1.04	0.45	0.16	1.71	2.23
	GDPJ	–1.01	1.30	0.29			
		Japan: Fluctuating Exchange Regime, 12 lags 1971/4 – 1983/4					
GDPJ	M1J	1.69*	2.85	0.01	0.45	0.90	2.18
	GDPJ	–0.10*	2.77	0.02			
M1J	M1J	–4.06	1.20	0.34	0.02	2.14	1.88
	GDPJ	–1.04	0.59	0.83			
		US.: Fixed Exchange Regime, 8 lags 1951/2 – 1971/3					
GNPUS	M1US	1.50**	1.57	0.15	0.22	1.02	2.05
	GNPUS	2.12*	3.35	a			
M1US	M1US	1.90*	2.30	0.03	0.26	0.60	2.01
	GNPUS	0.12*	2.97	0.01			
		U.S.: Fluctuating Exchange Regime, 8 lags 1971/4 – 1980/4					
GNPUS	M1US	5.85	0.74	0.66	0	1.18	2.19
	GNPUS	–2.02	0.64	0.73			
M1US	M1US	–0.64	0.93	0.51	0.32	0.77	2.08
	GNPUS	–0.69	1.13	0.38			

All variables are shocks to nominal values. GDPJ is the shock to nominal GDP for Japan; GNPUS is the shock to nominal GNP for U.S., and M1US is the shock to nominal money for the U.S.

Other symbols and notation are defined in Table 9.

respectively. There is no evidence here that this happened in Japan. The effect of real output shocks on monetary shocks is negative in Table 9, and there is no evidence of a positive influence of nominal GDP shocks on money in Table 10.

In contrast, the U.S. under fixed exchange rates appears to have permitted GNP shocks and past shocks to money to persist with effects on nominal GNP and money in subsequent periods. This is consistent with the very hesitant adjustment of short-term market rates by the Federal Reserve. Under the fluctuating exchange rate regime, the pattern of response appears to have changed. Past shocks to money and GNP appear to have no reliable information. These data suggest that, following the shift to fluctuating exchange rates, the unanticipated changes in money and GNP estimated by the Kalman filter, contain no information about future shocks. This finding is, of course, contrary to the conclusions reached by Barro (1978) using a different method of estimating unanticipated changes.[17]

The data in Table 10 suggest that the decline in the variability of output in Japan is, at least in part, a consequence of the change in monetary regime. The influence of past monetary shocks on GDP shocks has declined and, with it, the variability of GDP has declined, reducing uncertainty and increasing welfare. The variability of Japan's nominal GDP fell from 2.25, the square root of the forecast error variance for the fixed exchange rate period shown in Table 2 (in the same units), to 1.22 under fluctuating rates. Removing the effect of prior monetary shocks reduces variability to 1.61 under fixed rates and 0.90 under fluctuating rates. If we use these measures as estimates of the effect of changes in regime and in techniques of monetary management, it appears that the shift to fluctuating rates was followed by a reduction of nearly 50% in the standard error of forecast. A further reduction in variability of 25% (from 1.22 to 0.9) was achieved by improved domestic monetary control.

VAR's for Japan and the U.S. as a system, in Table 11, modify some of these findings and reinforce others. Under the fixed exchange regime, shocks to money have no reliable effects on GNP shocks in the U.S. as they did in Table 10. However Table 11 shows a stronger and more reliable relation between past shocks to money (the monetary base) and shocks to GNP under fluctuating exchange rates.

The VAR for Japan show considerable influence of past U.S. shocks on the shocks to Japan's money stock and GDP under fixed exchange rates. In contrast to Table 10, shocks to the Japanese money stock under fixed exchange rates are no longer purely random movements; they are strongly affected by shocks to the U.S. money stock. Nominal GNP shocks in the U.S. are mainly the result of an autoregressive process. The shocks to nominal U.S. GNP affect the U.S. money stock, the

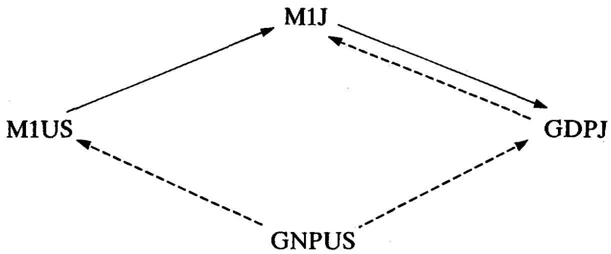
17. The difference may also result from differences in the choice of lags or from differences between nominal GNP shocks and Barro's use of real output to measure unanticipated changes in output.

Table 11 Interrelation of Domestic and Foreign Shocks VAR for Japan and U.S. as a System

Dependent Variable	Variable	Sum of Lag Coefficients	F-Statistic	Significance Level	$\bar{R}^2$	SEE	DW
		Fixed Exchange Regime, 8 lags 1959/2 – 1971/3					
GDPJ	M1J	0.73*	2.67	0.04	0.30	1.83	2.00
	GDPJ	0.01**	2.04	0.10			
	M1US	1.49	0.85	0.57			
	GNPUS	–0.03**	1.86	0.13			
M1J	M1J	0.84	1.66	0.18	0.59	1.15	1.78
	GDPJ	–0.22**	2.41	0.06			
	M1US	1.90*	3.46	0.01			
	GNPUS	0.88**	2.01	0.10			
GNPUS	M1J	0.58	0.60	0.77	0.34	0.84	2.04
	GDPJ	–0.19	1.00	0.46			
	M1US	3.84	1.71	0.17			
	GNPUS	–3.35**	2.07	0.10			
M1US	M1J	–0.22	1.06	0.43	0.54	0.56	2.12
	GDPJ	–0.32	1.53	0.22			
	M1US	–1.08	0.72	0.67			
	GNPUS	–1.68**	2.40	0.06			
		Fluctuating Exchange Regime, 6 lags 1971/3 – 1983/4					
GDPJ	M1J	0.21*	2.46	0.05	0.38	0.95	1.81
	GDPJ	0.40	1.62	0.18			
	BUS	0.10	1.55	0.20			
	GNPUS	0.58*	2.44	0.05			
M1J	M1J	0.12	0.62	0.72	0.22	1.90	1.80
	GDPJ	–0.44**	1.84	0.13			
	BUS	–2.58*	2.52	0.05			
	GNPUS	1.69	1.64	0.18			
GNPUS	M1J	–0.59	0.85	0.54	0.18	1.08	2.08
	GDPJ	–0.55	0.86	0.54			
	BUS	4.08*	3.98	0.01			
	GNPUS	–0.70	1.29	0.30			
BUS	M1J	a	0.70	0.65	0	0.62	1.94
	GDPJ	0.25	0.45	0.84			
	BUS	0.33	0.90	0.51			
	GNPUS	–0.57	0.36	0.90			

BUS is the U.S. monetary base.
Other symbols are defined in Tables 9 and 10.

Japanese money stock and the Japanese GDP directly and through the monetary system. The most reliable affects run from shocks to the U.S. money stock to shocks to Japan's money stock and then to Japan's GDP. The effects of past money shocks on U.S. GNP, visible in Table 10, are too unreliable to be accepted as significant. Interaction between nominal shocks in the two countries under fixed exchange rates, is summarized by the following schema. Lagged effects of a variable on itself are omitted. A solid line denotes a single asterisk in Table 11, and a broken line shows the weaker interactions shown by a double asterisk.



Some observers suggest that, under fluctuating exchange rates, the Bank of Japan intervenes to affect the exchange rate. See Fukao (1984). Table 11 shows a negative effect of shocks to the U.S. base on M1J. The response loses statistical significance, however, if we date the start of fluctuating exchange rates in second quarter 1973. For the shorter period, shocks to the Japanese money stock fluctuate randomly and have a relatively large quarterly forecast error. Estimates for the period 1973 to 1984 are given in Table 12. This table also shows estimates for the same period that include the change in the exchange rate, denoted DEXJ, as an additional variable.

Under the fluctuating exchange regime, shocks to the monetary base, and for the period beginning in second quarter 1973, shocks to money in Japan appear to be independent of other shocks in the system. These measures of money fluctuate randomly in response to shifting policies. Shocks to the base are followed by shocks to U.S. GNP, and shocks to the money stock in Japan are followed by shocks to Japanese GDP. Using a solid line to denote a single asterisk in Table 12 and a broken line to denote the weaker interactions represented by a double asterisk, we have the following schema.

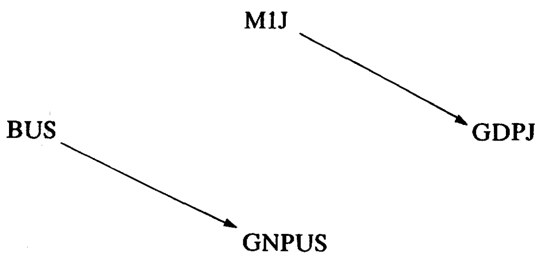


Table 12 Interrelation of Domestic and Foreign Shocks VAR for Japan and the U.S. as a System

Dependent Variable	Variable	Sum of Lag Coefficients	F-Statistic	Significance Level	$\bar{R}^2$	SEE	DW
	Fluctuating Exchange Regime, 6 lags, 1973/2 – 1983/4						
GDPJ	M1J	0.17**	2.51	0.07	0.26	0.93	2.02
	GDPJ	0.40	1.25	0.34			
	BUS	–1.21	0.69	0.66			
	GNPUS	1.45	1.64	0.21			
M1J	M1J	0.19	0.15	0.99	0.03	1.87	1.97
	GDPJ	–0.33	0.73	0.64			
	BUS	–0.24	1.55	0.23			
	GNPUS	0.85	1.40	0.28			
GNPUS	M1J	–0.71	0.85	0.55	0.26	1.07	2.03
	GDPJ	–0.80	1.18	0.37			
	BUS	3.99*	3.99	0.02			
	GNPUS	–1.15	1.74	0.18			
BUS	M1J	0.01	0.69	0.66	0	0.69	1.86
	GDPJ	–0.05	0.67	0.68			
	BUS	1.18	1.12	0.40			
	GNPUS	–1.15	0.92	0.51			
	Including Changes in Exchange Rate, 4 lags, 1973/2 – 1983/4						
GDPJ	M1J	–0.08*	3.06	0.04	0	1.09	1.98
	GDPJ	0.12	1.07	0.40			
	BUS	–0.21	0.46	0.76			
	GNPUS	0.29	0.76	0.56			
	DEXJ	0.08	0.46	0.77			
M1J	M1J	–0.14	1.54	0.23	0	1.92	2.06
	GDPJ	–0.63	0.63	0.64			
	BUS	1.77	1.01	0.43			
	GNPUS	0.26	0.90	0.48			
	DEXJ	0.01	1.16	0.36			
GNPUS	M1J	–0.31	1.12	0.38	0.29	1.05	2.21
	GDPJ	–0.52	0.67	0.62			
	BUS	0.60*	3.76	0.02			
	GNPUS	–0.56	0.96	0.45			
	DEXJ	0.05	1.25	0.32			
BUS	M1J	0.11	0.27	0.89	0	0.68	1.84
	GDPJ	a	0.36	0.83			
	BUS	–0.57	0.60	0.66			
	GNPUS	0.05	0.33	0.85			
	DEXJ	0.01	0.45	0.77			
DEXJ	M1J	–0.73	0.21	0.93	0.13	10.97	2.18
	GDPJ	–1.28	0.19	0.94			
	BUS	4.63	1.49	0.25			
	GNPUS	–3.13	1.49	0.25			
	DEXJ	0.46	1.61	0.21			

DEXJ is first difference of yen per dollar. Other symbols are defined on Tables 9, 10 and 11.

The regressions reported in Table 12 are consistent with a monetary theory of business fluctuations in which unanticipated changes in money (or the monetary base) are followed by unanticipated changes in nominal GNP under fluctuating exchange rates. They are inconsistent with a theory in which real shocks to GNP are interrelated and independent of prior monetary shocks or in which monetary shocks are mainly the result of prior shocks to nominal (or real) output. These findings are, at best suggestive, since they are based on findings for two countries during one relatively brief period.

Table 12 introduces the change in the yen-dollar exchange rate as an impulse. If the exchange rate is approximately a random walk, the change in the exchange rate is approximately white noise, comparable to the forecast errors of the other variables. The regressions reported in Table 12 test whether the change in the exchange rate is affected by past shocks to money and output and whether unanticipated movements of the exchange rate produce shocks to money and output.

Past shocks to money and output appear to have little effect on changes in the exchange rate, and there is little evidence of a systematic effect of past changes in the exchange rate on any of the nominal values in the table. The standard error of DEXJ shows that the variability of the exchange rate is relatively large, but I find no evidence of a systematic effect of the variability on other variables.

McKinnon (1984) emphasizes the effect of currency substitution on exchange rates and economic fluctuations. To study these effects, I used a bivariate system consisting of velocity shocks for U.S. and Japan under fixed and fluctuating exchange rates. The only persistent relations found are between lagged and current values of velocity within a country. There is no significant interaction between VJ and VB or VM at 4, 6, 8, 10 or 12 lags. An objection to this procedure is that central banks may smooth some of the shocks, so the partial effects may be obscured. Table 13 considers the interaction between shocks to money and velocity in Japan and U.S. under fixed and fluctuating exchange rates. For the fluctuating exchange rate regime, the change in the exchange rate, DEXJ, is included.

There is no evidence of a relation between VJ and VB under either fixed or fluctuating exchange rates. Unanticipated shifts in relative demands for currency have neither large nor reliable effects on velocity. There is, however, an effect of shocks to the demand for yen (relative to GDP) on changes in the yen-dollar exchange rate. The 4 lag coefficients are all negative, and the coefficient is largest at lag 2. The negative sign implies that, after 5 quarters, a 1% shock to VJ that raises the demand for yen relative to GDP (reducing velocity) depreciates the yen-dollar exchange rate by approximately 3% of its mean value.[18] This effect is perverse and may

18. The mean value for the period is approximately 260 with standard deviation of quarterly changes approximately 40.

Table 13 Interrelation of Money and Velocity Shocks under Fixed and Fluctuating Exchange Rates VAR for U.S. and Japan as a System

Dependent Variable	Variable	Sum of Lag Coefficients	F-Statistic	Significance Level	$\bar{R}^2$	SEE	DW
		Fixed Exchange Regime, 4 lags 1958/2 – 1971/3					
VJ	VJ	0.01	1.05	0.40	0.12	2.60	2.06
	M1J	0.83*	2.76	0.04			
	VB	0.63	0.74	0.57			
	BUS	–2.64**	1.82	0.15			
M1J	VJ	–0.59	1.66	0.18	0.10	1.84	1.93
	M1J	–1.09**	2.01	0.11			
	VB	–0.14	0.62	0.65			
	BUS	0.91	0.69	0.60			
VB	VJ	–0.17	1.68	0.18	0.28	0.98	1.84
	M1J	–0.26	1.37	0.26			
	VB	–1.20*	2.77	0.04			
	BUS	1.17	1.16	0.34			
BUS	VJ	–0.04*	4.58	a	0.17	0.39	1.81
	M1J	a**	1.83	0.14			
	VB	0.15	0.79	0.54			
	BUS	0.09*	2.67	0.05			
		Fluctuating Exchange Regime, 4 lags 1971/3 – 1983/4					
VJ	VJ	–0.02	1.56	0.22	0.13	2.28	1.74
	M1J	0.14*	2.74	0.05			
	VB	–0.39	1.61	0.20			
	BUS	0.48**	2.09	0.11			
	DEXJ	0.01	0.51	0.73			
M1J	VJ	–0.39**	2.21	0.10	0.26	1.86	1.93
	M1J	–0.97*	3.06	0.04			
	VB	0.86**	2.39	0.08			
	BUS	0.16*	4.48	0.01			
	DEXJ	–0.02	0.94	0.46			
VB	VJ	–0.57	1.12	0.37	0.03	1.43	2.17
	M1J	–0.75	0.64	0.64			
	VB	–0.64	0.78	0.55			
	BUS	0.99	0.36	0.84			
	DEXJ	–0.04	0.97	0.44			
BUS	VJ	–0.24	0.71	0.59		0.56	2.05
	M1J	–0.46	0.91	0.48			
	VB	0.20	1.15	0.36			
	BUS	0.18	0.94	0.46			
	DEXJ	0.02*	2.91	0.04			
DEXJ	VJ	–7.80**	2.00	0.12	0.06	11.33	1.84
	M1J	–9.95	1.63	0.20			
	VB	–2.36	0.59	0.67			
	BUS	–12.40	1.46	0.24			
	DEXJ	0.05	1.68	0.18			

VJ and VB are shocks to monetary velocity and base velocity in the U.S. and Japan respectively. All other symbols are defined in previous tables of this section.

be spurious. It does not recur in the money, output system reported in Table 12 or at other lags that I have considered.

Central banks engage in smoothing operations that are intended to offset changes in exchange rates. One interpretation of intervention is that a central bank, or central banks acting together, introduces unanticipated changes in money. Such changes appear to have no reliable effect on the change in exchange rates. Table 12 and 13 suggest that the changes in exchange rate have a relatively large standard error, but the size of quarterly changes is independent of monetary and other shocks. Again, this does not imply that the shocks have no effect. The effect on expected values has not been studied.

Some of these findings are altered for the period beginning second quarter 1973 examined in Table 12. There is, again, no evidence of a reliable systematic effect of exchange rate changes on the shocks to money and velocity in the two countries. Shocks to the U.S. monetary base have a larger (positive) effect on shocks to M1J, but the effect is no longer significant using 4 lags.[19] The main change in the shorter period is in the DEXJ equation. Shocks to the U.S. monetary base and to U.S. base velocity show significant negative effect on DEXJ at the .01 and .03 levels of significance. These findings suggest that unanticipated increases in U.S. nominal GNP were followed within a year by an unanticipated depreciation of the dollar against the yen. This result is sensible only if the shocks to money and velocity raise prices much more than real values.

A major reason for activist, discretionary monetary policies is that central banks seek to offset shifts in the demand for money. Variability is introduced into the stock of money to reduce variability in demand. Earlier, we found no evidence of a negative relation between shocks to money and velocity. Table 13 pursues the issue by testing for effects of unanticipated lagged changes in velocity on current monetary shocks. A negative coefficient for velocity in the equations for BUS or M1J would support the hypothesis that central banks offset past shocks with a lag.

For Japan, the coefficients are negative under both fixed and fluctuating exchange rates and weakly significant under fluctuating exchange rates. There is some evidence that monetary operations contributed to the decline in the variability of velocity in Japan. For the U.S., the coefficient of VB is positive, but not significant, in both the fixed and fluctuating exchange regimes. Federal Reserve efforts to offset shocks appear to have increased variability of money and other variables at home and abroad without smoothing shocks to the demand for money at home.

Past shocks to money are followed by unanticipated positive changes in velocity. For Japan, the effects are statistically significant under fixed and fluctuating ex-

19. BUS has a weakly significant effect on M1J if six lags are used. The output summarized in this paragraph is available from the author on request.

change rates. For the U.S., the responses are positive also, but they are not statistically significant. These findings are consistent with the findings in Table 12 showing a positive response of nominal GNP to monetary shocks.

The U.S. is generally thought to have pursued solely domestic goals under fixed exchange rates. A surprising finding in Table 13 is the negative effect of VJ on the U.S. monetary base during the fixed rate regime. The sum of the coefficients is small, because there are offsetting negative and positive coefficients. The initial effects of an increase in VJ lowered the unanticipated change in the monetary base but was followed after a year by an increase in BUS. The F-statistic suggests that the response was more reliable than any of the other variables in the equation.

One explanation of the response is that positive productivity shocks to output in Japan raised output and velocity. The increase in output was followed by an increase in exports from Japan to the U.S. Under fixed exchange rates, the rise in Japan's trade balance, and the decline in the U.S. trade balance, should raise Japan's money stock and lower the U.S. money stock. VJ has the expected negative effect on the U.S., but the effect on money in Japan is relatively weak, and the sum of the coefficients is negative, contrary to the hypothesis. An alternative explanation is that the productivity shock raised the return to capital in Japan and produced a capital flow toward Japan. The Federal Reserve's policy of targetting interest rates would lead to an increase in the base following an unanticipated change, not the observed decrease. A third alternative is that the shocks to money in Japan are to the demand for money. Increases in the demand for money lower velocity and raise interest rates. To increase the U.S. base, the rise in interest rates must affect U.S. and world interest rates. If this, in fact, occurred, the Federal Reserve policy procedures would produce a negative shock to the base. This reasoning assigns a larger effect to changes in the demand for money in Japan than seems consistent with the relative size of Japan and the U.S. at the time.

Table 13 again suggests that the relations between shocks and the transmission of impulses differed under the fixed and fluctuating rate regimes. If these differences are meaningful, studies that investigate these relations, and tests of "causality" that ignore differences between regime are likely to reach incorrect conclusions.

VI Conclusion

This study considers the types of shocks, or unanticipated changes, that affected the U.S. and Japan under fixed and fluctuating exchange rates. A multi-state Kalman filter uses Bayesian prior probabilities to separate errors into permanent changes in level, permanent changes in growth rate and transitory changes in level. Forecasts are made for one-period ahead using the prior probabilities to weight past permanent and transitory changes. The program treats each series as a univariate time series.

Vector autoregression is used, subsequently, to study the relation between shocks. The study is empirical; the only theoretical restriction imposed on the data is the quantity equation, and it is used only to compute monetary velocity.

One principal finding about shocks, or unanticipated changes, is that most shocks are classified by the statistical procedure as either permanent changes in level or permanent changes in the rate of change. This finding reinforces some of the conclusions reached by Nelson and Plosser (1982) and by Stulz and Wasserfallen (1985) using different methods and data. Unlike the well-known Lucas model of the Phillips curve, transitory changes in prices (or other variables) appear to be a relatively minor source of uncertainty. Unlike Stulz and Wasserfallen, who found that shocks are dominated by changes in stochastic growth rates, both transitory and permanent changes in growth rates appear to be important. Transitory changes in growth rate (or permanent changes in level) include the type of shocks that are called business cycles.

A second main finding concerns the effect of a change in regime. The shift from the fixed to fluctuating exchange rates is treated as a change in monetary regime. The paper explores the effect of the regime change on variability and uncertainty about future prices and output. Although much has been written about the instability arising from the fluctuating rate system, I find that, for Japan, the measured variability of money, velocity, real and nominal output is lower under fluctuating rates than under fixed rates and that, for the United States, measured variability of nominal and real output declined also. For Japan, the variance of forecast errors, obtained using the Kalman filter, declined markedly under fluctuating rates.

Additional reductions of forecast error variance for output and prices were found following the decision by the Bank of Japan to announce projections of monetary growth. These announcements, if credible, increase information about money growth and reduce uncertainty. Reductions in the variability of output and prices lower the risks faced by consumers and investors and raise welfare. Announcement of monetary targets by the Federal Reserve were not, as in Japan, followed by a reduction in uncertainty. Variability of output and base money increased slightly.

Vector autoregression was used to study the interaction between unanticipated changes in money and output in the U.S. and Japan and changes in the dollar-yen exchange rate. A related effort considered the interrelation of unanticipated money and velocity for the two countries and changes in the exchange rate. The variability of exchange rate changes is relatively large, but I found no systematic relation between prior changes in the exchange rate and subsequent unanticipated changes in money, in velocity or in nominal output. This does not imply that changes in exchange rate, or in other variables, are inconsequential. Such changes may affect anticipations. However, the findings here are consistent with the hypothesis that most of the changes are absorbed within the financial sector and do not introduce additional unforeseen changes in output or the demand for money.

These findings suggest that the financial system damps the influence of changes in exchange rates on output and prices. Further, I have found no evidence of the importance of currency substitution stressed by McKinnon (1984). Tests of McKinnon's hypothesis as a relation between unanticipated changes in the demands for money in Japan and the U.S. produce null results.

The output of the multi-state Kalman filter permits investigation of a type of Phillips curve. For Japan and the United States, there is no evidence of the positive relation between contemporaneous unanticipated changes in the level of prices and unanticipated changes in the level of output. For Japan, under fixed exchange rates, lagged shocks to real output are unrelated to price shocks and lagged shocks to the price level are unrelated to output shocks. Under fluctuating exchange rates, we find a significant negative effect of past price shocks on unanticipated output and a significant positive effect of the same magnitude in the opposite direction. These findings suggest that, in Japan, there was no reliable Phillips curve between shocks under the fixed exchange regime. Under fluctuating rates the pattern is one of dynamic interdependence between unanticipated changes rather than the structural relation that Phillips curve studies seek to isolate.[20]

The two step procedure used here is open to the criticism that the computation of unanticipated changes using the Kalman filter ignores information in related series. The use of VAR's to analyze these shocks provides some evidence of the extent of the inefficiency.[21] Comparing the lowest standard errors of estimate from any VAR to the standard error of forecast shows that reductions range from zero to 40%. The smallest reductions are for the monetary base and base velocity in the U.S. and for real GDP in Japan under fluctuating exchange rates; the largest reduction is for the money stock in Japan under exchange rates. For Japan, the average reduction in the estimated standard errors for prices, money, real and nominal output and velocity is approximately 18% in both regimes. For the U.S., the average reductions for the variables considered — monetary base, base velocity, money stock and nominal output — are approximately 20% in the fixed rate regime and 7% in the fluctuating rate regime. These estimates overstate the inefficiency. The reason is that standard errors of forecast from the Kalman filter are relatively small, so the absolute size of reductions is relatively small. The percentage reduction of the standard errors is comparable to a partial correlation coefficient. Further, the average reductions

20. The relation is studied in levels, but the conclusion drawn is unlikely to be affected. If transitory shocks to levels are small, as is often the case, the errors in the price level equation are similar to the errors in the rate of price change equation.

21. The VAR's mostly likely overstate the inefficiency because they estimate relations for the whole sample period using information that would not be available at the time.

achieved with the VAR's are not from a single system, so all of the reductions are not obtained simultaneously.

The larger part of the errors of forecast appear to be unrelated to past values of the variables considered. This suggests that many of the fluctuations called business cycles have relatively large, random components that are not likely to be predicted. For the present, these errors are treated as variability arising from nature, trading processes and institutional arrangements. Some of the errors are monetary, others real. If we use the standard errors of estimate, or the minimum values just discussed, as measures of the minimum values of these shocks under the prevailing regimes, the minimum values of shocks to real GDP and money in Japan appear to be between 1 and 2% after removing the estimated effects of past money and price shocks on output and of past output and price shocks on money. Under fixed rates, real shocks were somewhat larger than monetary shocks in Japan. Under fluctuating rates, monetary shocks have been larger. Velocity is subject to the largest relative errors of forecast, and most of the variability remained after removing effects of lagged shocks to money. Efforts to adjust money by forecasting quarterly values of the demand for money (or velocity) are not likely to minimize the risks that consumers bear. Table 14 shows these data.

Table 14 Japan: Standard Errors of Estimate (in percent)

	Money	Velocity	Real GDP	Price
		Fixed Rates		
From Kalman filter*	1.92	2.81	1.90	1.18
From VAR	1.75[c]	2.60[a]	1.94[b]	0.96[b]
		Fluctuating Rates		
From Kalman filter*	2.14	2.53	1.10	0.84
From VAR	1.86[a]	2.28[a]	1.00[b]	0.59[b]

* The square root in percent of the forecast error variance (divided by 100) in Table 2

a from Table 13

b from Table 9

c from Table 11

One reducible source of variability and uncertainty is the error in forecasts of the money stock. Forecast errors for money and the monetary base appear to be followed, after a lag, by forecast errors in nominal output in the U.S. and Japan. Under fluctuating rates, there appears little if any feedback to the base or money. Variability of the base and money appear to be entirely random fluctuations that can be reduced by improved monetary procedures.

The implication of this last finding is that institutional changes that produce more stable money or money growth would reduce variability and uncertainty. If both countries adopted independent, compatible monetary policies to achieve domestic price stability, the findings here suggest that shocks to output would be reduced. Although I have not investigated the effects of shocks on expectations, it seems likely that more stable monetary growth in both countries would contribute to more stable exchange rate expectations and more stable exchange rates as well.

The results reported here are subject to a number of limitations. Only a small number of variables have been considered. Interest rates and fiscal shocks have been ignored. Procedures are entirely empirical and are dependent to an unknown degree on the use of a particular forecasting technique and a particular statistical hypothesis. Many further estimates and tests will be required to explore the properties of the procedure and the robustness of the results.

REFERENCES

[1] Barro, Robert J., "Unanticipated Money Growth, Output and the Price Level in the U.S.", *Journal of Political Economy,* 86, August 1978, pp. 549-80.

[2] Bomhoff, Edward J., "Prodicting the Price Level in a World that Changes All the Time", *Carnegie-Rochester Conference Series on Public Policy,* 17, Spring 1982, pp. 7-56.

[3] Bomhoff, Edward J., *Monetary Uncertainty,* Amsterdam: North-Holland, 1983.

[4] Brunner, Karl, Cukierman, Alex and Meltzer, Allan H., "Money and Economic Activity, Inventories and Business Cycles", *Journal of Monetary Economics,* 11, May 1983, pp. 281-320.

[5] Brunner, Karl and Meltzer, Allan H., "The Uses of Money: Money in the Theory of an Exchange Economy", *American Economic Reviw,* December 1971.

[6] Cukierman, Alex and Meltzer, Allan H., "A Theory of Ambiguity, Credibility and Inflation under Discretion and Asymmetric Information", Carnegie-Mellon University, 1984, (unpublished).

[7] DeLong, J.B. and Summers, Lawrence H., "The Changing Cyclical Variability of Economic Activity in the United States", *NBER Working Paper,* 1450, September 1984.

[8] Doan, T.A. and Litterman, Robert B., *User's Manual RATS, Version 4.1,* Minneapolis: VAR Econometrics, 1981.

[9] Fischer, Stanley, "Stability and Exchange Rate Systems in a Monetarist Model of the Balance of Payments" in R. Aliber, ed. *The Political Economy of Monetary Reform,* New York: Allanheld, 1977, pp. 59-73.

[10] Flood, Robert P., "Capital Mobility and the Choice of Exchange Rate System", *International Economic Review,* 20, June 1979, pp. 405-16.

[11] Friedman, Milton, "The Case for Flexible Exchange Rates" in Friedman (ed.) *Essays in Positive Economics,* Chicago, 1953, pp. 157-203.

[12] Friedman, Milton and Schwartz, Anna J., *A Monetary History of the United States, 1867-1960,* Princeton for the National Bureau, 1963.

[13] Fukao, Mitsuhiro, "Monetary Policy under a Floating Rate System", Research Bureau, Economic Planning Agency (Japan), March 1984. (unpublished.)

[14] Gordon, Robert J., "Price Inertia and Policy Ineffectiveness in the United States, 1890-1980", *Journal of Political Economy,* 90, December 1982, pp. 1087-1117.

[15] Harrison, P.J. and Stevens, C.F., "Bayesian Forecasting", *Journal of the Royal Statistical Society,* Series B, 38, 1976, pp. 205-247.

[16] Ishida, Kazuhiko, "Divisia Monetary Aggregates and Demand for Money: A Japanese Case", *Bank of Japan Monetary and Economic Studies,* Vol. 2 No. 1, June 1984, pp. 49-80.

[17] Kool, C.J.M., "Forecasts with Multi-State Kalman Filters", Appendix 1 to Bomhoff (1983), 1983.

[18] Keynes, John Maynard, *A Tract on Monetary Reform (1923),* Volume IV of the *Collected Writings of John Maynard Keynes,* Macmillan and St. Martin's Press for the Royal Economic Society, 1971.

[19] Kindleberger, Charles, "The Case for Fixed Exchange Rates, 1969", *The International Adjustment Mechanism,* Federal Reserve Bank of Boston, Conference Series, 2, October 1969, pp. 93-108.

[20] Kydland, Finn and Prescott, Edward C., "Time to Build and the Persistence of Unemployment", *Econometrica,* 1983.

[21] Long, J.B. and Plosser, Charles I., "Real Business Cycles", *Journal of Political Economy,* 91, 1983, pp. 39-69.

[22] Lucas, Robert E. Jr., "Some International Evidence on Output Inflation Tradeoffs", *American Economic Review,* 63 June 1973, pp. 326-335.

[23] McCallum, Bennet, "Monetarist Rules in the Light of Recent Experience", *American Economic Review,* 74 May 1984, pp. 388-91.

[24] McKinnon, Ronald, *An International Standard for Monetary Stabilization,* Washington: Institute for International Economics, 1984.

[25] Meltzer, Allan H., "Rational Expectations, Risk, Uncertainty and Market Responses", in P. Wachtel (ed.) *Crises in the Economic and Financial Structure,* Lexington Books, 1982.

[26] Meltzer, Allan H., "Some Evidence on the Comparative Uncertainty Experienced under Different Monetary Regimes", Prepared for the Conference on Alternative Monetary Regimes, Dartmouth College, 1984.

[27] Meltzer, Allan H., "Rules for Price Stability: An Overview and Comparison", in *Price Stability and Public Policy,* Federal Reserve Bank of Kansas City, 1985, pp. 207-20.

[28] Nelson, C.R. and Plosser, Charles I., "Trends and Random Walks in Macroeconomic Time Series", *Journal of Monetary Economics,* 10, 1982, pp. 139-162.

[29] Sims, Christopher A., "Macroeconomics and Reality", *Econometrica,* 48 January 1980, pp. 1-48.

[30] Stulz, Rene M. and Wasserfallen, Walter, "Macroeconomic Time Series, Business Cycles and Macroeconomic Policies", *Carnegie-Rochester Conference Series on Public Policy,* 22 Spring, forthcoming.

[31] Suzuki, Yoshio, *Money and Banking in Contemporary Japan,* Yale University, 1980.

[32] Suzuki, Yoshio, "Financial Innovation and Monetary Policy in Japan", *Bank of Japan Monetary and Economic Studies,* Vol. 2 No. 1, June 1984, pp. 1-48.