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The Behavior of the Real Exchange Rate Under Fixed and Floating Exchange Rate Regimes

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Abstract

This article investigates the behavior of real exchange rates under fixed and flexible exchange rates. Using data from both the Bretton Woods and the modern floating periods, we decompose real exchange rate movements into components attributable to supply shocks, real demand shocks, monetary shocks, capital flows shocks, and real oil price shocks. Empirical results show that real demand shocks are an important source of real exchange rate movements under both fixed and flexible rates, while monetary shocks are negligible. Supply and oil price shocks seem to be more important under Bretton Woods, while capital flows shocks seem to explain a relatively higher proportion of real exchange rate movements under the modern floating period.

A commonly held view in international macroeconomics is that real exchange rates behave differently under different international monetary regimes. Evidence presented by Stockman (1983) and Mussa (1986), among others, shows that real exchange rate volatility is substantially higher under floating rates. Since nominal and real exchange rates are highly correlated under floating rates, this finding has been taken to imply sluggish commodity price adjustment. Mussa (1986), for example, shows that the variance of real exchange rates of major industrialized countries is 8 to 80 times higher under floating rate regimes than under fixed rate regimes. Grilli and Kaminsky (1989) present historical evidence that the volatility of the U.S. dollar/British pound real exchange rate is different under fixed and flexible exchange rate regimes.

The behavior of real exchange rates in the recent float has received considerable attention in the literature. Huizinga (1987) decomposes real exchange rates into transitory and permanent components using the Beveridge and Nelson (1981) technique and finds an important transitory component. Using a long-run neutrality restriction along the lines of Blanchard and Quah (1989), both

Lastrapes (1992) and Enders and Lee (1997) decompose the variance in real and nominal exchange rates into components induced by real and nominal factors. Both studies find that a significant percentage of the variation in real and nominal exchange rates has been due to real shocks. Enders and Lee (1997) suggest that real aggregate demand shocks rather than supply shocks have been responsible for the recent behavior of real exchange rates. Dibooglu (1996) and Zhou (1995) present evidence that real oil price shocks are significant in explaining real exchange rate movements in the post-Bretton Woods period. Clarida and Gali (1994) investigate the sources of real exchange rate fluctuations since the collapse of Bretton Woods. Employing a structural vector autoregression model (SVAR), they identify three shocks—supply, demand, and money (nominal). They find that nominal shocks explain a substantial amount of variance in \$/DM and \$/Yen real exchange rates but only a small amount of variance in \$/Pound and \$/Canadian Dollar real exchange rates. Demand shocks play a significant role in explaining the variance in real exchange rates for all four countries, but supply shocks are not significant. Employing a SVAR model, Rogers (1995) finds that monetary shocks account for 45% of the variance in \$/Pound real exchange rate. Preference shocks account for 35% and fiscal shocks account for 10% of the variation. Productivity shocks are insignificant at all horizons. Weber (1997) extends Clarida and Gali (1994) by decomposing supply shocks into labor supply and productivity shocks and monetary shocks into money demand and money supply shocks. He finds that 60%–85% of the short-term conditional variance in the level of \$/Yen, \$/DM, and \$/Pound real exchange rates can be attributed to demand shocks, and 10%–20% to monetary shocks, while supply shocks play no role.

This article reexamines the behavior of real exchange rates using a structural VAR framework. We impose a combination of short-run and long-run restrictions that are consistent with some structural exchange rate models to identify supply shocks, real demand shocks, monetary shocks, capital flows shocks, and real oil price shocks. More importantly, we examine the behavior of bilateral real exchange rates under *different* exchange rate systems to assess the impact of alternative international monetary arrangements.

Since the exchange rate system may influence the conduct of macroeconomic policy, it is important to distinguish between policy-induced shocks and shocks to the macroeconomic environment. For example, movements in real exchange rates in the post-Bretton Woods period may reflect exogenous real disturbances (such as real oil price shocks and supply shocks) requiring adjustments of the real exchange rate independent of the monetary regime. Similarly, by identifying macroeconomic policy shocks, it is possible to evaluate the effects of macroeconomic policy on real exchange rates, which may vary with the exchange rate regime. It is commonly believed that fixed rate regimes constrain discretionary demand policies, as such, real exchange rate behavior may be different under fixed rate environments. It is also possible to evaluate the extent of the so-called "overshooting" of the exchange rate, which is often cited as a major cause of excess volatility in exchange rates under a flexible exchange rate system. We present evidence for bilateral real exchange rates of the British pound, the Japanese yen, and the deutschemark against the U.S. dollar from the Bretton Woods and the modern floating period.

Our findings indicate that supply and oil price shocks seem to explain a sizable proportion of real exchange rate movements under Bretton Woods, while real demand and capital flows shocks play a significant role under both regimes. Section 1 presents the theoretical framework and methodology. Empirical results are analyzed in Section 2. Section 3 presents some extensions and checks for robustness, while Section 4 provides some concluding remarks.

1. Theoretical framework, data, and identiÆcation

A time series plot of bilateral real exchange rates of the Japanese yen (JY), British pound (BP), and deutschemark (DM) against the U.S. dollar($) is presented in Figure 1.[1] A casual inspection of the plots reveals that real exchange rates exhibit a relatively tranquil pattern during the Bretton Woods era followed by large fluctuations during the floating period. Adler and Lehman (1983), Corbae and Ouiliaris (1988), and Enders (1988), among others, argued that real exchange rates of industrial countries can be well approximated by a unit root process in the post-Bretton Woods period, with little or no tendency to revert to their mean. Froot and Rogoff's (1995) review of the literature reports a consensus decay factor in the neighborhood of 2% per month.

Are large fluctuations in real exchange rates under flexible exchange rates due to the exchange rate system (destabilizing speculation, large capital flows unwarranted by "macroeconomic fundamentals," and risk premiums), or are real

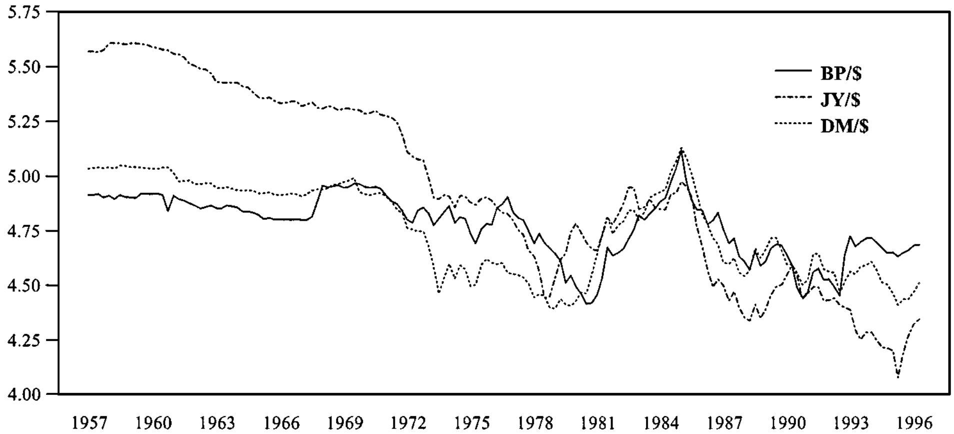


Figure 1. Real exchange rate indexes (1990 = 100, logarithmic scale).

exchange rates adjusting in response to exogenous changes in the macroeconomic environment (supply shocks, real oil price shocks, and changes in preferences)? Although it is hard to construct an adequate model capable of isolating all these factors, it is possible to identify a number of disturbances based on structural relationships such as interest parity, aggregate supply, and aggregate demand.

Figure 2 presents real interest differentials relative to the U.S. and the percentage change in real exchange rates for the entire period. It is apparent that real interest differentials closely track the percentage change in real exchange rates until the closing of the gold window in 1971. Subsequent changes in real exchange rates and interest differentials do not seem much correlated, with one exception. The real interest differentials in favor of the U.S. relative to Germany and Japan between 1979 and 1990 are evident in the real appreciation of the U.S. dollar between 1980 and 1984 and its depreciation in 1985–1990 (see Figure 1). It has been argued that U.S. aggregate demand shocks due to massive U.S. government spending were largely responsible for the real appreciation of the U.S. dollar in the early 1980s (Masson and Blundell-Wignall, 1985; Friedman, 1992). Recently, Enders and Lee (1997) found a significant relationship between swings in real U.S. government spending as a percent of GNP and the permanent component of the real value of the U.S. dollar and indicated that structural models of the exchange rate need to pay closer attention to real demand shocks. At a minimum, we believe that an empirical model needs to identify those shocks deemed important in driving the bilateral real exchange rates so that one can distinguish factors attributable to the regime/policy from those attributable to the macroeconomic environment. In this article, we identify supply shocks, real demand shocks, monetary shocks, capital flows shocks, and real oil price shocks.

In order to provide an identifying framework for these shocks, consider a two-country version of the Dornbusch (1976) model:

$$d'_t = \alpha_0 y'_t - \alpha_1 r'_t + \alpha_2 q_t + \varepsilon_{dt}, \tag{1}$$

$$m'_t = p'_t + y'_t - \lambda i'_t, \tag{2}$$

$$E_t e_{t+1} - e_t = i'_t + \varepsilon_{ct}, \tag{3}$$

$$E_t q_{t+1} - q_t = r'_t + \varepsilon_{ct}, \tag{4}$$

$$E_t p'_{t+1} - p'_t = \pi(d'_t - y'_t), \tag{5}$$

$$m'_t = m'_{t-1} + \varepsilon_{mt}, \tag{6}$$

$$y'_t = y'_{t-1} + \varepsilon_{st}, \tag{7}$$

where $y =$ full employment output, $d =$ aggregate demand, $i =$ nominal interest rate, $e =$ nominal exchange rate expressed as the domestic currency price of the U.S. dollar, $q =$ real exchange rate, $p =$ price level, and $m =$ money stock. The difference between domestic and foreign variables (e.g., $m' = m - m^*$, where an asterisk denotes the U.S. counterparts of domestic variables) is indicated by

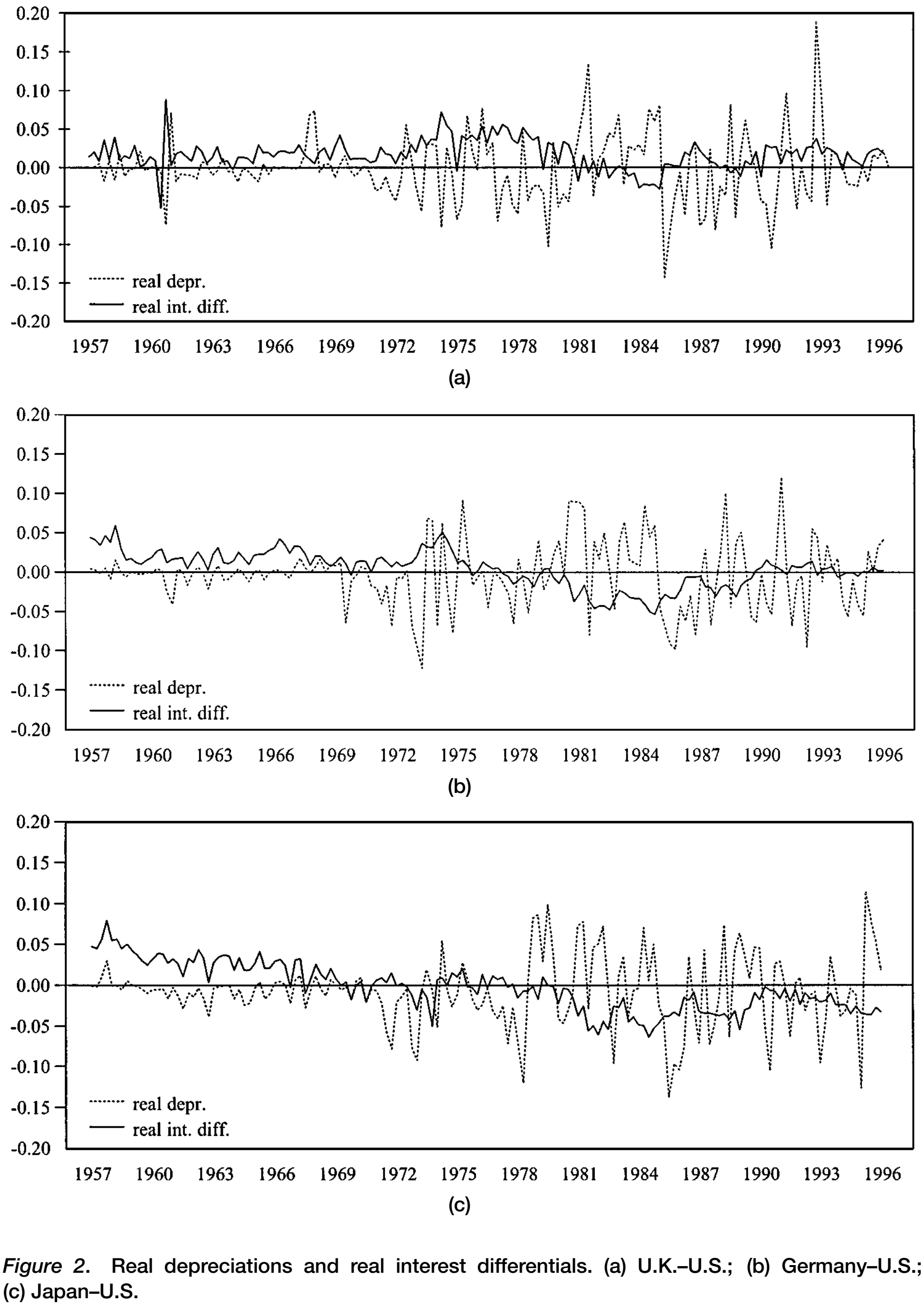


Figure 2. Real depreciations and real interest differentials. (a) U.K.–U.S.; (b) Germany–U.S.; (c) Japan–U.S.

(′); E_t is the conditional expectations operator, ε_i are stochastic disturbances, and all variables except interest rates are in logarithms.

Equation (1) is an aggregate demand equation where the relative aggregate demand for goods and services depends on the *ex -ante* real interest rate differential on and the real exchange rate, which is defined as the relative price of foreign goods. Equation (2) is a conventional money demand equation with unitary income elasticity. Equations (3) and (4) are uncovered interest parity defined in nominal and real terms, respectively. Equation (5) describes the evolution of prices and postulates that prices rise in response to excess demand, where a finite π implies sluggish price adjustment. For simplicity, Equations (6) and (7) assume exogenous random walk money and output processes. Given initial commodity prices, Equations (1) through (7) can be solved to obtain reduced-form expressions for the real exchange rate (see Enders and Lee, 1997). It can be shown that a permanent supply shock increases the real exchange rate permanently, provided that the marginal propensity to spend out of domestic income (α_0 in Equation (1)) is less than unity and that domestic and foreign goods are imperfect substitutes (i.e. α_2 in Equation (1) is finite). Moreover, a permanent aggregate demand shock decreases the real exchange rate permanently if domestic and foreign goods are imperfect substitutes, since it increases the relative demand for domestic goods. The model also implies long-run neutrality of money; however, with short-run "sticky" commodity prices, money supply shocks can have temporary positive effects on the real exchange rate.

The structural shocks assumed to drive the observed movements in the variables in the model are real demand shocks (ε_d), monetary shocks (ε_m), supply shocks (ε_s), and capital flows shocks (ε_c). Exogenous oil price changes are often suggested as possible causes of economic fluctuations. It is possible to augment Equation (5) by an exogenous world oil price

$$E_t p'_{t+1} - p' = \pi(d'_t - y'_t) + \gamma(rop_t), \tag{8}$$

where rop is the real world oil price such that $\Delta rop_t = \varepsilon_{rt}$, and ε_r is a "pure" shock to world oil prices.

1.1. Data and stochastic properties

Before outlining identification restrictions, it is important to test for time series properties of the data. Our theoretical framework suggests several variables to identify the structural shocks: output, interest rates, money, exchange rates, and real oil prices. We measure real output by the real GDP index, nominal interest rates by long-term government bond yield,[2] the money stock by M1, prices by the Consumer Price Index, the exchange rate by the period average nominal exchange rate, and the real oil price (rop) by the average price of crude oil deflated by the CPI. Quarterly data from 1957.I to 1996.II are obtained from the *International Financial Statistics* except for missing national accounts data, which have been obtained from the OECD National Accounts. GDP data for Germany between 1957.I and 1959.IV are from Moore and Moore (1985). The crude oil price is taken from the Citibase and updated from the Federal Reserve Bank of Saint Louis Online database (FRED).[3]

As a preliminary step, we use the KPSS test to characterize low-frequency properties of the data. The KPSS test is due to Kwiatowski et al. (1992) and tests stationarity as the null hypothesis against the alternative of a unit root. Table 1 reports test statistics for the Bretton Woods (1957.I–1973.I) and modern floating (1973.II–1996.I) periods at two different lag truncations $(l = 4, 8)$. The table indicates that relative monetary growth can be characterized as a stationary process, while the relative output level can be approximated by a unit root process in both periods. Test statistics for the remaining variables are not as clear. Real interest differentials tend toward a unit root at $l = 4$, while they are mostly stationary at the 5% significance level with $l = 8$. Although the Japanese–U.S. real interest differential seems to be a unit root process in the Bretton Woods period, we fail to reject stationarity around a linear trend.[4] We note that it is hard to reconcile a unit root in the real interest rate, given

Table 1. KPSS stationarity tests.[a]

	$\Delta m - \Delta m^*$	$y - y^*$	$r - r^*$	q	rop
Lag truncation, $l = 4$					
Bretton Woods					
Japan/U.S.	0.123	1.290	1.188	1.255	1.306
U.K./U.S.	0.168	1.115	0.118	0.135	1.322
Germany/U.S	0.203	0.495	0.323	0.938	1.239
Modern float					
Japan/U.S.	0.156	1.775	0.567	1.332	0.395
U.K./U.S.	0.073	1.181	0.645	0.292	1.422
Germany/U.S	0.261	0.863	0.411	0.288	0.411
Lag truncation, $l = 8$					
Bretton Woods					
Japan/U.S.	0.149	0.776	0.762	0.779	0.780
U.K./U.S.	0.175	0.671	0.164	0.095	0.799
Germany/U.S	0.209	0.350	0.264	0.631	0.755
Modern float					
Japan/U.S.	0.147	1.030	0.374	0.817	0.255
U.K./U.S.	0.075	0.739	0.407	0.192	0.841
Germany/U.S	0.236	0.551	0.263	0.182	0.255

[a]The test assumes an intercept. Critical values for the KPSS test are 0.347 (10%), 0.463 (5%), 0.574 (2.5%), and 0.739 (1%).

the strong prior on stationarity in the literature. Moreover, a unit root in the real interest rate is inconsistent with standard equilibrium growth models (Shapiro and Watson 1988). Hence we assume real interest differentials are stationary except for Japan in the Bretton Woods period, where it is trend stationary. The test statistics for bilateral real exchange rates are ambiguous in several cases. There is evidence that the real DM/$ rate under the Bretton Woods and the real Yen/$ rate under both periods are unit root processes. Given the debate surrounding the purchasing power parity (PPP) hypothesis, we do not make specific assumptions about PPP. Where feasible, we estimate the model under both stationary and unit-root real exchange rates. The test statistic for the real oil price tends mostly to a unit root, and we maintain that in our empirical analysis.

In order to properly specify the VAR, it is important to test for cointegration of the hypothesized unit root variables. To that end, we employ the Engle–Granger (1987) method to test for cointegration among relative output, relative money supply, real exchange rate, and the real oil price. As a first step, $(y-y^*)$ is regressed on a constant, $(m-m^*)$, q, and rop. Then the residual is tested for a unit root using an Augmented Dickey–Fuller (ADF) test. The critical values of the test are tabulated in Engle and Yoo (1987). The lag length in the ADF test is determined by the *general to specific rule* of Hall (1994). Starting from a maximum lag of 8, the lag length is pared down depending on the significance of the last coefficient. The results of the cointegration test are presented in Table 2.

The hypothesis of no cointegration is not rejected at the 5% significance level for relative output, relative money supply, the real exchange rate, and real oil price for both periods.[5] Overall, a plausible characterization of the data is that the vector $X_1 = [\Delta y - \Delta y^*, r-r^*, \Delta m-\Delta m^*, \Delta q, \Delta rop]'$ is stationary and can be properly specified as a VAR.

Table 2. Tests of cointegration.

	Bretton Woods		Modern float	
	lags[a]	ADF t-statistic[b]	lags[a]	ADF t-statistic[b]
Japan/U.S.	4	−3.58	8	−2.15
U.K./U.S.	2	−2.85	0	−3.27
Germany/U.S.	4	−2.16	0	−3.87

[a]The maximum lag in the ADF regression.
[b]The ADF t-statistic is the Augmented Dickey–Fuller test for a unit root in the residual from regression of $(y-y^*)$ on a constant, $(m-m^*)$, q, and rop. The critical value of the test for 4 variables and 50 observations at the 5% significance level is −4.35. The critical value for 100 observations is −4.22. Critical values are from Engle and Yoo (1987), p. 157.

1.2. Identification strategy

The “traditional” interpretation of macroeconomic fluctuations implies that aggregate demand shocks in the broad sense (goods market and money market shocks) have short-run effects on output, while supply shocks have permanent effects. Shapiro and Watson (1988), Blanchard (1989), Blanchard and Quah (1989), and Gali (1992) use this assumption to distinguish between supply shocks and demand shocks. Similarly, monetary shocks can be assumed to have no long-run effect on the real exchange rate when the latter is assumed to have a permanent component.

We consider five types of orthogonal structural shocks (supply, real demand, monetary, capital flows, and real oil price shocks), denoted by the vector $\varepsilon = [\varepsilon_s, \varepsilon_d, \varepsilon_m, \varepsilon_c, \varepsilon_r]'$, that are the source of variation in the vector $X_1 = [\Delta y - \Delta y^*, r - r^*, \Delta m - \Delta m^*, \Delta q, \Delta rop]'$. Assume that the covariance stationary vector X_1 can be written as an infinite moving average process in the structural shocks:

$$X_{1t} = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i} = A(L)\varepsilon_t, \tag{9}$$

where $A(L)$ is a matrix whose elements are polynomials in the lag operator L. For illustrative purposes, assume that the orthogonal shocks are normalized such that

$$E(\varepsilon_t \varepsilon_t') = I. \tag{10}$$

In order to identify the model, one can estimate a finite order VAR

$$X_{1t} = B_1 X_{1t-1} + \cdots + B_k X_{1t-k} + e_t, \tag{11}$$

where the lag length is chosen such that the residuals $e_{it} (i = 1, \ldots, 5)$ approximate white noise, and

$$E(e_t e_t') = \Sigma. \tag{12}$$

Under the assumption that X_1 is covariance stationary, the system in (11) can be inverted to obtain the moving average representation:

$$X_{1t} = \sum_{i=0}^{\infty} C_i e_{t-i} = C(L)e_t, \tag{13}$$

where $C_0 = I$. The contemporaneous relationship between the structural and the reduced form innovations is

$$e_t = A_0 \varepsilon_t, \tag{14}$$

where A_0 is a nonsingular matrix. Note from (9) that the *contemporaneous* interactions among the variables can be written as

$$HX_{1t} = \varepsilon_t, \tag{15}$$

where $H = A_0^{-1}$. Using (14) and evaluating the polynomials in (9) and (13) at $L = 1$ yields:

$$A(1) = C(1)A_0. \tag{16}$$

Given (10) and (14), the following relationship exists between the variance–covariance matrices:

$$E(e_t e_t') = A_0 E(\varepsilon_t \varepsilon_t') A_0' = A_0 A_0' = \Sigma. \tag{17}$$

Since Σ is a symmetric matrix with known elements (or can be estimated consistently), it imposes 15 restrictions on the elements of A_0. Just identification of A_0 requires an additional 10 restrictions. Identification through Choleski decomposition restricts A_0 to be a lower triangular matrix, while Bernanke (1986) and Sims (1986) introduce direct restrictions on the contemporaneous, short-run effects (the H matrix in (15)). Blanchard and Quah (1989), and Shapiro and Watson (1988) restrict the dynamic long-run effects of the innovations (the elements of the $A(1)$ matrix in (16)). Gali (1992) uses a combination of short-run and long-run restrictions on the H, A_0, and $A(1)$ matrices.

In order to properly identify the shocks to X_1, we specify the following restrictions on the H and $A(1)$ matrices [denote the i, j element of H by h_{ij} and the i, j element of $A(1)$ by $a_{ij}\ (1)$]:

1. Aggregate demand shocks $(\varepsilon_d, \varepsilon_m)$ have no long-run effect on output. This requires that $a_{12}(1) = a_{13}(1) = 0$ in the $A(1)$ matrix, and serves to distinguish demand shocks from supply shocks.
2. Monetary shocks have no long-run effect on the real exchange rate. This requires imposing the restriction $a_{43}(1) = 0$, and serves to distinguish real demand shocks from monetary shocks.
3. Real exchange rate depreciation responds to *contemporaneous* interest differentials; other variables affect the real exchange rate with a lag. This requires that $h_{41} = h_{43} = h_{45} = 0$, and can be justified on the grounds of uncovered interest arbitrage.
4. Real oil prices are “exogenous” within the time frame of a quarter; other shocks have no contemporaneous effect on oil prices. This is achieved by setting $h_{51} = h_{52} = h_{53} = h_{54} = 0$, and is consistent with the treatment of oil prices in the literature (e.g., Shapiro and Watson, 1988).

These assumptions provide the necessary 10 restrictions to recover the elements of A_0. Once A_0 is identified, one can construct the A_i matrices in (9) as $A_i = C_i A_0, i = 1, 2, \ldots,$ and obtain the structural shocks using (14). Except for assumption 2, these identifying assumptions are not dependent on whether the real exchange rate is a unit root process.

This identification strategy does not restrict the money supply process in a particular way. Allowing a more general specification for the money supply rule can accommodate different monetary practices under alternative exchange rate systems. However, our monetary shock is assumed to stem from money supply, not money demand. This assumption may not be a strong one, since Blanchard (1989) and Gali (1992) report that money supply innovations dominate money demand innovations in terms of their contributions to money and output. Although aggregate demand shocks have no long-run effect on output, they may influence output through their effect on the real exchange rate.

Finally, capital flows shocks are identified as movements in the real exchange rate that are not warranted by contemporaneous real interest differentials or lagged values of other variables in the system. In that sense, these shocks capture changes in the real exchange rate due to "speculative" short term capital flows that are not related to real interest differentials. Specifically, the identifying restriction regarding capital flows shocks is

$$\Delta q_t = \beta r_t' + \sum_{j=1}^{k} A_j^q X_{1t-j} - \varepsilon_{ct}, \tag{18}$$

where $\beta \equiv (h_{42}/h_{44})$, and A_j^q for $j > 0$ capture the relationship between the real exchange rate and past realizations of the variables in the system, including the real exchange rate. Notice that since we are not restricting β to be 1, and since A_j^q for $j > 0$ may be nonzero, this condition is weaker than conventional uncovered interest parity. Even though these identifying assumptions are relatively weak, we recognize that they are open to debate. The advantage of structural identification as opposed to the early VAR literature is that it makes the identification restrictions more explicit. One can also interpret the results such that the assumed effects dominate in the long run.

2. Empirical results

We first let $X_1 = [\Delta y - \Delta y^*, r - r^*, \Delta m - \Delta m^*, \Delta q, \Delta rop]'$ and estimate the VAR with four lags. Likelihood ratio tests and residual based Box–Pierce Q-statistics indicate that four lags are sufficient to render the residuals approximately white noise. We then invert the VARs to obtain the moving average representations and impose the identification restrictions outlined above. The model is estimated for the U.K., Japan, and Germany against the U.S. for the Bretton Woods period (1957.I–1973.I) and the modern floating period (1973.II–1996.II). In order to account for a structural break due to German unification, we include a dummy in the Germany–U.S. case ($d = 0$ for 1973.II–1990.IV and $d = 1$ for 1991.I–1996.II). Variance decompositions of the real bilateral exchange rates are given in the top portion of Table 3.

Table 3. Variance decomposition of the bilateral real exchange rate.

	Bretton Woods period–innovations in:					Modern float period–innovations in:				
k	ε_s	ε_d	ε_m	ε_c	ε_r	ε_s	ε_d	ε_m	ε_c	ε_r
A. Unit root real exchange rate										
Japan										
1	20.5	18.7	0.1	49.6	11.1	1.8	33.4	7.3	57.1	0.4
4	16.4	3.3	10.4	64.2	5.6	6.5	23.7	3.4	61.6	4.8
8	22.9	2.8	7.2	47.0	20.1	7.8	17.0	1.7	65.5	7.9
16	33.1	11.2	3.6	29.7	22.4	8.6	16.0	0.9	65.4	9.1
24	35.4	24.3	2.0	19.2	19.1	9.0	16.4	0.6	64.6	9.4
U.K.										
1	2.0	24.3	4.8	32.0	36.9	7.5	38.9	0.1	52.3	1.2
4	1.3	15.6	2.1	63.7	17.3	2.2	62.9	0.7	33.2	1.0
8	0.8	27.7	1.4	50.7	19.5	1.3	69.4	0.3	27.7	1.2
16	1.5	31.0	0.6	45.6	21.3	1.3	74.0	0.2	23.4	1.1
24	1.5	31.9	0.4	44.6	21.7	1.5	76.4	0.1	21.0	1.0
Germany										
1	29.8	42.6	2.6	14.3	10.7	2.1	17.4	0.0	78.7	1.7
4	23.6	45.0	0.7	23.0	7.7	1.3	8.4	0.4	85.8	4.0
8	14.7	62.7	0.5	11.9	10.2	1.7	8.4	0.2	83.4	6.3
16	5.6	72.5	0.3	4.5	17.0	2.9	10.2	0.1	79.2	7.5
24	3.5	73.2	0.2	3.5	19.6	3.8	12.1	0.1	75.9	8.2
B. Stationary real exchange rate										
U.K.										
1	5.4	11.7	0.2	64.3	18.4	3.9	44.9	0.9	48.3	2.0
4	5.2	4.7	0.5	82.5	7.1	0.4	61.3	0.2	35.4	2.7
8	8.5	6.8	1.7	75.1	7.8	0.1	67.4	0.3	28.4	3.9
16	7.7	10.3	4.7	68.0	9.4	0.2	72.9	0.5	21.6	4.9
24	6.8	10.9	5.9	66.6	9.8	0.6	76.4	0.8	17.2	5.1
Germany										
1						0.5	5.2	0.3	93.6	0.5
4						0.0	2.0	0.3	97.5	0.3
8						0.0	0.6	0.5	98.5	0.4
16						0.5	0.8	1.3	97.2	0.3
24						1.3	2.5	2.1	94.0	0.2

2.1. Variance decompositions

The VDCs reported in Table 3 indicate that the relative importance of different shocks in explaining the variation in real exchange rates have varied between the fixed and floating exchange rate regimes. These findings can be summarized as follows.

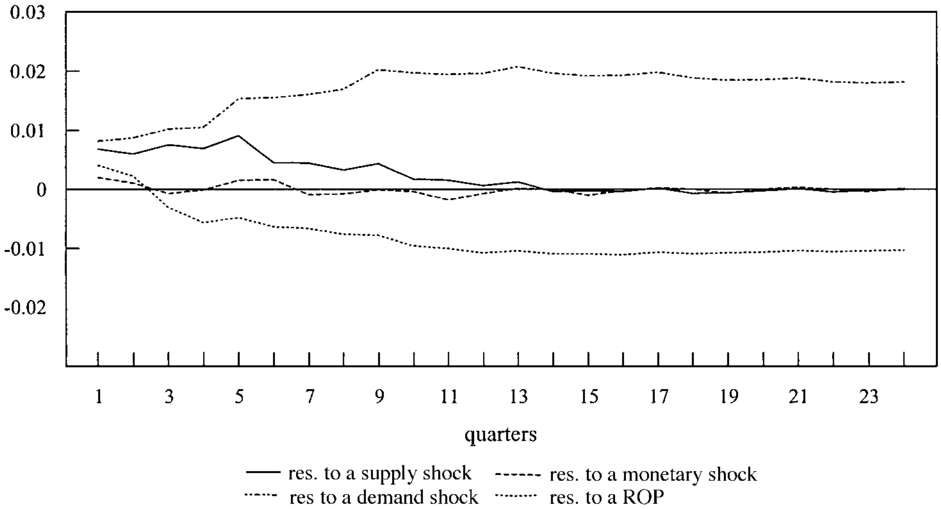
- Capital flows shocks are important for both periods but have become more important during the modern floating period.
- Supply shocks and real oil price shocks, which were more important during the Bretton Woods era, have become less important in explaining the variation in real exchange rates during the modern floating period.
- Aggregate demand shocks are significant in explaining the variation in real exchange rates during both periods.
- Monetary shocks have very little effect on the real exchange rates during both periods. These results are broadly in line with Lastrapes (1992) and Enders and Lee (1997), who find that real exchange rate movements in the post-Bretton Woods period are primarily due to real shocks. VDC results also confirm the conjecture by Enders and Lee (1997) in that real demand shocks seem to be an important determinant of real exchange rate movements.

An interesting aspect of these results is that real exchange rate movements under the float do not seem to be due to supply shocks or real oil price shocks. Indeed, these shocks seem more important in explaining real exchange rate movements under Bretton Woods. A possible explanation for the negligible impact of oil price shocks under the float is that these shocks are immediately reflected in nominal exchange rates and, to some extent, in price levels through inflationary expectations. However, under fixed nominal exchange rates, adjustment may be more gradual. This conjecture is supported by a formal "block causality" test. A likelihood ratio test that *lagged* values of real oil prices are insignificant for the vector $[\Delta y - \Delta y^*, r - r^*, \Delta m - \Delta m^*, \Delta q]$ cannot be rejected for all three cases for the floating period. However, real oil prices are significant for the Germany/U.S. and Japan/U.S. cases for the Bretton Woods period at conventional significance levels.

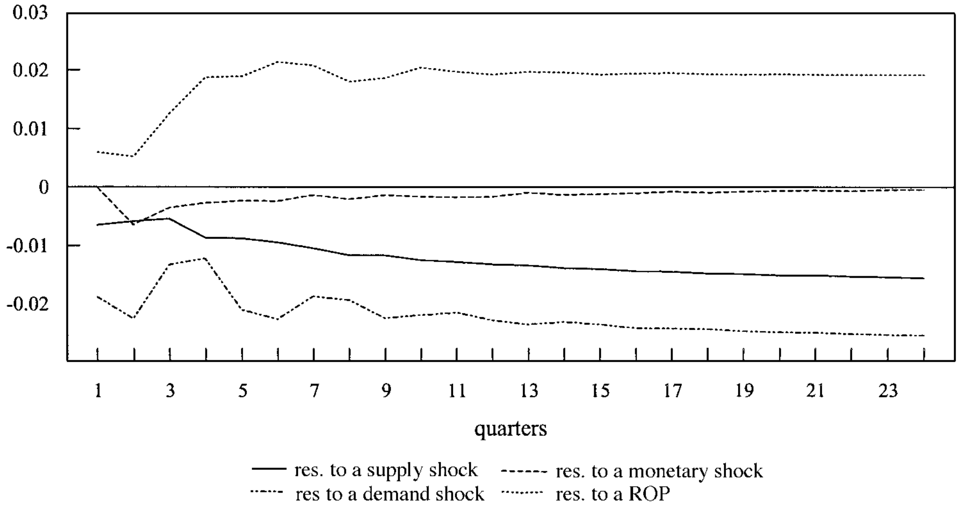
2.2. Impulse response functions

Impulse response functions in Figures 3–5 show the dynamic response of the real exchange rate to supply shocks, real oil price shocks, demand shocks, and monetary shocks.

The theoretical framework presented in Section 1 implies that a positive supply shock to home output leads to a fall in the relative price of home output and hence causes a permanent depreciation of the real exchange rate. Our empirical findings for Japan under Bretton Woods and for Japan and the U.K. during the modern floating period strongly conform to these theoretical predictions. The IRFs for Germany and the U.K. during the Bretton Woods period indicate a temporary depreciation of the real exchange rate, while the IRFs for Germany



(a)



(b)

Figure 3. Response of the real DM/$ exchange rate to various shocks. (a) Bretton Woods Period; (b) Modern Floating Period.

during the modern floating period show a permanent appreciation of the real exchange rate.

We find some evidence of overshooting for the real Yen/$ exchange rate during the modern floating period. In response to a monetary shock, the real exchange rate initially depreciates (possibly due to a depreciation of the nominal exchange rate) and then appreciates (possibly due to a rise in the domestic price

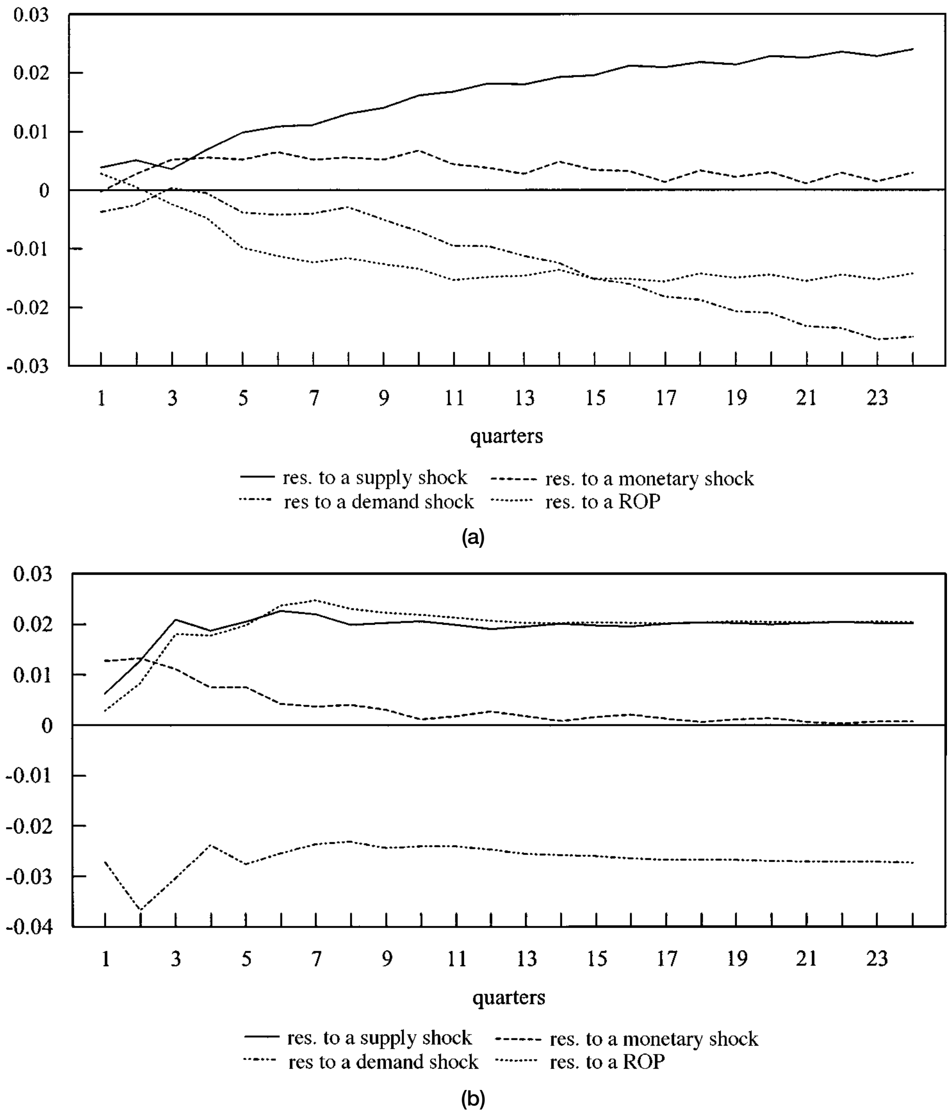
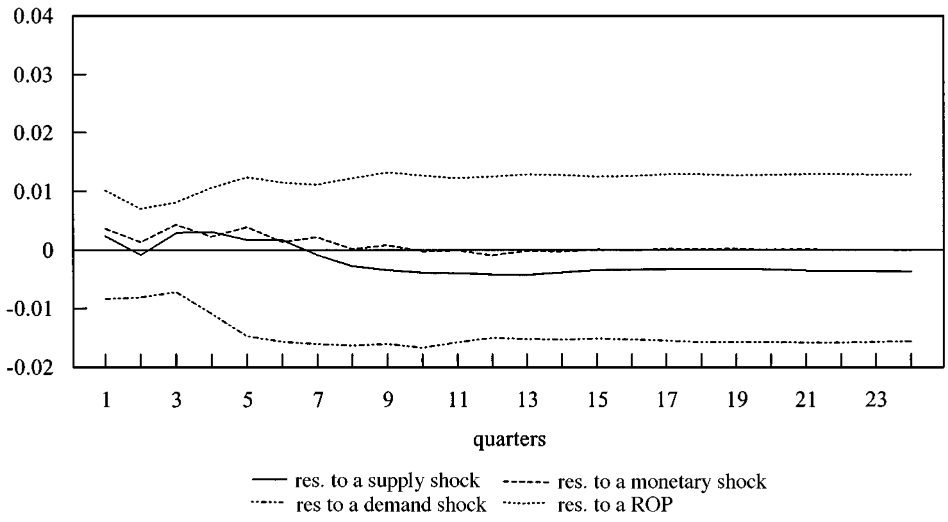


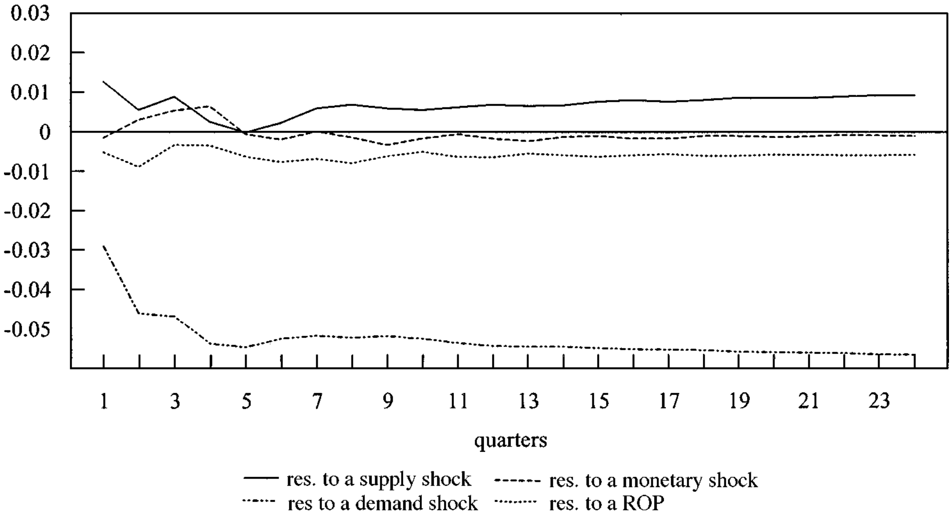
Figure 4. Response of the real Yen/$ exchange rate to various shocks. (a) Bretton Woods Period; (b) Modern Floating Period.

level). The evidence of overshooting for the real Pound/$ exchange rate is weak and does not exist for the real DM/$ exchange rate.

The theoretical framework presented in Section 1 implies that a positive demand shock to home output leads to a rise in the relative price of home output and hence causes a permanent appreciation of the real exchange rate.



(a)



(b)

Figure 5. Response of the real Pound/$ exchange rate to various shocks. (a) Bretton Woods Period; (b) Modern Floating Period.

Our empirical findings, with the exception of Germany during the Bretton Woods period, strongly confirm these theoretical predictions.

The IRFs indicate that the response of the real exchange rate to real oil price shocks during the fixed exchange rate period is exactly opposite to that during the modern floating period. Recall that oil prices can have complex effects.

To the extent that oil prices affect countries asymmetrically, they may influence the real exchange rate. Oil prices have inflationary effects because of rising production costs, while they have demand deflationary effects due to rising imports (for countries that depend on oil imports). Production costs depend on the wage response and other cost-cutting measures. Additional effects include an increase in substitutes for oil and an increase in demand for manufactured goods in oil-exporting countries.

During the Bretton Woods period, a shock to the real price of oil appreciates the real exchange rate for Germany and Japan and depreciates it for the U.K. During the floating period, however, the real oil price shock depreciates the real exchange rate for Germany and Japan and appreciates it for the U.K. A plausible explanation is that an oil price shock affects prices both at home and abroad. If, in response to an oil price shock under fixed exchange rates, the prices of German and Japanese goods rise more than the price of U.S. goods and the price of U.K. goods rises less than that of U.S. goods, then it is plausible that the real exchange rate for Germany and Japan appreciates while that for U.K. depreciates. Under flexible exchange rates, an oil price shock creates the expectation that the monetary authority would accommodate the shock and hence the nominal exchange rate would depreciate. Although the German and Japanese (U.K.) prices relative to U.S. prices are expected to rise (fall), it is plausible that this would be more than offset by the depreciation (appreciation) of the nominal exchange rate. This outcome would then imply depreciation of the real exchange rate for Germany and Japan and appreciation for U.K. under floating exchange rates.

3. Extensions and checks for robustness

In order to allow for the possibility of stationary real exchange rates in some cases,[6] we let $X_2 = [\Delta y - \Delta y^*, r - r^*, \Delta m - \Delta m^*, q, \Delta rop]'$ and substituted the restriction $a_{43}(1) = 0$ with $h_{23} = 0$ in the H matrix. The results are very similar to those obtained from the original model. The variance decompositions of this model are reported at the bottom of Table 3. Notice that with a stationary real exchange rate, a negligible proportion of exchange rate changes are explained in terms of demand or supply shocks. Variance decomposition results for the U.K. are mostly insensitive to assumptions regarding the unit root properties of the real exchange rate.[7]

Due to its unique position within the European Monetary System (EMS), we also estimated the system $X_1 = [\Delta y - \Delta y^*, r - r^*, \Delta m - \Delta m^*, \Delta q, \Delta rop]$ for Germany during the EMS period, 1979:II–1996:II. The evidence provided by IRFs in Figure 6 indicates that two anomalies that exist for the entire modern floating period—a permanent appreciation of the real exchange rate in response to a positive supply shock and a temporary appreciation of the real exchange rate in response to a monetary shock—no longer exist during the EMS period. The IRFs show that the real exchange rate permanently depreciates in response to

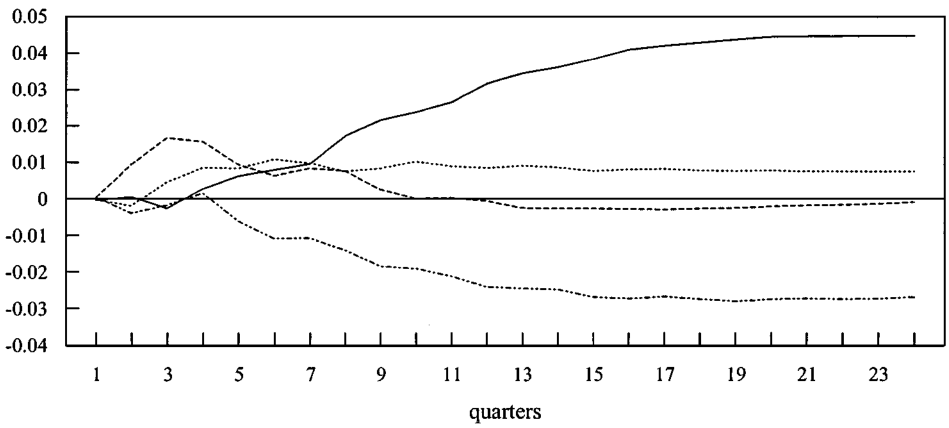


Figure 6. Response of the real DM/$ exchange rate to various shocks: EMS period.

a supply shock, as predicted by the model. There is also evidence for the overshooting hypothesis. The real exchange rate initially depreciates in response to a monetary shock and then appreciates over time, offsetting the effects of the initial depreciation.

Finally, we employed a broader definition of the money supply. Estimating the model with M2 yielded similar results. Monetary shocks still account for a negligible proportion of real exchange rate movements. The only noticeable difference seems that the proportion of the real Yen/$ forecast error variance attributable to real demand shocks diminishes under floating.

4. Summary and concluding remarks

It is well known that the behavior of real exchange rates is different under different exchange rate systems. An important question is whether changes in real exchange rates can be traced to factors attributable to the exchange rate system. The exchange rate system may influence the conduct of macroeconomic policy, where floating rates can be considered relatively prone to discretionary demand policies. If commodity prices are sticky, nominal exchange rate changes translate into real exchange rate changes under floating. It is also argued that nominal exchange rate fluctuations may stem from "currency premiums," self-fulfilling prophecies, or haphazard short-term capital flows that are not warranted by macroeconomic fundamentals. Events such as the change in the nominal Yen/$ rate by nearly 65% between 1995 and 1997 has called into question how well the foreign exchange market is functioning. Although many recognize the difficulty of a fixed rate system *a la* Bretton Woods, some suggest stabilizing exchange rates by a "Tobin tax" imposed on capital flows (Frankel, 1995). The alternative is that fluctuations in real exchange rates may be due to the macroeconomic environment (supply shocks, oil price shocks, etc.) Within the context of a conventional exchange rate model and structural VARs, we provide some answers to these questions by identifying real exchange rate movements attributable to supply shocks, real demand shocks, monetary shocks, capital flows shocks, and real oil price shocks. We compare results from the Bretton Woods and modern float periods regarding three bilateral real exchange rates: the Japanese yen, the British pound, and the deutschemark against the U.S. dollar.

Empirical results show that real aggregate demand shocks are an important source of real exchange rate movements under both fixed and flexible rates, while monetary shocks are negligible. The importance of demand shocks in explaining real exchange rate fluctuations in the post-Bretton Woods period is broadly in line with Clarida and Gali (1994) and Weber (1997). Interestingly, our results indicate that supply shocks and real oil price shocks seem to be more important under Bretton Woods than the subsequent float. As one may expect, capital flows shocks explain a relatively higher proportion of real exchange rate movements under floating, particularly for the real DM/$ and Yen/$ rates. Recall that capital flows shocks capture movements in real exchange rates that are not warranted by contemporaneous real interest differentials or lagged variables in the system. To the extent that capital flows shocks reflect short-term capital flows unwarranted by macroeconomic fundamentals, their preponderance under floating for the real DM/$ and Yen/$ rates can be attributed to the exchange rate system.

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Notes

1. We define the bilateral exchange rate, q_t as the relative price of U.S. goods in terms of domestic goods: $q_t = e_t - p_t + p_t^*$, where e_t is the log of the nominal exchange rate and p_t and p_t^* are the logs of domestic and U.S. price levels, respectively. Similarly, the real interest differential is defined as $r_t - r_t^*$, where in the empirical analysis, r_t is the ex post real interest rate, $i_{t-1} - \Delta p_t$; r_t^* is similarly defined.
2. Government bond yield is not available for Japan in 1957–1966; we substituted the lending rate for the Bretton Woods period.
3. We also checked data from different sources for consistency.
4. The estimated η_τ statistic for the Japan–U.S. real interest differential at $l = 4$ is 0.076, and $\eta_\tau = 0.073$ at $l = 8$. The critical values of the η_τ statistic are 0.119 at 10%, 0.146 at 5%, and 0.176 at 2.5%.
5. We recognize that using a different cointegration method may yield different results. See, for example, MacDonald (1999).

6. Estimation under a stationary real exchange rate was not feasible in some due to the inability to obtain the infinite moving average representation.
7. Since the Japan–U.S. real interest differential is trend stationary in the Bretton Woods period, we also estimated the model with detrended real interest differentials. The results were similar and are not reported.

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