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Oil prices and the rise and fall of the US real exchange rate

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Abstract

Questions of the relative importance of real vs. monetary shocks in explaining exchange rate movements still have no widely accepted answer, despite their importance both for the research agenda and for policy questions. We examine this issue using a variety of empirical techniques for the US effective exchange rate. We find that a stable link exists between oil price shocks and the US real effective exchange rate over the post-Bretton Woods period. The results suggest that oil prices may have been the dominant source of persistent real exchange rate shocks and that energy prices may have important implications for future work on exchange rate behavior. © 1998 Elsevier Science B.V. All rights reserved.

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Over the last 10 years, the main message of empirical exchange rate research has been a negative one. Surveys of exchange rate models, such as Meese (1990) and

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MacDonald and Taylor (1992), tend to agree on one central point: that existing exchange rate models are unsatisfactory. Monetary models that appeared to fit the data for the 1970s were rejected when the sample period was extended to the 1980s (for example, see Backus, 1984). Later work on the monetary approach, such as that of Meese and Rogoff (1988), found that even quite general predictions about the comovements of real exchange rates and long-term real interest rates did not seem to conform with the evidence. The application of newer time-series techniques have tended to confirm these results by showing that monetary and portfolio-balance models generally do not provide a cointegrating relationship for the exchange rate (for example, see Adams and Chadha, 1991). Finally, application of non-parametric and time-varying parameter estimation find that existing models are unable to beat a random walk consistently in out-of-sample forecasting (see for example Meese and Rose, 1991). In total, these results suggest that exploring a different model of exchange rate determination may prove fruitful.

In this article we explore the ability of real oil prices to explain movements in the US real effective exchange rate. The potential importance of the price of oil for exchange rate movements has been noted by, *inter alia*, Krugman (1983a,b) and Golub (1983). Although the models these authors present are intuitively appealing, to our knowledge very little work has carefully examined whether a stable link exists between oil prices and the US exchange rate. Advances in econometric techniques for analyzing non-stationary series made in the last few years also make a re-examination of the stylized facts seem worthwhile.

To preview our results we find: (i) significant evidence that both the real US price of oil and the US real effective exchange rate contain a unit root; (ii) these two variables are cointegrated; (iii) the price of oil Granger-causes the exchange rate and not vice versa; and (iv) a stable dynamic model using lagged real oil prices that forecasts significantly better out-of-sample than a random-walk model.

These findings contribute to several recent areas of macroeconomic research. First, they contribute to an empirical literature which suggests that energy price changes can account for innovations in major US macroeconomic variables. For example Hamilton (1983) finds that major oil price increases have preceded almost all post-WWII recessions in the United States. Dotsey and Reid (1992) show that the measure of US monetary policy proposed by Romer and Romer (1989) is coincident with several major oil price shocks and that its explanatory power for output vanishes when oil prices are included in their analysis. Loungani (1986) finds that a significant fraction of the dispersion of employment growth across different industries may be attributed to oil price shocks. To our knowledge, comparable studies of the effect of oil price movements on the exchange rate have not been done.

Second, the results would seem to present an additional test to real-business cycle (RBC) models that aim to capture macroeconomic stylized facts. Recently, the problems of expanding RBC models to an international setting has been explored by Mendoza (1991) and Backus et al. (1992). McCallum (1989) and others have emphasized the importance of including oil price shocks in RBC models. Researchers, such as Finn (1991) and Kim and Loungani (1992), have postulated a specific structural model driven by energy price shocks and examined the extent to which the model captures other important stylized facts. Evidence of a systematic relationship between oil prices and the exchange rate provides additional stylized facts for such models to attempt to capture.

Third, this study contributes to investigations into the link between real exchange rate fluctuations and real international interest rate differentials. A series of recent articles including Campbell and Clarida (1987); Meese and Rogoff (1988); Baxter (1994); Clarida and Gali (1994) and Edison and Pauls (1993) have documented the failure of real interest parity and the lack of a cointegrating relationship between real interest rates and exchange rates. This has led some to suggest that an unidentified real factor may be causing persistent shifts in real equilibrium exchange rates. Several of the above authors search for such a factor, but tests of various series including measures of fiscal policy and external indebtedness fail to produce evidence of cointegration. Evidence of a cointegrating relationship between oil prices and the exchange rate offers a potential explanation for failure of real interest rate parity.

Fourth, our evidence complements structural time-series work on the determinants of real exchange rate fluctuations. All the studies that we are aware of (Huizinga, 1987; Canarella et al., 1990; Lastrapes, 1992; Evans and Lothian, 1993; Clarida and Gali, 1994) find that non-monetary shocks seem to play a major and significant role in explaining real exchange rate fluctuations. Our results are consistent with this body of evidence, despite using a much more explicit approach to identifying the source of real shocks.

The structure of the article is as follows. In the next section we describe the data and examine its time series properties and the long-run explanatory power of oil prices for the real exchange rate. Sec. 2 investigates the apparent causal relationships between exchange rates and oil prices. In Sec. 3 we begin with a unrestricted error-correction model that is sequentially reduced until an error-correction model with reasonable properties is derived. Sec. 4 presents evidence that shows that our simple model forecasts significantly better than a random walk in out-of-sample forecasting exercises. Sec. 5 discusses the possible mechanisms whereby an oil price shock may influence the real exchange rate while Sec. 6 offers some concluding remarks.

1. Data description and cointegration results

The data we use are monthly observations of the real effective (i.e. trade-weighted) value of the US dollar and US real price of oil over the 1972.2–1993.1 sample period. The real US dollar effective exchange rate is defined in terms of the currencies of 15 other industrial countries and deflated by wholesale price indices, as calculated by Morgan Guaranty. The oil price series is the US dollar spot price of West Texas Intermediate Crude Oil deflated by the US consumer price index. Both variables are used in logarithmic form. We should note that our conclusions appear robust to the use of different price deflators and measures of the US real effective exchange rate. This is not really surprising as the different measures are highly correlated. For instance, the Morgan Guaranty 40-country and the International Monetary Fund's MERM measures of the US real effective exchange rate are over 98% correlated with the Morgan Guaranty 15-country measure. Accordingly, we simply chose the series that gave us the longest time span.

It is now common practice to examine the time series properties of economic data as a guide to subsequent multivariate modelling and inference. If we find the variables to be integrated of order greater than or equal to one then it could be the case that these variables are cointegrated (see Engle and Granger, 1987). We begin by testing the null hypothesis of an autoregressive unit root using the augmented Dickey and Fuller (1979) and Phillips and Perron (1988) tests. However, finite-sample evidence from Schwert (1987) indicates that these standard unit-root tests often have weak power against persistent alternatives, so we also use the Kwiatkowski et al. (1992) test for the null hypothesis of stationarity.[2] The unit-root and stationarity test statistics are reported in Table 1. For the both the US real effective exchange rate and price of oil, the unit-root tests are unable to find any significant evidence of stationarity while the KPSS test finds evidence of a unit root in the series that is significant at the 5% level. We therefore conclude that the real exchange rate and the price of oil can be well characterized as I(1) processes.

Next we examine whether the real exchange rate and the price of oil form a cointegrating relationship. The tests for cointegration allow us to gauge the adequacy of specifying the long-run value of the real exchange rate simply as a function of the price of oil. If the long-run real exchange rate is determined by factors other than those associated with the price of oil, then their omission should in theory prevent us from finding significant evidence of cointegration. On the

Table 1
Tests for unit-roots Augmented Dickey–Fuller (ADF), Phillips–Perron (PP) and Kwiatkowski, Phillips, Schmidt and Shin (KPSS) tests[a] (sample: 1972.2–1993.1)

Variable	ADF Lags	ADF *t*-statistic	PP *t*-statistic	KPSS
US dollar	1	−1.667	−1.673	0.550**
Price of oil	2	−2.103	−2.503	0.686**

[a] Henceforth, ***, ** and * indicates significance at the 1, 5 and 10% levels, respectively. We tested each series for statistically significant evidence of drift using the general-to-specific testing strategy proposed by Perron (1988). No evidence of drift is found for any of the variables. The ADF test critical value (CV) is calculated from MacKinnon (1991), the PP test CV is taken from Fuller (1976) and the KPSS test CV from Kwiatkowski et al. (1992). For the ADF test we used a data-dependent lag length selection procedure advocated by Ng and Perron (1995) and a 5% CV. The initial number of AR lags is set equal to the seasonal frequency plus one or 13. The PP and KPSS tests are calculated using the VAR(1) prewhitened quadratic kernel long-run variance estimator developed by Andrews and Monahan (1990).

[2] Monte Carlo analysis by Amano and van Norden (1992) shows that this type of joint-testing procedure can substantially reduce the frequency of incorrect conclusions about a series' data generation process.

Table 2
Johansen–Juselius test for cointegration[a] (estimation under assumption of restricted drift; number of lags = 4)

Number of cointegration vectors	Trace statistic	λ Max. statistic
≥ 1	23.511**	17.448**
≥ 2	6.063	6.063

[a]We perform testing under the assumption of restricted drift since a likelihood ratio test of this restriction under the maintained hypothesis of one cointegrating vector cannot reject the restriction even at the 10% level. The critical values are taken from Johansen and Juselius (1990). Appropriate lag lengths are determined using standard likelihood ratio tests with a finite-sample correction. We begin with 13 lags and tested down.

other hand, evidence of cointegration implies that the price of oil captures the dominant source of persistent innovations in the real effective exchange over this period.

To test for cointegration we use the systems approach developed by Johansen and Juselius (1990). Monte Carlo work by Gonzalo (1994) suggests that the Johansen and Juselius (JJ) approach performs better than both single equation and alternative multivariate methods in detecting cointegration. The JJ test results, reported in Table 2, show significant evidence of cointegration regardless of which test statistic we use, suggesting that the real effective exchange rate is cointegrated with real oil prices.[3]

In sum, the results so far suggest that the US real effective exchange rate and the US price of oil are both integrated of order one and are jointly cointegrated.[4] This has a number of interesting implications. First, finding significant evidence of a unit root in the real effective exchange rate (rather than just failing to reject the null hypothesis of a unit root) is itself interesting evidence against the hypothesis of long-run Purchasing Power Parity (which would require that real exchange rates be stationary). Second, the fact that the price of oil and the exchange rate have trended together over time is a challenging feature of the data for RBC models to try to capture. Third, our results also bear directly on the failure to find cointegration between real exchange rates and international real interest rate differentials. While Baxter (1994) and Meese and Rogoff (1988) suggest that their inability to

[3]These conclusions are robust to drift and no-drift assumptions.

[4]To those sceptical about the reliability of tests for unit roots or cointegration, we would make three observations. First, our principal conclusions about Granger-causality (Sec. 2), about the validity of the error-correction model (Sec. 3) and about the model's out-of-sample forecasting performance (Sec. 4) would be unchanged if we were to assume that both data series are stationary instead of I(1). Second, we have avoided many potential sources of size distortion in these tests by using data-dependent lag truncation parameters (see Ng and Perron, 1995) and avoiding over-parameterization in the VAR for the cointegration test (see Godbout and van Norden, 1997). Third, the low power of unit-root tests cannot explain why we find significant evidence of unit roots in both series.

find evidence of cointegration between the two variables is due a omitted real variable, the evidence presented above suggests otherwise. Our evidence of cointegration between the price of oil and the real exchange rate suggests that real interest rate differentials are not part of any long-run relationship with the real exchange rate and that at most they explain only short-run exchange rate movements. We explore this possibility further in Sec. 3. For the time being we simply note the possibility that real interest rate differentials may be I(0) instead of I(1). While standard tests typically find no significant evidence of stationarity in long-run real differentials, we know of no significant evidence of unit roots in them either, suggesting that the data may simply be uninformative. This would certainly be more consistent with models of long-term international capital flows, which lead us to expect a convergence in real interest rates across nations over time.

2. Causality results

In this section we investigate the issue of causality. From Engle and Granger (1987), we know that cointegration implies that at least one of our two variables must Granger-cause the other (bi-directional causality is also a possibility). Understanding the apparent causal relationship in the data is interesting both for econometric and economic reasons.

On the econometric side, Granger-causality has important implications for inference and for evaluating the accuracy of conditional forecasts. Johansen (1992) shows that one of the conditions necessary to perform inference in a single-equation framework is weak exogeneity of the cointegrating variables with respect to the first variable under consideration. Ericsson (1992) notes that valid predictions from a conditional model require strong exogeneity (i.e. both weak exogeneity and Granger-causality). If this were not the case, then it is possible for a misspecified model to give better conditional forecasts than a correctly specified model. For example, it has become common practice to compare the forecast performance of structural exchange rate models to that of a random walk. However, if the model's forecasts use information on future values of variables that may be Granger-caused by the exchange rate (such as relative price levels, output, trade balance, etc.), then even misspecified models should be able to out-perform a random walk.

Causality might also shed light on the economic mechanism creating the long-run link between oil prices and the US exchange rate. For example, it could be argued that the US dollar exchange rate causes fluctuations in US dollar oil prices, not vice versa.[5] Finding that Granger-causality runs from oil prices to the exchange rate and not the reverse would be evidence against such a mechanism. However, even if oil prices are not affected by exchange rate movements, we might still expect to find that exchange rates Granger-cause oil prices. For example, if forward-looking agents treat exchange rates as asset prices, then they should

[5]For a simple theoretical model of this effect see Boughton et al. (1986).

Table 3
Johansen weak exogeneity tests

Variable	Test statistic	Significance level
US dollar	10.680	0.3E-03
Price of oil	0.799	0.371

reflect all publicly available information, including future expected changes in oil prices. However, if oil prices have predictive power for subsequent exchange rate changes, this raises the question of whether exchange rates properly incorporate all available public information.[5,6]

Our first step in testing for causality is to test for 'long-run causality', or more accurately, whether the real price of oil is weakly exogenous in the sense of Engle et al. (1983). This can be tested using the likelihood-ratio test described in Johansen and Juselius (1990). The results, shown in Table 3, imply that the price of oil is weakly exogenous, while the real exchange rate is not. In other words, in the long-run the level of the real effective exchange rate adjusts to the price of oil and not vice versa.

Next, we test for causality in the more general sense of standard Granger-causality using standard tests on the vector autoregression level representation of our system. As demonstrated in Sims et al. (1990), standard inference procedures are valid in this case under the maintained hypothesis of one cointegrating vector and provided that we test the exclusion restrictions on one variable at a time. Since all results are based on asymptotic approximations, we use the limiting χ^2 critical values instead of their more common F-distributed counterparts.

The results from our tests are reported in Table 4. They indicate that while the price of oil Granger-causes the real exchange rate, there is no evidence to support the converse. This is consistent with the weak exogeneity results mentioned above. Therefore the causality results suggest that, even though the price of oil is typically quoted in US dollars, movements in the external value of the US dollar have no significant effect on the price of oil. This conclusion is consistent with the results of Hamilton (1983), who uses Granger-causality tests with a wide range of US macroeconomic variables and finds support for the proposition that oil price shocks are exogenous to the United States. Similar conclusions have been reached by Burbidge and Harrison (1984) and Mork (1989).

Although this result may be counter-intuitive to some, a review of the behaviour of real oil prices (Fig. 1) over the most recent floating exchange rate period shows

[6] If exchange rate movements are predictable, then at least one of the following statements must be true: (a) some of these predictable variations are offset by variations in international interest rate differentials so that there is no opportunity to make financial profits; (b) some of these predictable variations are offset by variations in foreign exchange risk premiums so that there is no opportunity to make economic profits; or (c) foreign exchange markets are inefficient in the sense that, using publicly available information, there are unexploited profit-making opportunities.

Table 4
Granger-causality tests[a]

Dependent variable	Number of lags	Independent variable	Significance level
US dollar	4	Price of oil	0.001
Price of oil	4	US dollar	0.906

[a] Lag lengths were selected on the same basis as in footnote a, Table 2. However, the conclusions are robust for lag lengths 1–13.

that the series is dominated by major persistent shocks around 1973–1974, 1979–1980 and 1985–1986, with another large but transitory shock in 1990–1991. The historical record offers us a very plausible explanation for these shocks; that they are supply-side shocks that are themselves the results of political conflicts specific to events in the Middle East.[7] Note that we are not arguing that oil prices (or the stability of cartels) are immune to the laws of supply and demand or that they cannot be affected by shifts in the growth rates of the industrialized world.

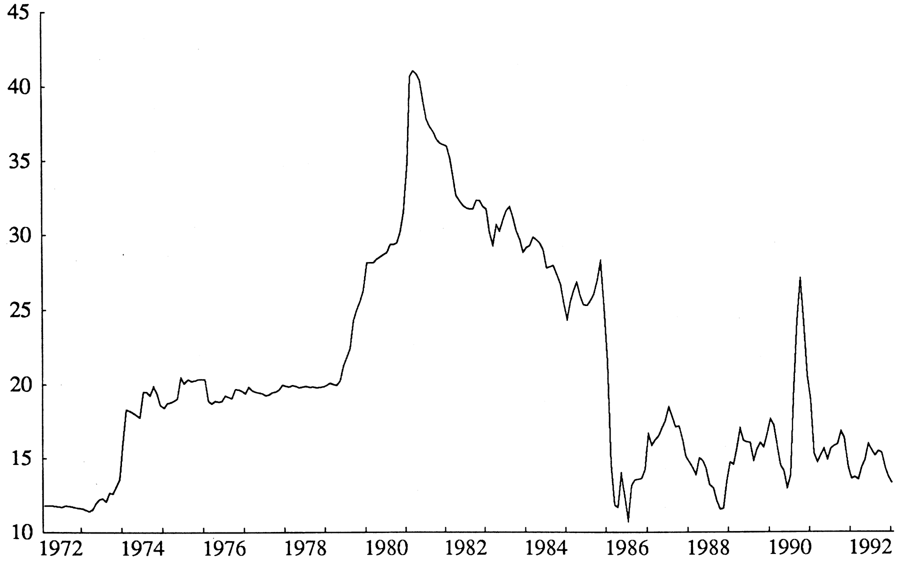

Fig. 1. The real US dollar price of oil based on 1983 US dollars.

[7] Specifically, the 1973–1974 episode corresponds to the OPEC oil embargo following an Arab–Israeli war, the 1979–1980 episode was due to supply changes associated with the Iranian revolution, the 1985–1986 change was due to the fallout of the Iran–Iraq war on OPEC solidarity and the temporary 1990–1991 shock was the result of the Gulf War. Attributing any of these Middle Eastern conflicts in turn to macroeconomic developments in the G-7 would be literally incredible.

Instead, we feel that there is ample reason to believe that such demand-side factors have been small relative to the supply shocks experienced over the last 20 years and that the supply shocks have been exogenous in the sense of most macroeconomic models.

3. An error-correction model

In this section we determine how well the dynamic process generating the US real exchange rate can be captured by a single-equation error-correction model (ECM). According to the Engle and Granger (1987) Representation Theorem, the presence of cointegration in a system of variables implies that a valid error-correction representation exists. This theorem together with the evidence of weak exogeneity found above suggests that we can use a single equation error-correction representation without the loss of either efficiency or the ability to perform proper inference.[8] In general, we can write the single equation ECM as

$$\Delta Y_t = \alpha(Y_{t-1} - X_{t-1}\beta) + \sum_{i=0}^{k} Z_{t-i}\gamma_i + \epsilon_t, \quad (1)$$

where $Y - X\beta$, represents the error correction mechanism and the parameter α gives the speed of adjustment towards the system's long-run equilibrium; Z represents a matrix of stationary variables, possibly including contemporaneous and lagged differences of X and Y, that attempts to capture the short-run dynamics of the dependent variable; β and γ are vectors of parameters while ϵ is an error term.

In our model, Y is equal to the real exchange rate (RE) and X represents the price of oil (POIL). We define Z to include the lagged dependent variable, an international interest rate differential measure and the first differences of the real price of oil.[9] In preliminary work we tried three different measures of an interest rate differential, viz. (i) US vs. Japan; (ii) US vs. Germany; and (iii) a weighted measure constructed to reflect the make-up of the effective US real exchange rate.[10]

We set $k = 12$ and estimate Eq. (1) over the 1972.2–1985.12 sample period using non-linear least squares. The estimation sample is truncated early to allow us to perform out-of-sample forecasting exercises with the remainder of the data. We

[8] According to Johansen (1992), if the price of oil is weakly exogenous with respect to the real exchange rate, then estimation and inference on a single equation will be asymptotically equivalent to that on the full system. See Phillips and Loretan (1991) for a discussion of inference in an ECM under the assumption of weak exogeneity.

[9] Augmented Dickey and Fuller (1979) and Phillips and Perron (1988) tests find the dependent variable, the interest rate differentials and the first difference of the price of oil to be stationary. In order to capture better the stance of monetary policy, the interest rate measure for each nation is defined as the difference between their short and long rates. Results did not seem to be sensitive to this definition.

[10] Precise interest rate differential defintions are available from the authors upon request.

Table 5
Error-correction model results [$\Delta RE_t = \alpha(RE_{t-1} - \beta_0 - \beta_1 \mathrm{POIL}_{t-1})$; sample: 1972.2–1985.12]

	Parameter estimate	Standard error	t-Statistic
Adjustment	−0.028	0.013	−2.087
Constant	3.033	0.707	4.290
Price of oil	0.513	0.230	2.233
Residual diagnostic tests[a]			
LM(1)	0.073	ARCH(1)	0.056
LM(4)	0.707	ARCH(4)	0.101
LM(12)	0.179	ARCH(12)	0.804
Kurtosis	0.12E-4	Skewness	0.328

[a] Reported values are the marginal significance levels.
LM(k) represents Lagrange Multiplier tests for autocorrelation of order k.
ARCH(k) represents autoregressive conditional heteroskedasticity tests of order k.

reduce the dynamics of the ECM by successively omitting variables with the lowest t-statistics and re-estimating. The resulting ECM (reported in Table 5) is simply:

$$\Delta RE_t = \alpha(RE_{t-1} - \beta_0 - \beta_1 \mathrm{POIL}_{t-1}). \tag{2}$$

Despite the remarkably simple specification, the R^2 statistic indicates that the price of oil can account for 6.7% of the month-to-month variation and most of the longer horizon systematic movements in the real exchange rate. Specifically, the residual diagnostic tests yield little evidence of autocorrelation and autoregressive conditional heteroskedasticity (see residual diagnostic tests in Table 5).[11] The test for kurtosis, however, forces us to reject the null hypothesis of no kurtosis. We note that such a result is common in financial time series and that given our large number of observations and the absence of serial correlation, this is unlikely to affect our inference. As for the parameter estimates, the speed of adjustment term (α) is − 0.028, indicating that approx. 28.6% of adjustment toward the long-run equilibrium is completed within 1 year, giving a half-life of 2.1 years. A 1% increase in the price of oil will lead to an 0.513% appreciation of the dollar in the long-run. For now we simply note that this result is consistent with a variety of economic models and defer discussion of its interpretation to Sec. 5. It is noteworthy that the long-run parameter estimate from the single equation approach is within one standard error of its estimated value of 0.42 from the Johansen and Juselius (1990) system estimation approach.

Fig. 2 presents both in-sample and out-of-sample dynamic simulations of the specification starting in 1972.2. The simulations to the right of the vertical line at 1986.1 are post-sample dynamic simulations. It is readily apparent that the ECM tracks the realized values reasonably well both in- and out-of-sample. This again

[11] Since there is evidence of non-spherical residuals at the10% level, we re-estimated our ECM with Newey and West (1987) standard errors. This did not change the significance of the parameter estimates.

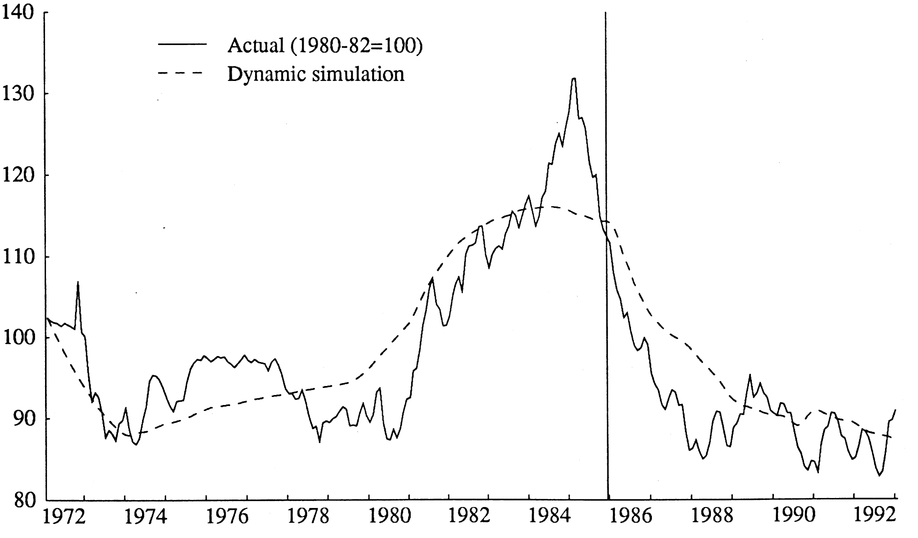

Fig. 2. Dynamic simulation of the ECM.

suggests that the long-run value of the real exchange may adequately be specified as simply a function of the price of oil.

Another criteria of a model's adequacy is parameter stability over the sample period. As Hendry (1979) has shown, dynamic misspecification can be critical to the stability of an equation, so parameter instability may suggest that the specified dynamic structure is inadequate. Therefore we use a sequential Chow test to determine the stability of our ECM over the 1972.2–1993.1 period. Note that this sample period includes data that were not used in the specification of our final ECM. The results from the sequential Chow test (Fig. 3) suggest that the specification is stable over the sample period.[12]

The results of this section show that consideration of the effects of oil price changes can lead to a simple, stable model of exchange rate changes with good apparent explanatory power, particularly at lower frequencies. Taken together with the results on cointegration and causality presented previously, this suggests that oil price effects have the potential to improve the performance of structural exchange rate models, a possibility that we explore further in the next section. We were surprised, however, by our failure to find any significant role for the real interest rate differentials in explaining even transitory exchange rate changes. It is possible that this is due to our particular measures of the real interest rate and that the use of other proxies for unobserved expectations of inflation might alter this

[12]Andrews (1993) points out that if a break point is determined by a search over the sample, then the standard critical values are smaller than the appropriate values and inference is biased against the null of stability. To control for this effect we use critical values calculated by Andrews (1993).

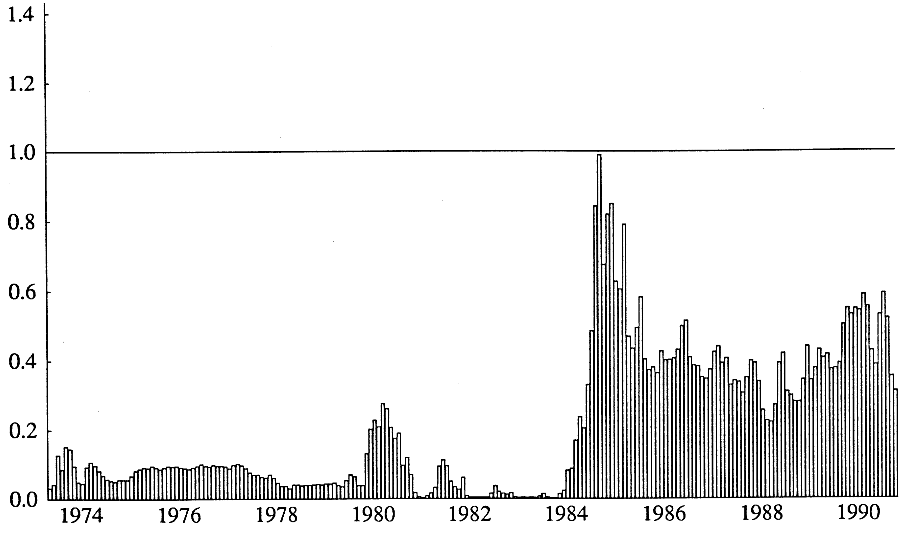

Fig. 3. Sequential Chow-test statistics normalized to 1.0 using the 5% critical value.

conclusion. On the other hand, it is broadly consistent with the limited explanatory power of this variable reported by Campbell and Clarida (1987); Meese and Rogoff (1988); Edison and Pauls (1993) and Clarida and Gali (1994). It is also possible that the limited explanatory power of real interest rates at medium-to-low frequencies that Baxter (1994) reports may be captured more effectively by the oil price variable.

4. Can we forecast exchange rate changes?

In Sec. 2 we established the strong exogeneity conditions required to perform valid out-of-sample forecasting comparisons. Therefore we now consider the ECM's ability to forecast out-of-sample exchange rate changes. First, we follow the methodology used by Meese and Rogoff (1983) and compare the out-of-sample forecasts produced by the ECM to those generated by a random walk. Specifically, we begin by estimating the specifications on data up to 1985.12 and then generating forecasts for all monthly horizons up to 24 months using realized values of POIL. Another month of data is then added, the equation is re-estimated and new forecasts are generated for all horizons. This process is repeated until the end of our data set (1993.1). Finally, forecast errors are then calculated for all estimation periods and all horizons. Table 6 reports Theil's U-statistic which is the ratio of the model forecast's root-mean-squared-error (RMSE) to the RMSE of a random walk forecast. Values less than 1 therefore imply that the model performs better than a random walk while values greater indicate the reverse. The U-statistics suggest that

Table 6
Theil's U-statistic for forecast comparisons: model-based vs. random walk (starting point: 1986.1)

Horizon	1	2	4	12	24
U-statistic	0.973	0.957	0.927	0.806	0.694

the ECM performs better than the random walk over the forecasting sample, with the model's performance improving slowly as the forecasting horizon increases.

While the results for the ECM are suggestive, it would be useful to determine whether the model forecasts significantly better than a random walk. To address this issue we now turn to the concept of forecast encompassing, which allows us to test formally the forecast performance of different models.[13] A model is said to encompass a competing formulation if its forecasts help to predict the forecast errors of its competitor, but its competitor's forecasts give no information about the first model's forecast errors. Tests of forecast encompassing are easily calculated, based on an artificial regression involving only forecasts and their errors

$$u_t^{\mathrm{A}} = \alpha + \beta(F_t^{\mathrm{A}} - F_t^{\mathrm{B}}) + \epsilon_t, \tag{3}$$

where u_t^{A} is the forecast error from model A, F_t^{B} and F_t^{A} the forecasts of model B and A, respectively, α and β are parameters. If β is statistically significant, this implies that model B forecast encompasses model A, suggesting that model B provides information not admitted by model.[14] In Table 7 we report the marginal significance level associated with the t-statistic on β from OLS estimation of Eq. (3). Since fully efficient multi-step forecasts are linear combinations of the one-step ahead forecasts, only the one-step ahead forecast need be considered here. The

Table 7
Forecast encompassing tests[a] (starting period: 1986.1)

Hypothesis	$\alpha = 0$	$\beta = 0$	$\alpha = \beta = 0$
Model	0.903	0.044	0.012
Random walk	0.902	0.884	0.943

[a] Reported values are the marginal significance levels. 'Model' indicates that we are testing the null hypothesis that the ECM does not forecast encompass the random walk where as 'random walk' indicates that we are testing the null hypothesis that the random walk does not forecast encompass the ECM.

[13] For general expositions on forecast encompassing see Chong and Hendry (1986).

[14] Since we are comparing our model (A) to a random walk (B), Eq. (3) simply suggests regressing the ECM's forecast errors on its predicted exchange rate changes. If β were significantly different from zero, this would imply that the ECM's forecasts are systematically over- or under-predicting the amount of exchange rate movement. When we reverse the test to see if the ECM encompasses the random walk, we simply change the dependent variable from the ECM's forecast errors to actual exchange rate changes.

results imply that the ECM forecast-encompasses the random walk, suggesting that our simple specification provides us with additional information relative to a random walk.

One potential criticism of these forecast-encompassing tests is that they rely on inference in small samples where non-normality is suspected, yet inferences are based on the assumption of normality. To avoid this problem, we consider a non-parametric test recently proposed by Pesaran and Timmermann (1992).[15] The test examines the predictive accuracy of a set of forecasts to predict the direction of the change in a variable. Since the test is non-parametric, it does not require assumptions about the distribution or the parameters of the sampled population. Pesaran and Timmermann (PT) derive the test statistic and find it to be distributed normally with zero mean and unit variance. A rejection of the null hypothesis suggests that the model generating the forecasts has a statistically significant ability to predict changes in a variable. We dynamically simulate the ECM starting in 1973.3 and calculate the PT test statistic. We calculate the test statistic to be equal to 2.14 which allows us to reject the null at the 3% level and conclude that the ECM is able to significantly predict changes in the US real exchange rate.

5. Understanding the effect of oil price shocks

Our analysis has established the presence of a long-run relationship between the real exchange rate and oil prices, found that causality runs from oil prices to the real exchange rate and not vice versa, and developed a stable single equation representation of the relationship that has significant ability to predict exchange rate changes out-of-sample. In this section, we turn our attention to the sign of this long-run relationship.

While the United States is a major importer of both crude oil and energy, our results imply that higher energy prices lead to an appreciation of the US dollar in the long-run.[16] This 'reverse' effect is not entirely counter-intuitive; in fact it is consistent with explanations offered by various sources. Unfortunately, these explanations vary considerably across sources, indicating that there is substantial disagreement. In this section, we review briefly one possible link between oil price shocks and the long-run exchange rate, and evidence for that channel of transmission.[17]

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[15] We also used Spearman's rank correlation coefficient as a non-parametric test of whether, $\beta = 0$ in Eq. (3). This gave the same conclusions as the parametric tests reported in Table 7.

[16] We note that the United States is not the only nation for which there is evidence of such a 'reverse' effect; Amano and van Norden (1995) present evidence of a similar effect for Canada, where higher energy prices lead to a weaker Canadian dollar despite the fact that Canada is a substantial exporter of energy.

[17] See Amano and van Norden (1993) for a discussion of other links between oil prices and exchange rates.

Since the price of oil is global, it is important to consider the effect of oil price shocks on exchange rates in a multi-country framework. Golub (1983) and Krugman (1983a,b) note that in a three-country world (Europe, America and OPEC) higher oil prices will transfer wealth from the oil importers (America and Europe) to the oil exporter (OPEC). However, the resulting effect on the balance of trade (at unchanged exchange rates) is ambiguous. This implies that the long-run effect on the exchange rate is also ambiguous. In particular, if America is a relatively small share of OPEC's export market but a large share of OPEC's import market, then the transfer of wealth from the industrial countries to OPEC would tend to improve the US trade balance.

If we compare the US share of industrial country imports from and exports to oil-exporting nations, we find that the United States generally had a larger share of exports than imports for most of the floating exchange rate period. For example, in 1972 their share of industrial country imports from oil-exporters was 14.0% compared to an export share of 24.7%, whereas by 1991 the comparable figures were 20.2% and 25.0%.[18] Golub (1983) and McGuirk (1983) both find that this kind of effect helps to explain the appreciation of the US dollar in response to higher oil prices.[19] McGuirk calculated that the rise in real oil prices from their 1972 levels to their 1980 levels would worsen the 1985 US balance of trade in energy by $23 billion, but that this deterioration would be offset by an improvement in US exports to oil-exporting nations of $36 billion.[20] The net improvement in the balance of trade would then required a real appreciation of the US dollar to restore external equilibrium.

6. Conclusions

We have explored whether a link exists between the price of oil and the US real exchange rate. The results presented above show that the US real exchange rate appears to be cointegrated with the real price of oil, which suggests that oil prices may have been the dominant source of persistent real shocks over the post-Bretton Woods period. Causality tests also indicate that causality runs only from oil prices to exchange rates and not vice versa. The single-equation ECM relating these two variables is stable and captures much of the in- and out-of-sample movement in the exchange rate in dynamic simulations. Tests show that the ECM has significant out-of-sample predictive ability for both the size and sign of changes in the real effective exchange rate.

[18] Figures for 1972 are from Golub (1983) Table 1. Figures for 1991 are taken from the IMF Direction of Trade Yearbook.

[19] Note, however, that Golub argues shifts in market share and changes in portfolio preferences may have changed the expected relationship between oil prices and the US exchange rate around the time of the second OPEC shock.

[20] McGuirk (1983) Table 10.

Our results make several useful contributions. They show that real oil prices can account for innovations in another important US macroeconomic variable and thereby add to the literature that documents the influence of oil price shocks on the US economy. They also provide support for McCallum's (1989) conjecture that oil price shocks should be incorporated into models of real business cycles and present another challenging stylized fact that models of international business cycles will need to capture. In addition, the evidence advances the research on the failure of real interest rate parity and on structural identification of shock to exchange rates by identifying a real factor that can account for the non-stationarity in real exchange rates.

References

Adams, C., Chadha, B., 1991. Structural models of the dollar. IMF Staff Pap. 38, 525–559.

Amano, R.A., van Norden, S., 1992. Unit-root tests and the burden of proof. Working paper 92-7, Bank of Canada, Ottawa, ON.

Amano, R.A., van Norden, S., 1993. Oil prices and the rise and fall of the US real exchange rate. Working paper 93-15, Bank of Canada, Ottawa, ON

Amano, R.A., van Norden, S., 1995. Terms of trade and real exchange rates: The Canadian evidence. J. Int. Mon. Fin. 14, 83–104.

Andrews, D.W.K., 1993. Tests for parameter instability and structural change with unknown change point. Econometrica 61, 821–856.

Andrews, D.W.K., Monahan, J.C., 1990. An improved heteroscedasticity and autocorrelation consistent matrix estimator. Econometrica 60, 953–966.

Backus, D.K., 1984. Empirical models of the exchange rate: Separating the wheat from the chaff. Can. J. Econ. 17, 824–846.

Backus, D.K., Kehoe, P.J., Kydland, F.E., 1992. International real business cycles. J. Pol. Econ. 100, 745–775.

Baxter, M., 1994. Real exchange rates and real interest differentials: Have we missed the business-cycle relationship. J. Monet. Econ. 33, 5–37.

Boughton, J.M., Haas, R.D., Masson, P.R., Adams, C., 1986. Effects of exchange rate changes in industrial countries. Staff Studies for the World Economic Outlook. International Monetary Fund, Washington, DC.

Burbidge, J., Harrison, A., 1984. Testing for the effects of oil-price rises using vector autoregressions. Int. Econ. Rev. 25, 459–484.

Campbell, J.Y., Clarida, R.H., 1987. The dollar and real interest rates. Carnegie–Rochester Conf. Ser. Public Pol. 27, 103–140.

Canarella, G., Pollard, S.K., Lai, K.S., 1990. Cointegration between exchange rates and relative prices: another view. Eur. Econ. Rev. 34, 1303–1322.

Chong, Y.Y., Hendry, D.F., 1986. Econometric evaluation of linear macro-economic models. Rev. Econ. Stud. 17, 824–846.

Clarida, R.H., Gali, J., 1994. Sources of real exchange rate fluctuations: how important are nominal shocks? Working paper no. 4658, NBER, Cambridge, MA.

Dickey, D.A., Fuller, W.A., 1979. Distributions of the estimators for autoregressive time series with a unit root. J. Am. Stat. Assoc. 74, 427–431.

Dotsey, M., Reid, M., 1992. Oil shocks, monetary policy and economic activity. Fed. Res. Bank Richmond Econ. Rev. 78, 14–27.

Edison, H.J., Pauls, B.D., 1993. A re-assessment of the relationship between real exchange rates and the real interest rates: 1974–1990. J. Monet. Econ. 31, 165–187.

Engle, R.F., Granger, C.W.J., 1987. Co-integration and error correction: Representation, estimation and testing. Econometrica 55, 251–276.

Engle, R.F., Hendry, D.F., Richard, J.F., 1983. Exogeneity. Econometrica 51, 277–304.

Ericsson, N.R., 1992. Cointegration, exogeneity and policy analysis. J. Pol. Model. 14, 251–280.

Evans, M.D.D., Lothian, J.R., 1993. The response of exchange rates to permanent and transitory shocks under floating exchange rates. J. Int. Mon. Fin. 12, 563–586.

Finn, M.G., 1991. Energy price shocks, capacity utilization and business cycle fluctuations. Discussion paper 50, Institute for Empincal Macroeconomics, Federal Reserve Bank of Minneapolis, MN.

Fuller, W.A., 1976. Introduction to statistical time series. John Wiley and Sons, New York.

Godbout, M.J., van Norden, S., 1997. Reconsidering cointegration in international finance: Three case studies of size distortion in finite samples. Working paper 97-1, Bank of Canada, Ottawa, ON.

Golub, S.S., 1983. Oil prices and exchange rates. Econ. J. 93, 576–593.

Gonzalo, J., 1994. Comparisons of five alternative methods of estimating long-run equilibrium relationships. J. Econometr. 60, 203–233.

Hamilton, J.D., 1983. Oil and the macroeconomy since World War II. J. Pol. Econ. 91, 228–248.

Hendry, D.F., 1979. Predictive failure and econometric modelling in macroeconomics: The transaction demand for money. In: Ormerod, P. (Ed.), Economic Modelling. Heinemann Education Books, London.

Huizinga, J., 1987. An empirical investigation of the long-run behavior of real exchange rates. Carnegie-Rochester Ser. Public Pol. 27, 149–215.

Johansen, S., 1992. Cointegration in partial systems and the efficiency of single equation analysis. J. Econometr. 52, 389–402.

Johansen, S., Juselius, K., 1990. The full information maximum likelihood procedure for inference on cointegration. Oxford Bull. Econ. Stat. 52, 169–210.

Kim, I.M., Loungani, P., 1992. The role of energy prices in real business cycle models. J. Monet. Econ. 29, 173–189.

Krugman, P., 1983a. Oil and the dollar. In: Bhandari, J.S., Putnam, B.H. (Eds), Economic Interdependence and Flexible Exchange Rates. MIT Press, Cambridge, MA.

Krugman, P., 1983b. Oil shocks and exchange rate dynamics. In: Frenkel, J.A. (Ed.), Exchange Rates and International Macroeconomics. University of Chicago Press, Chicago.

Kwiatkowski, D., Phillips, P.C.B., Schmidt, P., Shin, Y., 1992. Testing the null hypothesis of stationarity against the alternative of a unit root: How sure are we that economic time series have a unit root?. J. Econometr. 54, 159–178.

Lastrapes, W.D., 1992. Sources of fluctuations in real and nominal exchange rates. Rev. Econ. Stat. 74, 530–539.

Loungani, P., 1986. Oil price shocks and the dispersion hypothesis. Rev. Econ. Stat. 68, 536–539.

MacDonald, R., Taylor, M.P., 1992. Exchange rate economics: A survey. IMF Staff Pap. 39, 1–57.

MacKinnon, J.G., 1991. Critical values for cointegration tests. In: Engle, R.F., Granger, C.W.J. (Eds.), Long-run Economic Relationships: Readings in Cointegration. Oxford University Press, Oxford.

McCallum, B.T., 1989. Real business cycles. In: Barro, R. (Ed.), Modern Business Cycle Theory. Harvard University Press, Cambridge, MA.

McGuirk, A.K., 1983. Oil price changes and real exchange rate movements among industrial countries. IMF Staff Pap. 30, 843–883.

Meese, R.A., 1990. Currency fluctuations in the post-Bretton Woods era. J. Econ. Lit. 4, 117–134.

Meese, R.A., Rogoff, K., 1983. Empirical exchange rate models of the Seventies: Do they fit out of sample?. J. Int. Econ. 14, 3–24.

Meese, R.A., Rogoff, K., 1988. Was it real? The exchange rate-interest differential relation over the modern floating-rate period. J. Fin. 43, 933–948.

Meese, R.A., Rose, A.K., 1991. An empirical assessment of non-linearities in models of exchange rate determination. Rev. Econ. Stud. 58, 603–619.

Mendoza, E.G., 1991. Real business cycles in a small open economy. Am. Econ. Rev. 81, 797–818.

Mork, K.A., 1989. Oil and the macroeconomy when prices go up and down: An extension of Hamiltons's results. J. Pol. Econ. 97, 740–744.

Newey, W.K., West, K.D., 1987. A simple positive definite heteroskedasticity and autocorrelation consistent covariance matrix. Econometrica 55, 703–708.
Ng, S., Perron, P., 1995. Unit root tests in ARMA models with data dependent methods for the selection of the truncation lag. J. Am. Stat. Assoc. 90, 268–281.
Perron, P., 1988. Trends and random walks in macroeconomic time series: Further evidence from a new approach. J. Econ. Dynam. Con. 12, 97–332.
Pesaran, M.H., Timmermann, A., 1992. A simple nonparametric test of predictive performance. J. Bus. Stat. 10, 461–465.
Phillips, P.C.B., Loretan, M., 1991. Estimating long run economic equilibria. Rev. Econ. Stud. 58, 407–436.
Phillips, P.C.B., Perron, P., 1988. Testing for a unit root in time series regression. Biometrika 75, 335–346.
Romer, C.D., an Romer, D.H., 1989. Does monetary policy matter? A new test in the spirit of Friedman and Schwartz.. Nat. Bur. Econ. Res. Macroecon. Ann. 4, 122–170.
Schwert, G.W., 1987. Effects of model specification on tests for unit roots in macroeconomic data. J. Monet. Econ. 20, 173–1103.
Sims, C.A., Stock, J.H., Watson, M.W., 1990. Inference in linear time series models with some unit-roots. Econometrica 58, 113–144.