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Real Exchange Rate Fluctuations and the Business Cycle: Evidence from Japan

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Abstract

This paper analyzes the relationship between the real exchange rate and the business cycle in Japan during the floating rate period. A structural vector autoregression is used to identify different types of macroeconomic shocks that determine fluctuations in aggregate output and the real exchange rate. Relative nominal and real demand shocks are found to be the main determinants of variation in real exchange rate changes, while relative output growth is driven primarily by supply shocks. Historical decompositions suggest that the sharp appreciations of the yen in 1993 and 1995 and its subsequent depreciation can be attributed primarily to relative nominal shocks.

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Summary

This paper examines the relationship between the exchange rate and the business cycle in Japan during the post-Bretton Woods period of floating exchange rates. Theory predicts that movements in the real exchange rate over the business cycle depend on the relative importance of different "shocks" that drive the business cycle. For instance, while an autonomous contraction in aggregate demand can be expected to lead to a depreciation, a recession induced by monetary tightening or a contraction in aggregate supply would be expected to lead to an appreciation.

A structural vector autoregression is used to estimate the relative importance of different types of macroeconomic shocks—real demand, nominal or monetary, and supply shocks—for fluctuations in output, the exchange rate, and the aggregate price level. In the framework of the traditional IS-LM macroeconomic model, these shocks can be thought of as shocks to goods and money markets (that shift the IS and LM curves), respectively, and shocks that affect the longer-run level of capacity output.

The structural decomposition indicates that, over the floating-rate period, nominal and real demand shocks have been the main determinants of variations in the first differences of the real exchange rate, while supply shocks have played a smaller role. Relative output growth fluctuations, in contrast, have been driven primarily by supply shocks. Over the course of the recent cycle, the sharp appreciations of the yen in 1993 and 1995 and the subsequent sharp depreciation can be attributed primarily to nominal shocks.

I. Introduction

The relationship between the exchange rate and fluctuations in aggregate output is in general complex. Theory predicts that movements in the real exchange rate over the business cycle depend on the relative importance of different "shocks" that drive the business cycle. For instance, while an autonomous contraction in aggregate demand should generally lead to a depreciation of the exchange rate, a recession induced by monetary tightening or a contraction in aggregate supply would be expected to lead to an appreciation.

This paper examines the relationship between the exchange rate and the business cycle in Japan during the post-Bretton Woods floating rate period. The importance of this relationship has been highlighted during the recent cyclical episode. Following the bursting of the asset price bubble in 1990, the Japanese economy entered what appears to be the longest and deepest recession of the postwar period. During this period, sharp movements in the yen played a critical role in affecting the pace and composition of economic activity. The sharp appreciations of the yen in mid-1993 and the spring of 1995 negatively impacted business and consumer confidence and (with a lag) led to a withdrawal of external demand, slowing the recovery of activity. The rapid depreciation of the yen in the summer of 1995 was pivotal in restoring confidence and setting the stage for a recovery.

This paper constructs a structural vector autoregression (VAR) model along the lines of Blanchard and Quah (1989) and Clarida and Gali (1994) to estimate the relative importance of different types of macroeconomic shocks for fluctuations in output, the exchange rate and the aggregate price level. Three distinct types of shocks are identified. In the framework of the traditional IS-LM macroeconomic model, these shocks can be thought of as shocks to goods and money markets (that shift the IS and LM curves), respectively, and shocks that affect the longer-run level of capacity output. The shocks to goods markets are referred to as real demand shocks, while shocks to money markets are referred to as nominal or monetary shocks. Shocks affecting the long-run level of capacity output are referred to as supply shocks. The model is identified using a set of restrictions on the long-run multipliers of the system, thereby allowing for unrestricted short-run dynamics. The estimated model can then be used to decompose historical variation in these three variables into the components attributable to each of these three shocks.

A complementary approach to that adopted in this paper has been to examine the relationship between variations in the real exchange rate and a more directly related set of determinants such as differentials in inflation and interest rates (see, e.g., Cumby and Huizinga (1991)). The advantage of the structural decomposition approach adopted in this paper is that it identifies the fundamental macroeconomic shocks that could simultaneously affect variables such as real exchange rates and interest differentials and does not impose reduced-form causal relationships in the estimation. In addition, the decomposition permits the separate identification of nominal and real shocks, which could affect inflation and interest differentials and other variables in very different ways.

The structural decomposition indicates that nominal and real demand shocks have been the main determinants of variations in the real exchange rate, while supply shocks have played a smaller role. Over the course of the recent cycle, the contribution of real demand shocks, which had created pressures for the yen to appreciate during the bubble period, has declined steadily since 1993. The sharp appreciations in 1993 and 1995 and the subsequent sharp depreciation of the yen can be attributed primarily to nominal shocks.

The analysis in this paper is related to the extensive literature on sources of business cycles in Japan (see, e.g., Yoshikawa and Ohtake (1987) and West (1992)). The methodology implemented in this paper, however, abstracts from global shocks and examines the relative importance of fundamental macroeconomic shocks for country-specific fluctuations in Japanese output. The results indicate that relative output growth fluctuations in Japan are largely determined by supply shocks, with demand shocks having an important but smaller role and nominal shocks being relatively unimportant.

The next section of the paper reviews the historical relationship between the Japanese real exchange rate and the business cycle in Japan during the floating rate period, and characterizes the movements of the yen over the course of the recent cycle. Section III discusses the predictions from standard macroeconomic models for the path of the exchange rate over the course of the business cycle. Section IV describes the econometric framework used in this paper and presents some preliminary data analysis. Section V presents the main empirical results from the estimation. Section VI summarizes the main results and concludes the paper.

II. Stylized Facts

This section examines the historical relationship between the exchange rate and the business cycle in Japan during the floating rate period, with particular attention to recent movements in the yen. The appropriate real exchange rate measure for this analysis needs to be considered carefully. Rather than use a bilateral exchange rate, we construct a measure of the real effective exchange rate vis-à-vis the other G-7 countries.[1] This provides a more comprehensive picture of the relationship between the domestic economy and the real external value of the Japanese yen. Another issue in constructing the real effective exchange rate is the choice of the appropriate aggregate price deflator. From a macroeconomic perspective, the CPI provides a broad measure of the price level that can be most directly linked to cyclical

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[1]A significant portion of Japan's trade is with APEC economies that are not part of the G-7. However, data constraints precluded the construction of a broader real effective exchange rate measure including all of Japan's trading partners over the full floating rate period.

movements in output. Hence, we use domestic and partner country CPIs to construct the real effective exchange rate. Trends and recent developments in measures of the real effective exchange rate using alternative price deflators such as the WPI and unit labor costs are presented in Appendix 1. In the remainder of the paper, the term "exchange rate" will refer to the CPI-based real effective exchange rate.

The top two panels of Figure 1 show the (log) levels of domestic output and the real exchange rate. Note that the real exchange rate is defined here as the external value of the domestic currency, i.e., an increase in the exchange rate indicates an appreciation of the domestic currency. The levels of these two variables are clearly nonstationary and raw correlations between the two series would not be informative. It is necessary to first derive the stationary components of these two variables, which may be interpretable as the cyclical components. The choice of the appropriate stationarity-inducing transformation is a delicate issue.[2] In this section, instead of taking a stand on the nature of nonstationarity in the two variables, we examine correlations of the stationary components of these variables using one popular filter. Formal tests for the characterization of the nonstationary components of these variables are presented in the next section.

The third panel of Figure 1 plots the cyclical components of output and the real exchange rate, where the cyclical components of both series are obtained using the Hodrick-Prescott filter, a stationarity-inducing transformation of the data that has been widely used in recent business cycle literature.[3] It shows that, during the floating rate period, the behavior of the yen has differed markedly across business cycles. Movements in the yen have been procyclical at some times and countercyclical at others. The recession induced by the oil-price shocks in the 1970s was accompanied by an appreciated yen (relative to trend), while the downturn in 1982-84 was accompanied by a considerably depreciated yen. Following the Plaza Accord in 1985, the yen appreciated very sharply and activity slowed. As activity boomed during the ensuing bubble years, the yen remained at an appreciated level before depreciating sharply in 1989-90, preceding the bursting of the asset price bubble and the slowdown in activity. During the most recent cycle, the yen appreciated persistently through the onset of the downturn in economic activity in 1992, appreciating above trend in early 1993, and rising substantially above it in the spring of 1995. The rapid depreciation starting in mid-1995 then brought the yen by October to trend. Since then, the yen has depreciated

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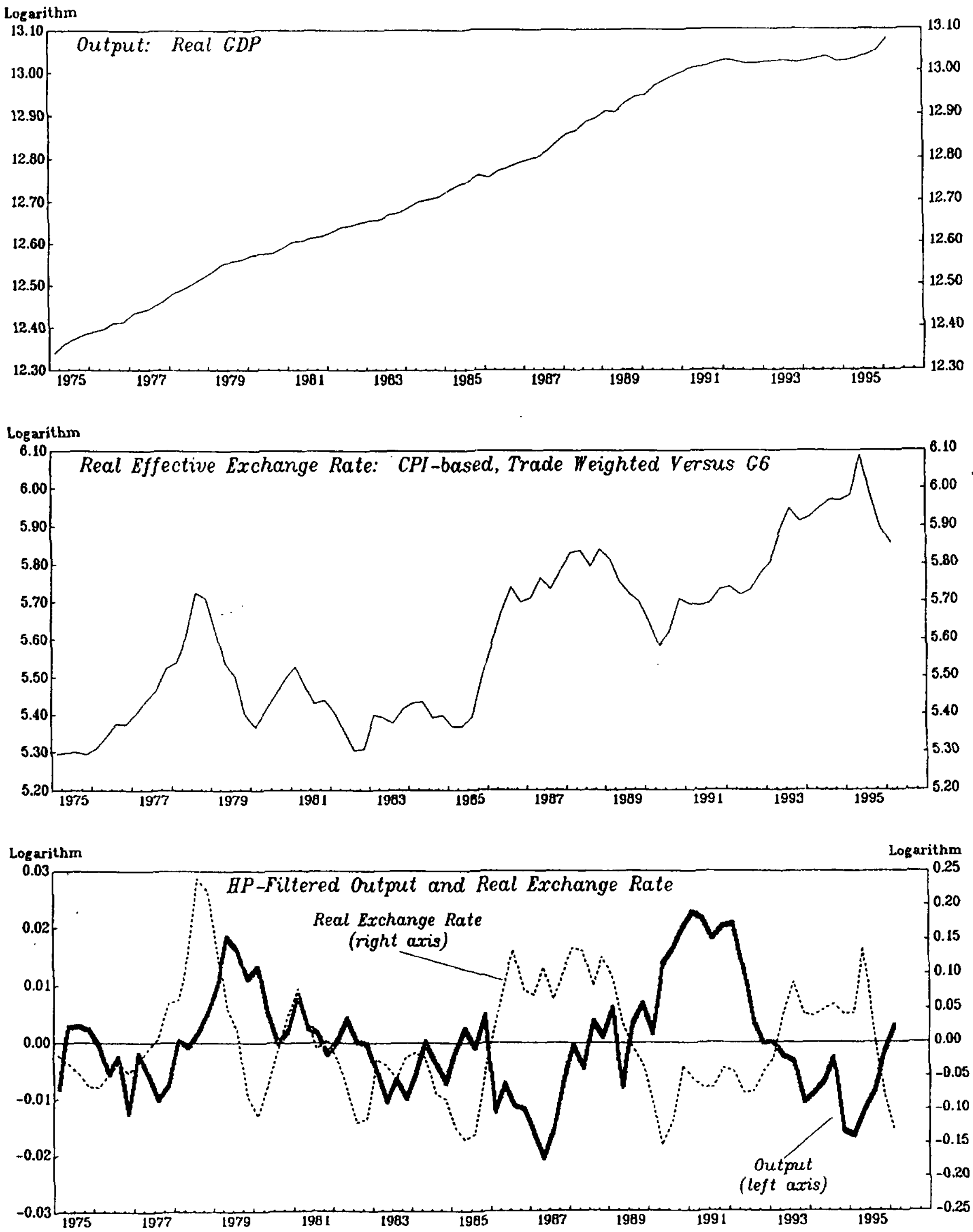
[2]See Chadha and Prasad (1994) for an example of how the choice of detrending procedure can affect the interpretation of the cyclical relationship between different economic variables.

[3]The Hodrick-Prescott filter involves solving the following minimization problem:

$$\underset{\{q_t\}}{\text{Min}} \; \frac{1}{T}\sum_{t=1}^{T}(y_t - q_t)^2 + \frac{\lambda}{T}\sum_{t=2}^{T-1}[(q_{t+1} - q_t) - (q_t - q_{t-1})]^2$$

where y_t is the original series, q_t is the trend or growth component, and $y_t - q_t$ is the residual. In our computations, we set $\lambda = 1600$ as suggested by Prescott (1986) for quarterly data. See King and Rebelo (1993) for an analysis of the properties of this filter.

Figure 1
Japan
Output and the Real Exchange Rate, 1975-1996.



Note: The HP-filtered cyclical components of output and the real exchange rate can be interpreted as percentage deviations from trend.

gradually. In order to provide a framework for interpreting the observed relationship between exchange rate variation and business cycle fluctuations, the next section of the paper provides a brief overview of the theoretical relationships between different macroeconomic shocks and real exchange rate variation.

III. THEORETICAL CONSIDERATIONS

Theory predicts that cyclical movements in the real exchange rate over the business cycle depend on the relative importance of different shocks that drive the cycle. The traditional Mundell-Fleming model in which capital is mobile predicts that autonomous contractions in aggregate demand should lower interest rates, leading to a capital outflow and a depreciation of the exchange rate on impact. Interest parity then implies that the decline in domestic interest rates translates into an expectation of future appreciation. That is, as aggregate demand recovers, and output returns to potential, the real exchange rate is expected to appreciate and return to trend. During the recessionary period, the relatively depreciated exchange rate tends to stimulate net exports and moderate the decline in aggregate demand. If the recession is induced by a monetary tightening, on the other hand, interest rates would be expected to rise, leading to a capital inflow, and the exchange rate should appreciate. Similarly, if the recession reflects primarily a contraction in aggregate supply, the real exchange rate would also be expected to appreciate. Thus, knowing the cyclical state of the economy alone is insufficient for determining where the current level of the exchange rate should be.[4]

Real economies are, of course, subject simultaneously and continuously to a variety of shocks. Therefore, only in the unlikely event that one type of shock clearly dominates for an extended period of time, would it be possible to argue a priori what the exchange rate should be at a particular point in the business cycle. The simultaneous operation of these factors complicates any informal identification of the shocks affecting exchange rates. Appendix 2 provides formal econometric evidence, using a number of standard exogeneity tests, to show that there are no obvious causal relationships between the real exchange rate and the business cycle. We interpret these results as indicating that a reduced-form approach to estimating the relationship between exchange rate and business cycle fluctuations would be inadequate.

Clearly, the relationship between the exchange rate and the business cycle is complex and, in an economy subject to a variety of shocks, this is indeed what would be expected. During the recent Japanese recession, for example, several types of shocks occurred. Moreover, their relative importance would appear to have varied over the course of the cycle. The bursting of the asset-price bubble in 1990 that led to a sharp deterioration of business and consumer balance sheets and confidence could be identified as a negative real demand shock,

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[4]Clarida and Gali (1994) present a stochastic open economy macro model that formalizes the theoretical relationships discussed in this paragraph.

suggesting that the yen should have depreciated. The bursting of the asset price bubble in 1990 was, however, preceded by a series of increases in policy interest rates, and the monetary tightening should have created pressures for the exchange rate to appreciate. Subsequently, however, monetary policy was eased and, since mid-1991, interest rates have been lowered repeatedly. Money markets were affected by a host of other factors during the period. Fragilities in the financial system and changes in the spreads between bank borrowing and lending rates as a consequence likely affected the demand for money. In addition, there is evidence to indicate that during the period there were changes in portfolio preferences, particularly those of Japanese institutional investors, for yen assets. The long recession and continued structural changes in the Japanese economy suggest also that there were shocks to the supply of output.

The relative importance of these factors in affecting the level of the yen has implications for policy. In the face of an autonomous contraction in aggregate demand, a benchmark for the stance of monetary policy, one that is "cyclically neutral," is provided by the case where the exchange rate depreciates by the amount suggested by the operation of the negative demand shock. If it was established that negative real demand factors were causing the exchange rate to depreciate, but these were being offset by negative monetary factors causing the exchange rate to appreciate, there would be a case for an easing of monetary policy.

To identify the factors driving short-run movements in the exchange rate, it is necessary to impose identifying assumptions or restrictions that impose structure on short and/or long-run movements in the exchange rate. These could be in the form of a structural model. The residuals of the equations could then be examined to assess actual short-run movements in exchange rates. The well-known failure of structural models in explaining and forecasting exchange rate movements suggests, however, that they are unlikely to provide a reliable guide to assessing short-run movements in exchange rates.[5] In addition, classification of the residuals of a structural exchange rate model into real demand, nominal, and supply shocks and, therefore, into their effects on exchange rates is not a straightforward matter. An alternative is to impose a set of parsimonious statistical restrictions that identify the shocks directly based on historical response patterns. This is the approach adopted here.

IV. Econometric Framework

Following Clarida and Gali (1994), we estimate a three-variable VAR with relative output, the real effective exchange rate, and the relative price level. As described in more detail below, three restrictions are required in order to uniquely identify a transformation of this reduced-form model that separately identifies three types of "fundamental" shocks:

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[5]For a discussion of the failure of structural models in explaining short-run exchange rate movements, see Meese and Rogoff (1983).

supply, real demand, and nominal shocks. The identifying restrictions employed here take the form of restrictions on certain long-run multipliers in the structural model. In line with standard macroeconomic models, it is posited that demand shocks (that shift the IS curve) and nominal shocks (that shift the LM curve) have no long-run effect on the level of aggregate output, yielding two restrictions. A third restriction imposed is that the real exchange rate is homogeneous with respect to nominal shocks, that is nominal shocks do not affect the long-run level of the real exchange rate.[6] Using these restrictions on the implied long-run multipliers, the errors from the reduced-form VAR model are then transformed into a set of "fundamental" structural disturbances that have an economic interpretation--nominal shocks, demand shocks, and supply shocks. An important virtue of this framework is that the short-run dynamics are left completely unconstrained. That is, all three shocks are allowed to affect any of the variables in an unconstrained manner in the short run.[7]

Before describing the implementation of the econometric model, a few preliminaries need to be discussed. As real exchange rates are affected not just by domestic macroeconomic conditions but also by conditions in other countries, relative rather than domestic measures of the business cycle and other macroeconomic conditions are relevant for the determination of the exchange rate. For Japan, relative output is defined as the level of real GDP in Japan minus a trade-weighted average of real GDP in the remaining G-7 countries. The real effective exchange rate is constructed using bilateral exchange rates vis-à-vis these countries and the same set of trade weights. The relative price level is defined as the level of the Japanese CPI minus the trade-weighted average of the CPIs in the other G-7 countries. The measures of the real effective exchange rate, relative output, and prices, are thus derived consistently.[8]

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[6]Standard open economy macroeconomic models predict that shocks in the money market that affect the level of the money supply or shift the level of money demand without affecting the long-run level of interest rates have no long-run effects on the real exchange rate. See, for example, Dornbusch (1976).

[7]Other papers that use VARs with long-run identifying restrictions in an open economy context include Lastrapes (1992), Ahmed, Ickes, Wang, and Yoo (1993), and Hoffmaister and Roldos (1996)

[8]In order to obviate problems caused by differences in units and base years across countries, trade weights were first applied to output growth rates for Japan's trading partner countries. This trade-weighted aggregate was subtracted from domestic output growth and the difference was then cumulated to derive an index for the level of relative output. A similar procedure was adopted for computing the relative price level.

A. Preliminary Data Analysis

The next step is to determine the time series properties of the variables entering the VAR. The top panel of Figure 2 shows that relative output in Japan peaked towards the end of 1991 and has fallen continuously since. This is partly because of the recent recession in Japan but also reflects the resurgence in U.S. output following the 1992-93 recession. The second panel shows a trend appreciation in Japan's real effective exchange rate, although there have been large fluctuations around this trend. Finally, reflecting Japan's relatively lower inflation rate, the bottom panel shows a steady decline in Japan's relative CPI since the mid-1970s.

Figure 2 shows that all three variables exhibited trends over the sample period. In order to derive the appropriate econometric specification of the empirical model, it is necessary to determine whether these variables are stationary around stochastic or deterministic trends. Table 1 presents a number of univariate stationarity tests for the data. The first panel of this table indicates that the null hypothesis of a unit root in each series can not be rejected against the alternative hypothesis of stationarity around a deterministic linear trend. For all three variables, the Augmented Dickey Fuller (ADF) test statistics and the test statistics for the two tests proposed by Phillips are all smaller than the 5 percent critical values. To confirm that the variables are first difference stationary, we also computed these test statistics for the first differences of each variables. In this case, the alternative hypothesis is that of stationarity around a constant term. The test statistics are all greater than their respective 5 percent critical values, confirming that all three variables are first difference stationary.

These results are consistent with the findings of other authors on the univariate time series properties of postwar Japanese real GNP. For instance, Iwamoto and Kobayashi (1992) test for a unit root in Japanese output and can not reject this null hypothesis against the alternative hypothesis of a segmented linear trend if the break point in the trend is not specified a priori. They conclude that fluctuations in Japanese real GNP are dominated by permanent shocks. Similarly, Campbell and Mankiw (1989) find that measures of Japanese relative output, measured against each of the other G-7 countries' output, exhibit a high degree of persistence, similar to the findings reported in this paper.

It is also necessary to check for cointegration among the levels of the variables used in the analysis. If the variables are indeed cointegrated, then a VAR in first differences would be misspecified. In addition, long-run relationships among the levels of the variables could then be exploited to obtain more efficient estimates of short-run dynamic relationships among the variables. Table 2 presents a number of tests for cointegration. Results for two test statistics based on Johansen's maximum likelihood procedure, Stock and Watson's tests for common trends, and Park's test procedure are presented in this table. The first three tests indicate that the null hypothesis of no cointegrating relationships among the three variables can not be rejected. Park's procedure, which tests for the null hypothesis of cointegration, indicates that the hypothesis of cointegration can be rejected at the 5 percent level.

Figure 2

Relative Output, Real Exchange Rate, and Relative Price Level, 1975-1996.

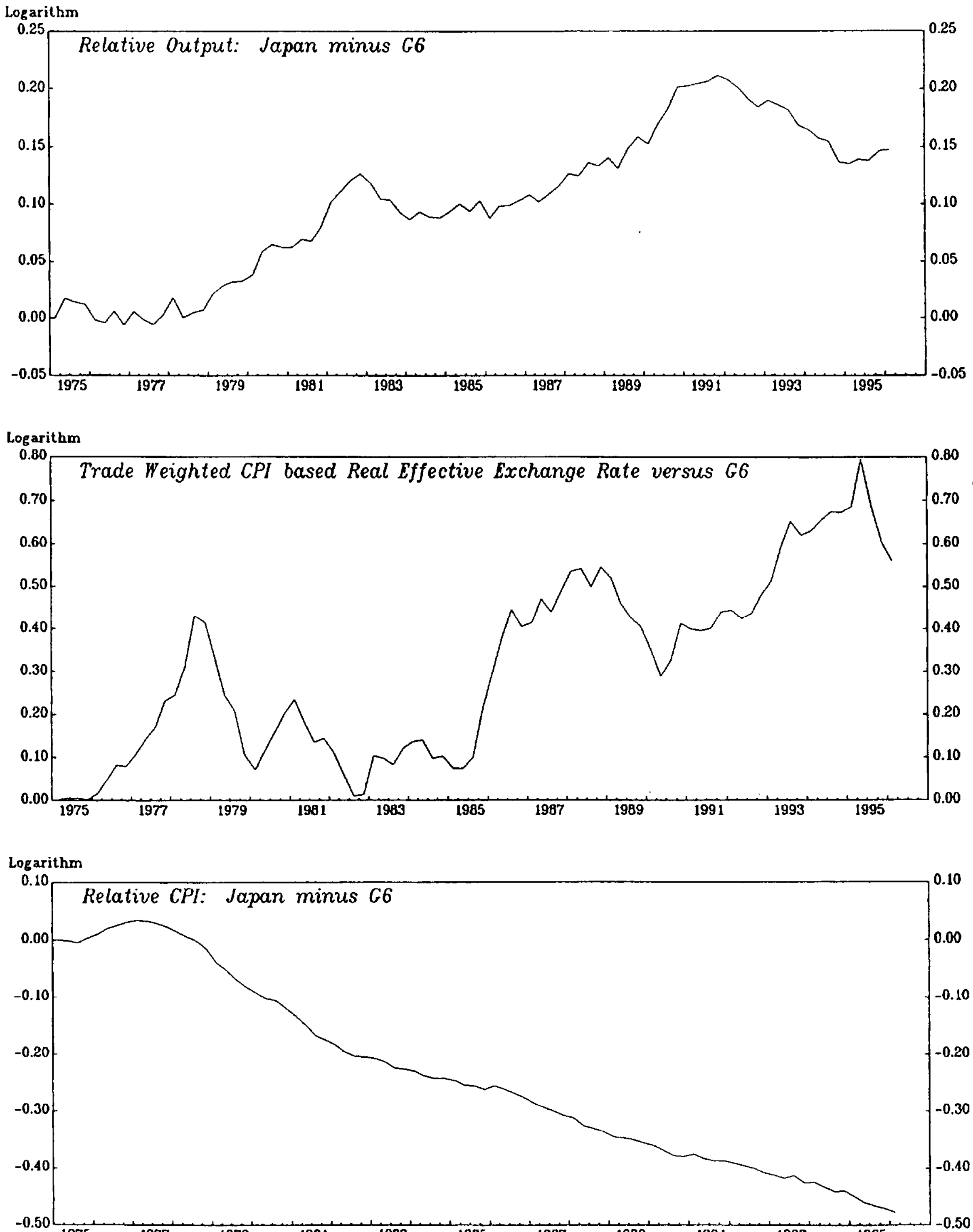

Table 1
Stationarity Tests

	LEVELS			FIRST DIFFERENCES		
	ADF test (4 lags)	Phillips Z(alpha) test	Phillips Z(t) test	ADF test (4 lags)	Phillips Z(alpha) test	Phillips Z(t) test
Relative output	−2.11	−4.78	−1.28	−3.10	−84.10	−8.69
Real eff. exchange rate	−2.70	−14.97	−2.75	−4.39	−52.24	−6.15
Relative price level	−2.58	−5.78	−1.74	−3.27	−37.41	−5.07
5 percent critical value	−3.46	−20.84	−3.46	−2.92	−13.69	−2.92

Note: Criterion is that the null hypothesis of a unit root is rejected if the test statistic is smaller (i.e., more negative) than the critical value. The regressions for testing the stationarity of the levels were run with a constant and a time trend and, for the first differences, with only a constant.

Table 2
Tests for Cointegration

Null	Alternative	Test statistic	95 percent critical value
Johansen's likelihood ratio trace statistic test			
h = 0	h = 1	22.33	29.51
h =< 1	h = 2	8.13	15.19
h =< 2	h = 3	2.22	3.96
Johansen's maximal eigenvalue test			
h = 0	h >= 1	14.20	20.78
h =< 1	h >= 2	5.91	14.04
h =< 2	h = 3	2.22	3.96
Stock–Watson common trends test (reject null if test statistic < critical value)			
h = 0	h >= 1	−9.51	−25.89
Park's test for null of co–integration			
Null	Alternative	Test statistic	p–value
h >= 1	h = 0	8.14	0.02

Note: An intercept and a time trend were included in the fitted regressions. The letter h indicates the number of cointegrating relations under different hypotheses.
The critical values for the Johansen ML test statistics are from Hamilton (1994, tables B.10 and B.11).

In summary, the three variables considered in the analysis are all found to be difference stationary and there is no evidence of cointegration among these variables. Hence, we include the (logarithmic) first differences of relative output, the real effective exchange rate and the relative CPI in the estimated VARs.

B. Implementation of the Methodology

The first step is to estimate the following reduced-form VAR:

$$B(L)X_t = \epsilon_t , \qquad \text{var}(\epsilon_t) = \Omega \tag{1}$$

where X_t is a vector containing the first differences of relative output, the real exchange rate, and relative CPI, and B(L) is a 3 x 3 matrix of lag polynomials. This VAR can then be inverted to obtain the following moving average representation:

$$X_t = C(L)\epsilon_t , \quad \text{where} \quad C(L) = B(L)^{-1} \text{ and } C_0 = I. \tag{2}$$

The objective of this methodology is to derive an alternative moving average representation of the form

$$X_t = A(L)\eta_t , \qquad \text{var}(\eta_t) = I \tag{3}$$

where the mutually uncorrelated shocks η_{1t} , η_{2t} , and η_{3t} can be interpreted as fundamental macroeconomic shocks.[9] Comparing equations (2) and (3), it is evident that $A_j = C_jA_0$ for j=1,2,...; and that $\eta_t = A_0^{-1}\epsilon_t$. Using the fact that $A_0A_0' = \Omega$ yields a set of six restrictions on the elements of the A_0 matrix since the variance-covariance matrix Ω is symmetric.

In order to identify the A_0 matrix, three additional restrictions are imposed on the system. These restrictions constrain certain long-run multipliers in the system to be zero. The long-run multipliers of the above system are denoted by the matrix $A(1) = [A_0 + A_1 + A_2 + ...]$. Using the relation derived above between A_0 and A_j for j=1,2,..., this can be rewritten as $A(1) = [I + C_1 + C_2 + ...]*A_0$, where I denotes the identity matrix. Thus, given the estimates of C_j for j=1,2...., a restriction on a particular long-run multiplier effectively imposes a linear restriction on the elements of the A_0 matrix. As noted above, we

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[9]Lippi and Reichlin (1994) raise some concerns about the interpretation of "fundamental" macroeconomic shocks that are identified from structural VARs. Nevertheless, we are encouraged by the fact that the impulse response functions from our analysis are quite similar to what we would expect from standard macroeconomic models.

assume that nominal shocks and demand shocks have no long-run effect on the level of output. In addition, we impose the restriction that nominal shocks do not have a permanent effect on the level of the real exchange rate. These restrictions constrain the (1,2), (1,3) and (2,3) elements of A(1) to be zero and, using the relation between the elements of A(1) and A_0, jointly make the A_0 matrix uniquely identified. The lower triangular structure of A(1) implies that η_{1t} , η_{2t} , and η_{3t} can be interpreted as the underlying supply, demand, and nominal shocks, respectively.

The operational procedure to derive A_0 is as follows. Given the ordering of the variables in the VAR, A(1) is lower triangular as noted above. The reduced-form model described in equation (1) is estimated and C(1) is computed, where $C(1) = [I + C_1 + C_2 + ...]$. A Cholesky decomposition then yields the unique lower triangular matrix H such that $HH' = C(1)\Omega C(1)'$. Since $\epsilon_t = A_0\eta_t$, $A(1) = C(1)^*A_0$, and $var(\eta_t) = 1$, it follows that $C(1)\Omega C(1)' = A(1)A(1)'$. Hence, we can deduce that A(1) = H. Then, given that $A_0 = C(1)^{-1}A(1)$ and $A_j = C_j^*A_0$, it is straightforward to derive $A_j \; \forall \, j = 0,1,2....$

V. RESULTS

This section presents results from the empirical implementation of the structural VAR developed in the previous section. There are a number of alternative ways of examining the effects of the estimated structural shocks on the variables in the system. We first examine the impulse responses of each of the variables to a unit positive innovation in each of the "fundamental" shocks.[10] Variance decompositions of the forecast errors based on the VAR are also examined. Finally, historical decompositions are presented that show what fraction of the in-sample variation in each series can be attributed to each of the structural shocks. Note that, since relative measures of output and prices are used in the estimation, the shocks are more appropriately thought of as relative demand shocks, relative nominal shocks and relative supply shocks. For the sake of brevity, this terminology is used sparingly below.

The unrestricted reduced-form VARs were estimated over the period 1975:1-1996:1 with eight lags of each variable in each of the three equations. This appeared to be a reasonable minimum number of lags required to adequately capture important features of business cycle dynamics. We performed a series of likelihood ratio tests to test for higher order lags. The null hypothesis that higher order lags in the VAR are insignificant could not be rejected at conventional levels of significance.[11]

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[10]By construction, the shocks are uncorrelated and have unit standard deviation.

[11]To conserve space, these results are not presented here but are available from the authors.

A. Impulse Responses

The impulse responses are presented in Figure 3. Since the variables were entered in first differences in the VAR, the resulting impulse responses were cumulated in order to derive the impulse responses shown in this figure for the levels of the variables. The top panel of this figure shows that supply shocks have a permanent effect on relative aggregate output. Demand and nominal shocks have smaller impact effects on relative aggregate output than supply shocks, and the long-run effects of these two shocks asymptote to zero. The responses of the real exchange rate are as expected.[12] A supply shock has a permanent negative effect on the level of the real exchange rate, exactly opposite to the effect of a real demand shock. Nominal shocks, on the other hand, lead to an initial depreciation of the exchange rate. The exchange rate then appreciates toward its trend level. This result is consistent with the overshooting in Dornbusch's (1976) sticky-price model. The impulse responses of the relative price level are also as expected. Demand and nominal shocks have a permanent positive effect on the relative price level while supply shocks have a permanent negative effect. Thus, the impulse responses indicate that the estimated structural shocks have reasonable properties in terms of their effects on the variables in the model.[13]

B. Variance Decompositions

Next, in Table 3 we present the forecast error variance decompositions for the estimated model. This table shows, for each variable, what fraction of the forecast error variance at different forecast horizons can be attributed to each shock in the model. The variance decomposition for the first difference of relative output is presented in the first panel. This panel shows that supply shocks are the most important factor for variation in the first differences of relative output, contributing about two-thirds of the forecast error variance at all forecast horizons. Demand shocks account for about a third of the forecast error variance

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[12]As noted earlier, an increase in the real exchange rate denotes an appreciation.

[13]The matrix of long-run multipliers of the system, which indicates the long-run effects of the different shocks on the levels of the variables in the VAR, is as follows:

$$A(1) = \begin{bmatrix} 0.0114 & 0.0000 & 0.0000 \\ -0.0340 & 0.0307 & 0.0000 \\ -0.0005 & 0.0019 & 0.0069 \end{bmatrix}$$

The zeros in the (1,2),(1,3) and (2,3) elements of this matrix indicate that the zero restrictions on the relevant long-run multipliers have been imposed successfully.

Figure 3

Impulse Responses of Output, Real Exchange Rate, and Price Level.

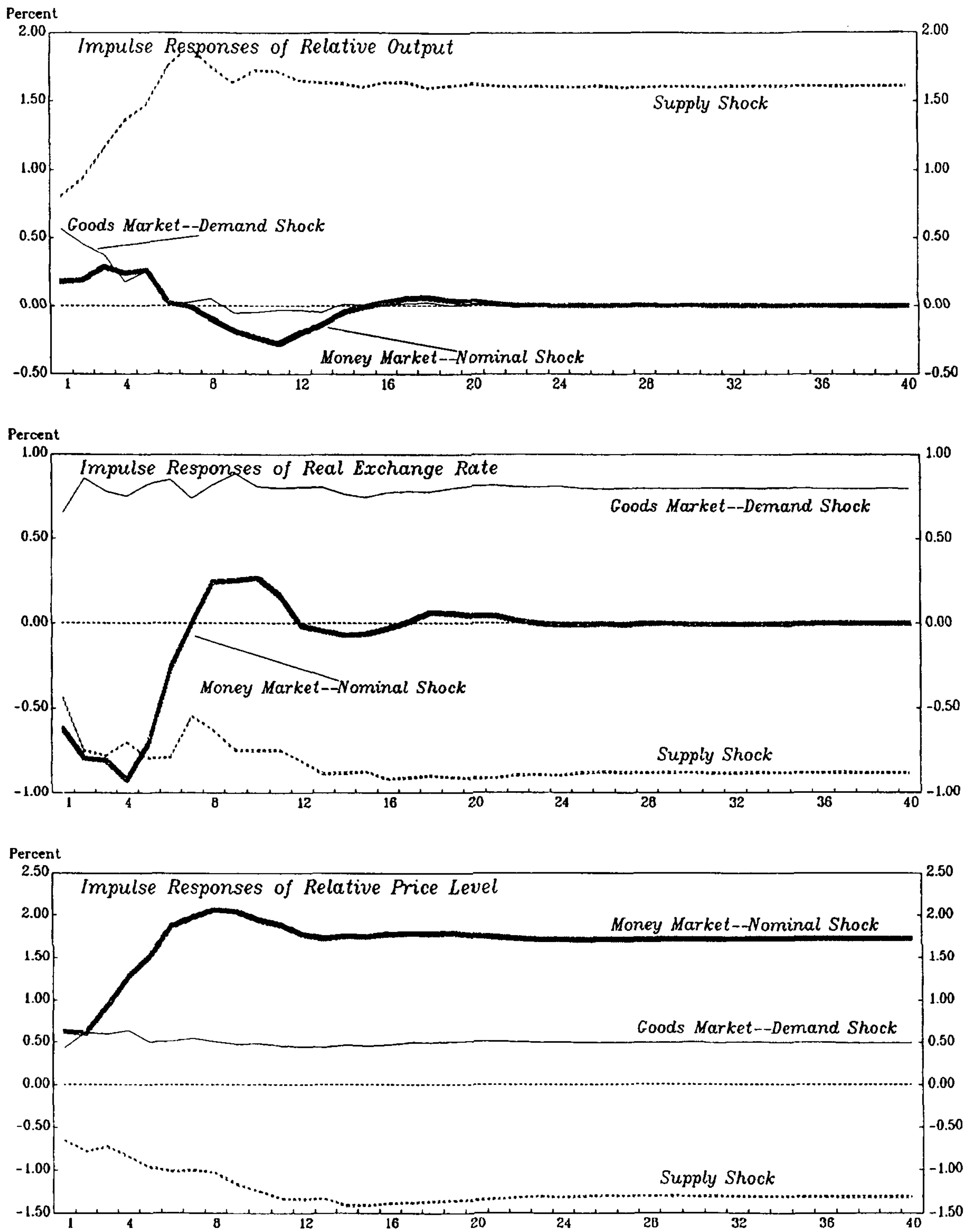

Table 3
Forecast Error Variance Decompositions for Baseline Specification
(all variables in logarithmic first differences)

Variable:	RELATIVE OUTPUT			REAL EFFECTIVE EXCHANGE RATE			RELATIVE CPI		
Shock :	Supply	Demand	Nominal	Supply	Demand	Nominal	Supply	Demand	Nominal
1	64.8 (6.6)	32.1 (6.3)	3.1 (0.7)	19.1 (8.4)	42.4 (8.1)	38.5 (7.0)	42.7 (8.3)	18.6 (5.9)	38.6 (6.9)
2	64.6 (6.4)	32.3 (6.2)	3.0 (0.7)	24.7 (8.5)	39.8 (7.8)	35.5 (6.6)	42.3 (8.2)	20.9 (5.8)	36.8 (6.5)
3	65.2 (6.1)	31.1 (5.8)	3.7 (0.8)	24.6 (8.4)	40.1 (7.8)	35.3 (6.5)	38.5 (7.7)	18.9 (5.1)	42.6 (6.7)
4	64.1 (5.9)	32.3 (5.7)	3.7 (0.8)	24.7 (8.2)	39.5 (7.7)	35.8 (6.5)	35.5 (7.6)	17.1 (4.9)	47.4 (7.0)
8	61.8 (5.5)	30.6 (5.1)	7.6 (1.5)	22.2 (6.9)	29.8 (6.1)	48.0 (6.7)	31.1 (7.1)	15.8 (4.1)	53.0 (6.8)
16	60.5 (5.5)	30.1 (5.0)	9.4 (1.9)	22.6 (6.8)	29.1 (6.0)	48.3 (6.6)	32.3 (6.8)	15.3 (3.9)	52.4 (6.6)
32	60.5 (5.5)	30.0 (5.0)	9.5 (1.9)	22.6 (6.8)	29.1 (5.9)	48.4 (6.6)	32.3 (6.8)	15.3 (3.9)	52.4 (6.6)
40	60.5 (5.5)	30.0 (5.0)	9.5 (1.9)	22.6 (6.8)	29.1 (5.9)	48.4 (6.6)	32.3 (6.8)	15.3 (3.9)	52.4 (6.6)

Notes: The forecast error variance decompositions are for the changes in each variable (i.e., first differences of log levels). These decompositions indicate the proportion of the variance of the k-period ahead forecast error that is attributable to each shock. Relative output is defined as the level of Japanese GDP minus a trade-weighted average of GDP in the other six G-7 countries. Likewise for relative CPI. The real effective exchange rate is also computed using trade weights and CPIs for the same six countries. One standard error bands for the variance decompositions are reported in parentheses. Approximate standard errors were computed using Monte Carlo simulations with 1000 replications.

and nominal shocks play only a very small role.[14]

These variance decomposition results for relative output growth presented in Table 3 are more comprehensive than in earlier studies since they allow for very general specifications of the stochastic trend in output and explicitly allow for unrestricted short-run dynamic effects of different fundamental macroeconomic shocks on output fluctuations. Nevertheless, it is useful to compare these results with results from previous studies. The results discussed above are consistent at a broad level with the findings of Yoshikawa and Ohtake (1987). Using disaggregated industry data over the period 1958-84, these authors conclude that "real shocks" are more important than monetary shocks in explaining Japanese business cycle fluctuations. However, they also argue that real demand shocks are more important than supply shocks for variation in aggregate output. One possible explanation for the different conclusion reached by these authors is that, by removing deterministic trends from the output data, the relative importance of supply shocks--that are the main determinants of long-run output fluctuations--in accounting for cyclical fluctuations is diminished. In addition, the relatively greater importance of supply shocks in the 1970s and 1980s could account for part of the differences in the results.

Using a much shorter sample period (1975-87), West (1992) finds that "cost shocks," which he interprets as supply shocks, are not very important for Japanese aggregate output fluctuations but account for almost half of the fluctuation in inventories. However, due to the small sample period, the confidence intervals around the point estimates presented by West are very large and almost no reasonable theory can be rejected statistically.[15]

We turn next to the forecast error variance decompositions for changes in the real exchange rate, presented in the second panel of Table 3. Unlike in the case of relative output, supply shocks are relatively less important for fluctuations in the first differences of the real exchange rate, accounting for only about a quarter of the forecast error variance. Nominal and demand shocks are both quite important for this variable. The relative importance of nominal shocks increases somewhat at longer forecast horizons and the role of demand shocks falls by a corresponding amount. This is similar to the results reported by Clarida and Gali (1994) using the bivariate Japan-U.S. real exchange rate and is consistent with the findings of

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[14]The forecast error variance decompositions for the *level* of relative output would, by construction, force the contribution of supply shocks to asymptote to 100 percent as the forecast horizon lengthened and the contributions of the other shocks would commensurately decline towards zero.

[15]Taylor (1989) shows that output fluctuations were smaller in Japan than in the United States over the period 1972-86 and suggests that differences in wage determination and monetary policy account for these differences in output fluctuations. Prasad (forthcoming) analyzes the relative importance of labor demand and labor supply shocks in Japanese fluctuations. For a comprehensive analysis of postwar business cycles in Japan, see Ito (1992).

other authors that nominal and real exchange rate fluctuations are closely related (see, e.g., Mussa, 1986). These results suggest, for example, that monetary and fiscal policies can have a substantial effect on real exchange rate variation at business cycle frequencies, while the role of technology and productivity shocks is relatively small.

Finally, the third panel of Table 3 presents the forecast error variance decompositions for the change in the relative price level. For this variable, supply shocks are the most important contributor to the forecast error variance at short horizons, although both nominal and demand shocks contribute a significant fraction. At long forecast horizons, nominal shocks account for the largest fraction of the forecast error variance. This result is plausible and is consistent with the view that, in the long run, the levels of output and the money supply determine the aggregate price level.

These forecast error variance decompositions indicate that supply shocks have an important role in determining the variation in all three variables. Although nominal shocks play a very small role in relative output growth fluctuations, these shocks appear to have the dominant role in determining variation in changes of the real exchange rate and the relative price level. Demand shocks determine a fairly large fraction of the variation in relative output growth and real exchange rate changes but have a smaller role in affecting relative price variation.

C. Historical Decompositions

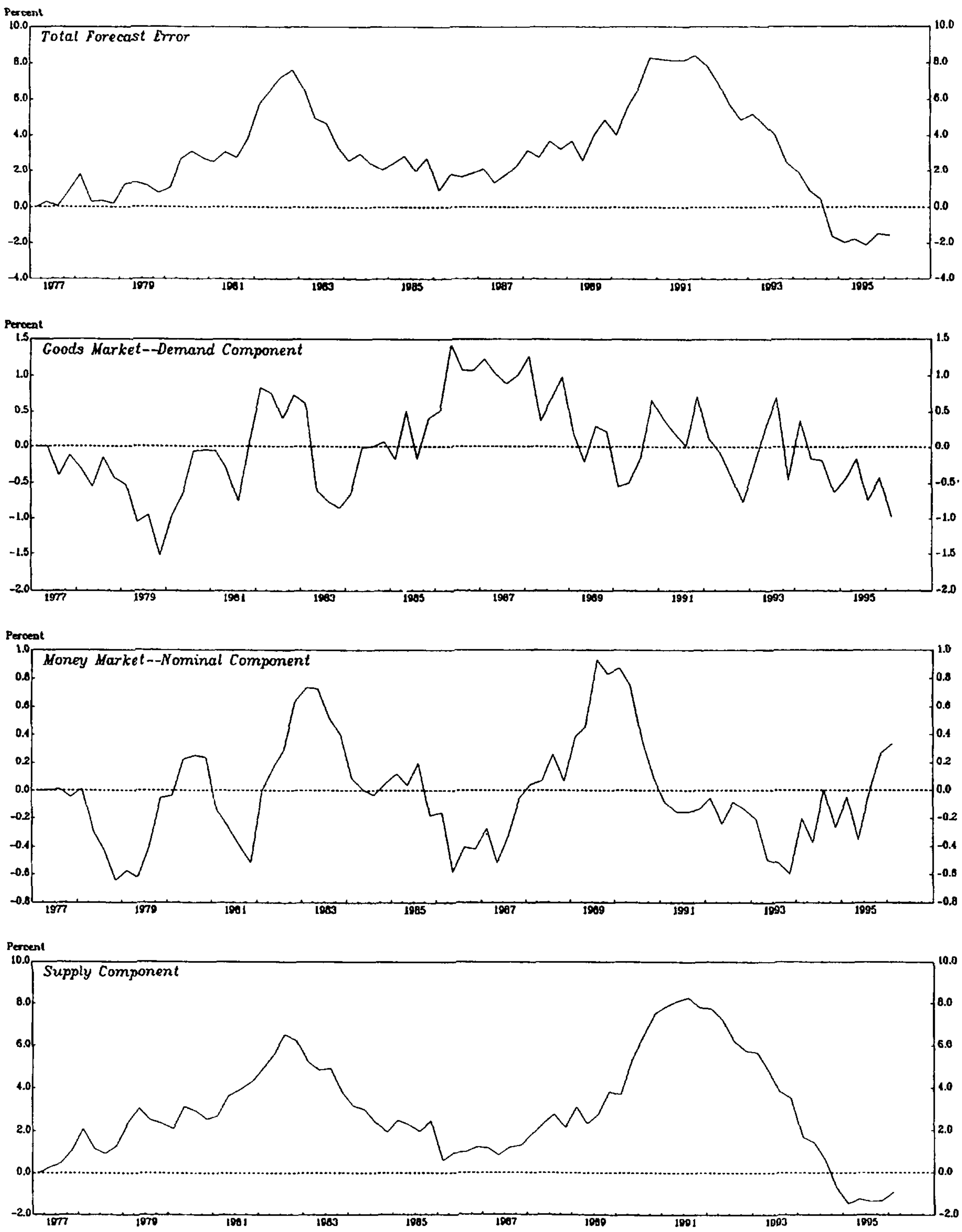
Using the estimated VARs, it is possible to construct measures of the unconditional forecast error for each variable. This forecast error is defined as the difference between the realized level of the variable and the unconditional forecast from the VAR, which is essentially a drift term. The forecast errors in the level of each variable can be decomposed into components attributable to each of the shocks.

Figure 4 plots the unconditional forecast error for relative output and shows the decomposition of this forecast error into the components attributable to the supply, demand, and nominal components.[16] Similar plots for the real exchange rate and the relative price level are presented in Figures 5 and 6. Figures 4-6 confirm several widely held notions about the shocks driving movements in output and the real exchange rate over the sample period. In the case of output, the relative real demand component of output was large and positive in 1986-88, as would be suggested by the rapid growth of demand in Japan during the bubble

[16] For relative output, the supply component defines the stochastic trend, since the other two shocks have only temporary effects on output by construction. For the real exchange rate and the relative price level, on the other hand, there can be persistent forecast errors (i.e., persistent differences between the actual levels and the respective drift terms) because of movements in either supply or the other shocks that are allowed to have permanent effects on these variables.

Figure 4

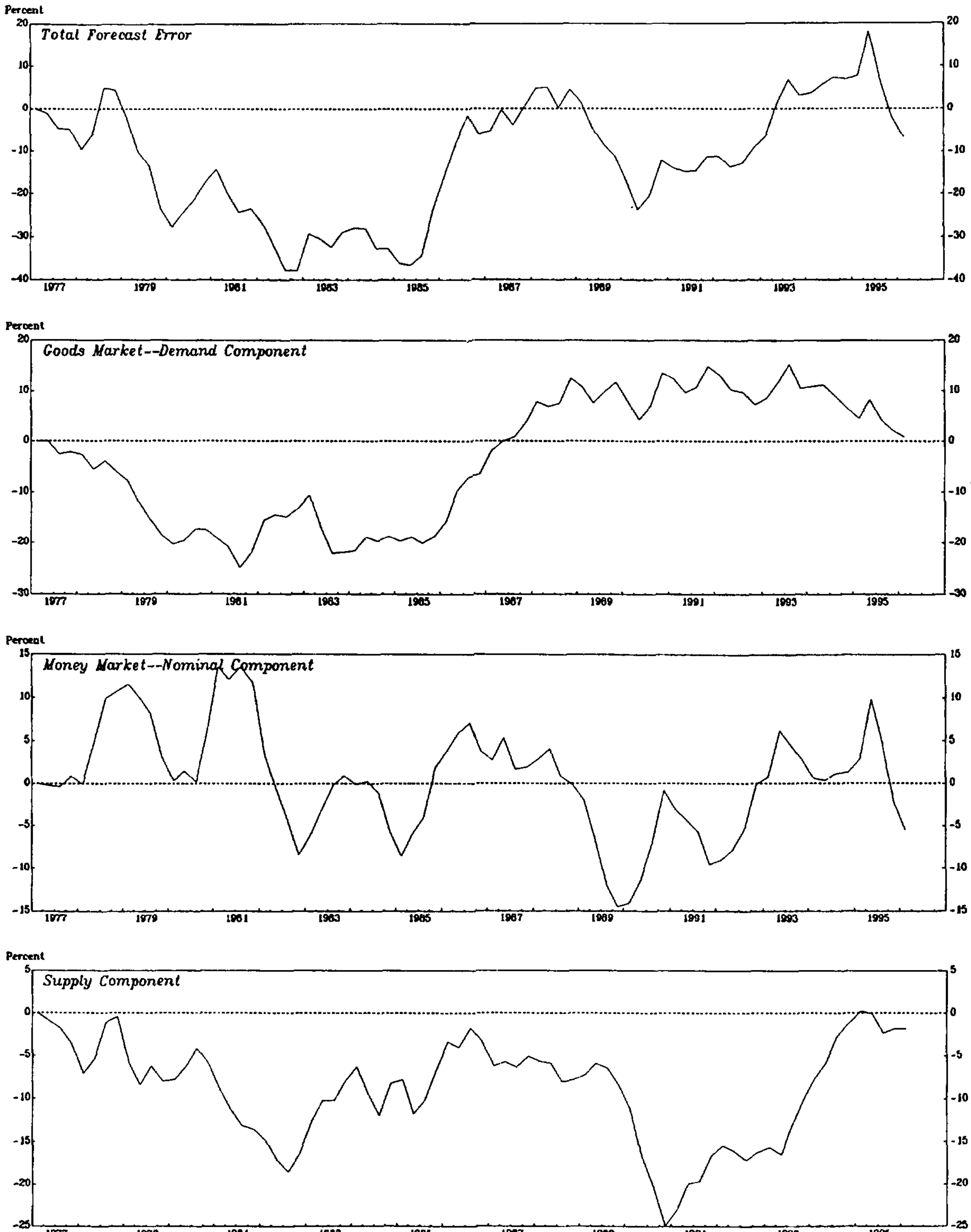
Decomposition of Forecast Errors in Relative Output.



Note: Demand, nominal and supply components sum to total forecast error.

Figure 5

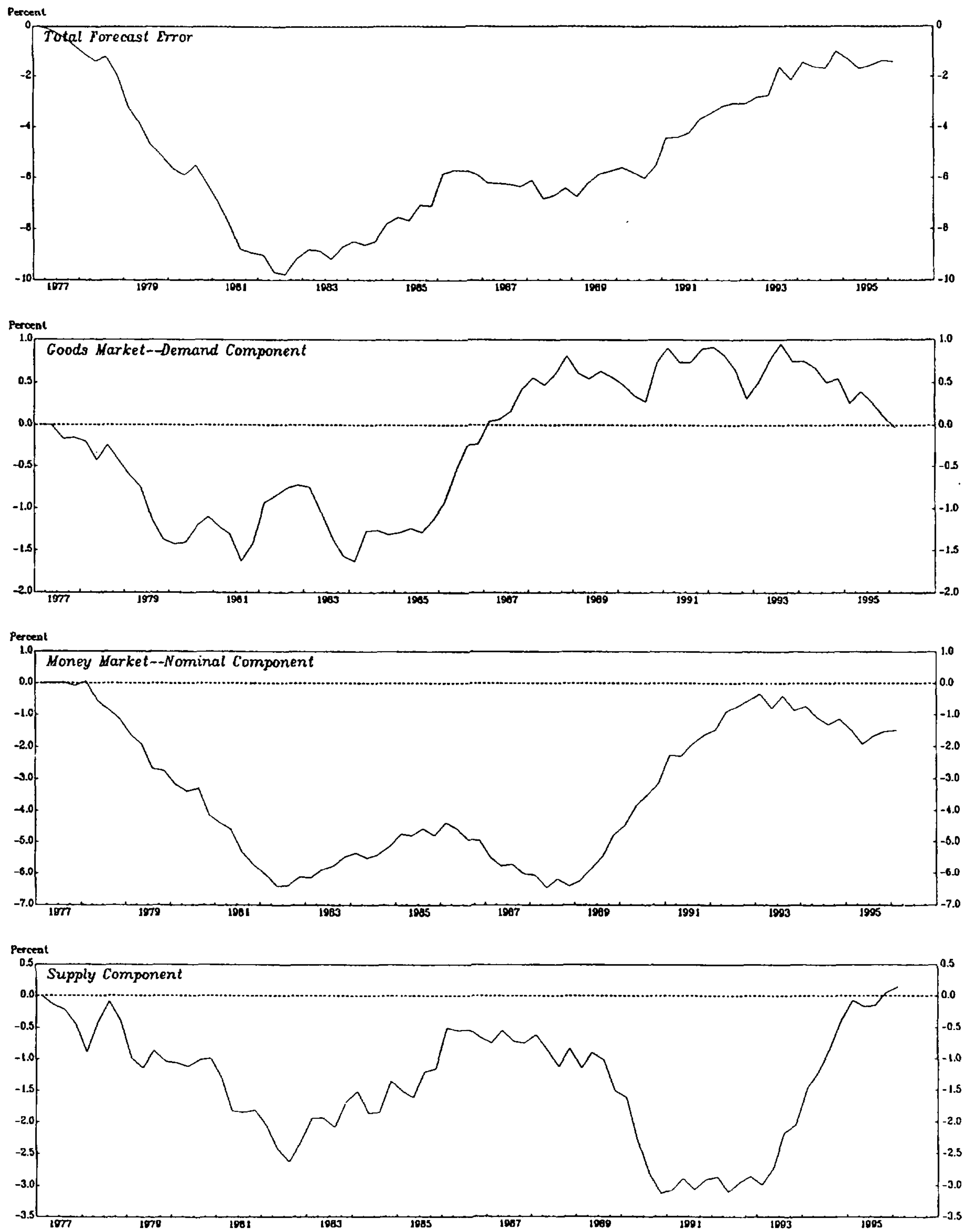
Decomposition of Forecast Errors in Real Exchange Rate.



Note: Demand, nominal and supply components sum to total forecast error.

Figure 6

Decomposition of Forecast Errors in Relative Price Level.



Note: Demand, nominal and supply components sum to total forecast error.

years. During 1990-93, the demand component fluctuated around zero, conforming with the fact that the recession in Japan has represented a stagnation rather than a sharp decline in output. Movements in the nominal component of output are particularly revealing. This component of output rose rapidly in 1988 as the bubble grew, peaking in late 1989-early 1990, and then fell sharply--as the bubble burst. It turned negative in 1991, declining through 1993, then moderated in 1994-95, before finally turning positive in the second half of 1995. This pattern confirms the view that relative monetary conditions played an important role in both creating and subsequently in the bursting of the asset-price bubble and the consequent slowing of (relative) economic activity in Japan. Moreover, monetary conditions continued to remain "tight" well after the onset of the downturn, easing only in mid-1995, following the decisive easing of monetary policy in the summer of 1995.[17]

Relative real demand factors kept the real exchange rate at a relatively depreciated level through the mid-1980s. The real demand component then rose steadily during 1986-88, and then held steady through the early 1990s, maintaining pressures for the real exchange rate to appreciate. The real demand component has declined steadily since 1993 and, by the first quarter of 1996, is estimated to have little effect on the level of the exchange rate. The nominal component caused the exchange rate to depreciate during 1989-92, but these factors were steadily reversed, and by early 1993 were causing the exchange rate to appreciate. In early 1995, nominal factors again exerted pressures for the exchange rate to appreciate. It is notable that the two spikes in the real exchange rate in mid-1993 and mid-1995 correspond closely to the spikes in the nominal component. In the first quarter of 1996, the depreciation of the Japanese real exchange rate relative to its exogenous component can be attributed primarily to nominal factors while the other components have little impact.

VI. Conclusions

This paper has examined the relationship between real exchange rate variations and aggregate business cycle fluctuations in the Japanese economy during the post-Bretton Woods floating rate period. A structural vector autoregression was used to identify three distinct types of "fundamental" macroeconomic shocks--supply, real demand, and nominal shocks--and their impact on output and the real exchange rate. The model was identified using plausible long-run identifying restrictions while allowing for unrestricted short-run dynamics in response to these shocks.

The structural decomposition indicated that supply shocks have been the primary determinant of variation in output growth, with demand shocks playing an important but subsidiary role. Real exchange rate changes, on the other hand, were driven in about equal

[17]It is perhaps worth emphasizing that the nominal shocks represent a composite relative shock to money markets. That is, they represent shocks to both money demand and to money supply relative to that in partner countries.

part by demand and nominal shocks, with supply shocks playing only a minor role. In the case of changes in the price level, supply shocks and nominal shocks account for a substantial fraction of the forecast error variance, with nominal shocks becoming more important at longer forecast horizons.

A historical decomposition of the fluctuations in each of the variables into the components attributable to the different types of shocks was also performed. These results generally accorded with conventional informal accounts of the sources of fluctuations in previous cyclical episodes. Of particular interest is the result that, over the course of the recent cycle, the contribution of real demand shocks, which created pressures for the yen to appreciate during the bubble period, declined steadily from 1993 onwards. The sharp appreciations of the yen in 1993 and 1995, and the subsequent sharp depreciation of the yen, can apparently be attributed primarily to shocks in money markets.

APPENDIX 1

Alternative Measures of the Real Effective Exchange Rate

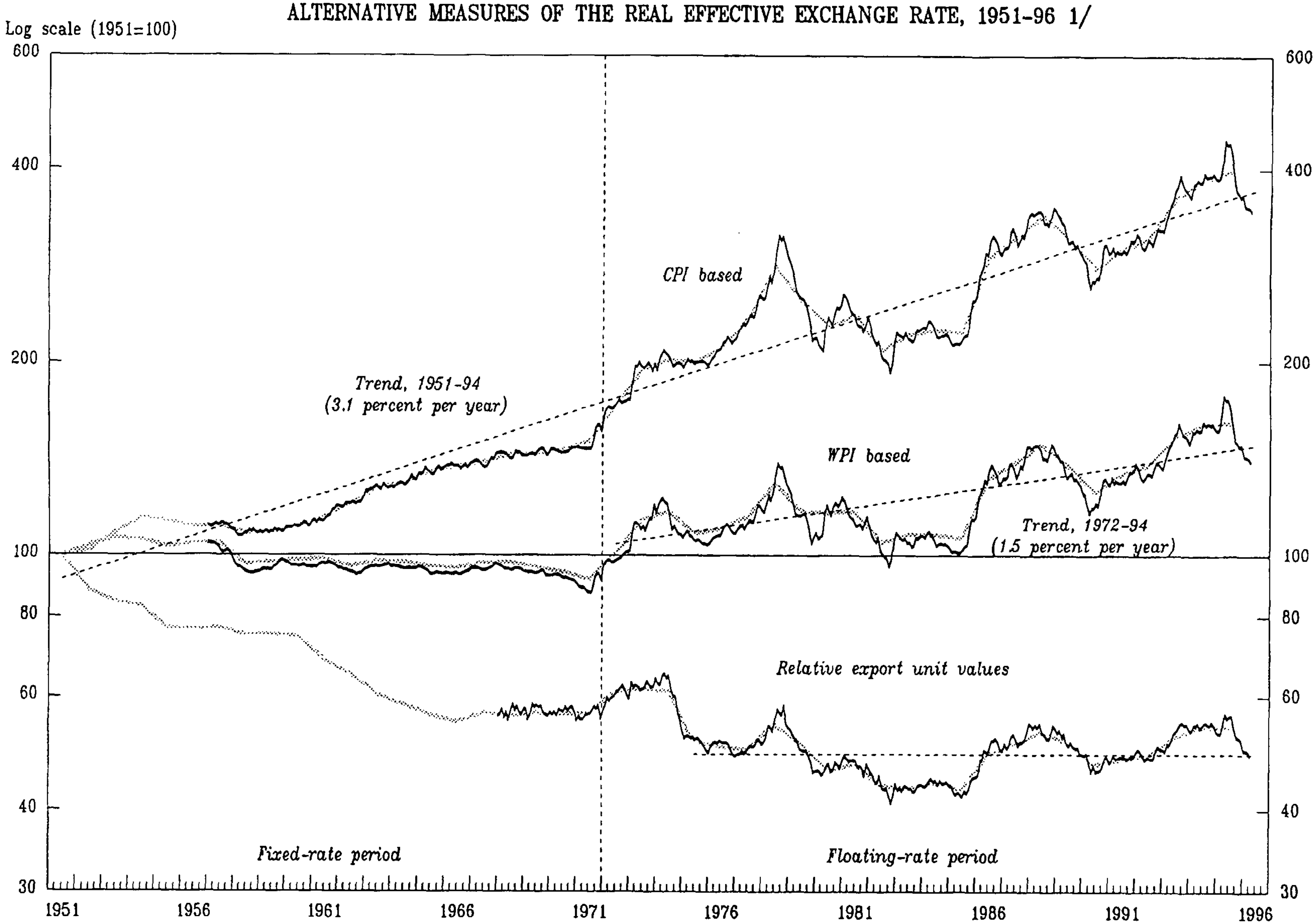
This appendix provides a brief description of historical developments in alternative measures of the real effective exchange rate for Japan.[18] Figure A1 displays data on the real value of the yen based on consumer prices, wholesale prices, and relative export unit values over the last 45 years. The Japanese CPI- and WPI-based real effective exchange rates have trended upwards during the postwar period, while the prices of Japanese exports relative to those of partner countries have fluctuated around a stable mean level during the floating rate period.

The secular appreciation of the CPI- and WPI-based real exchange rates can be explained by differential rates of productivity growth between the traded and nontraded goods sectors in Japan relative to its trading partners, while allowing it to maintain the competitiveness of its export industries (see, e.g., Hsieh, 1982, and Marston, 1987). Since short-run changes in the real exchange rate have been driven predominantly by movements of nominal exchange rates, it is notable that all three measures of the real exchange rate display similar deviations from trend (mean levels). Keeping in mind that all three measures of the real exchange rate display similar deviations from their longer-run levels, the paper focusses on the CPI-based exchange rate. As noted in the text, from a macroeconomic perspective, the CPI provides a broad measure of the price level that can be most directly linked to cyclical movements in output.

[18]For a detailed analysis of long-run movements in the yen see Chadha (1995).

Figure A1
JAPAN

ALTERNATIVE MEASURES OF THE REAL EFFECTIVE EXCHANGE RATE, 1951-96 1/



1/ CPI-base rate employs an average of G-7 partner countries; WPI-based rate employs an average of G-7 partner countries for which WPIs are available: US, GR, UK; Relative export unit values are based on G-7 partner countries.

Appendix 2

Bivariate Exogeneity Tests

This appendix first describes the test procedures for some standard exogeneity tests used in a preliminary analysis of the relationship between the exchange rate and the business cycle. The results of these tests are then summarized briefly.

Two sets of tests were implemented for examining whether variable Y is exogenous with respect to variable X (or, in slightly more loaded terminology, whether Y is 'caused' by X). The Granger causality test involves estimating the following regression by OLS:

$$Y_t = \alpha + \sum_{j=1}^{k} \beta_j Y_{t-j} + \sum_{i=1}^{m} \gamma_j X_{t-j} + \epsilon_t$$

The Granger test is essentially an F-test on the joint exclusion restriction for the coefficients γ_j, j = 1,..,m. A more robust test proposed by Geweke, Meese, and Dent (GMD) involves estimating the following regression by OLS:

$$X_t = \alpha + \sum_{j=-k_1}^{k_2} \beta_j Y_{t-j} + \sum_{i=1}^{m} \gamma_j X_{t-j} + \epsilon_t$$

GMD propose an F-test for the joint exclusion restriction on the coefficients β_j for j = -1 to $-k_1$ (where a negative lag denotes a lead). This test is implemented by regressing current X on lagged X and a two-sided distributed lag of Y and testing a joint exclusion restriction on the leads of Y.

Table A1 reports the results from these exogeneity tests run on the stationary components of output and the real effective exchange rate. These stationary components were constructed using three different filters. The Granger tests were run with eight lags and the GMD tests were run with eight lags and four leads. Adding more lags did not significantly affect any of the results.

The test statistics indicate that none of the exogeneity restrictions can be rejected at conventional levels of significance. This indicates that there are no strong causal links from output to the real exchange rate or vice versa. We interpret these results as evidence that the two variables are generally simultaneously determined. This provides the motivation for a structural rather than reduced-form approach to studying the dynamic relationship between the real exchange rate and the business cycle.

Table A1
Bivariate Exogeneity Tests:
Stationary Components of Output and the Real Exchange Rate

	Does the exchange rate Granger–cause output		Does output Granger–cause the exchange rate	
	GS test	GMD test	GS test	GMD test
HP filter	0.61 (0.76)	0.33 (0.86)	0.87 (0.55)	1.13 (0.35)
Linear trend	0.26 (0.98)	0.26 (0.90)	0.56 (0.81)	0.95 (0.44)
First difference	0.79 (0.61)	0.31 (0.87)	0.35 (0.94)	0.59 (0.67)

Notes: The table shows F–test statistics with the significance level shown in parentheses below the test statistics. The null hypothesis for the first panel is that output is exogenous with respect to the exchange rate, i.e., that the real exchange rate does not Granger–cause output. Similarly, the null hypothesis for the second panel is that the real exchange rate is exogenous with respect to output. The GS regressions were run with eight lags; the regressions for the GMD tests included eight lags and four leads.

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