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Exchange Rates and Oil Prices

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Abstract

The authors document a robust and interesting relationship between the real domestic price of oil and real effective exchange rates for Germany, Japan and the United States. They explain why they think the real oil price captures exogenous terms-of-trade shocks and why such shocks could be the most important factor determining real exchange rates in the long run.

Résumé

Les auteurs mettent en évidence une relation robuste et intéressante entre le prix intérieur réel du pétrole et les taux de change effectifs réels pour l'Allemagne, le Japon et les États-Unis. Ils expliquent pourquoi ils sont d'avis que le prix réel du pétrole saisit les variations exogènes des termes de l'échange et pourquoi ces dernières pourraient constituer le facteur le plus important dans la détermination des taux de change réels à long terme.

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1. Introduction

The exchange rate is arguably the most difficult macroeconomic variable to model empirically. Surveys of exchange rate models, such as those of Meese (1990) and Mussa (1990), tend to agree on only one point: that existing models are unsatisfactory. Monetary models that appeared to fit the data for the 1970s are rejected when the sample period is extended to the 1980s (see for example Meese and Rogoff 1983). Later work on the monetary approach, such as Campbell and Clarida (1987), Meese and Rogoff (1988), Edison and Pauls (1993) and Clarida and Gali (1994), find that even quite general predictions about the comovements of real exchange rates and real interest rates are rejected by the data. In short, there are several reasons to doubt the ability of traditional exchange rate models to explain exchange rate movements.

Quite recently, however, we have begun to see more positive (but still controversial) results emerging in three areas. First, work by researchers such as MacDonald and Taylor (1994) has shown that a long-run relationship exists among the variables in the monetary model of exchange rates, and that such models perform better than a random walk in out-of-sample forecasting. The data, however, reject most of the parameter restrictions imposed by the monetary approach, so it is uncertain whether these results are really evidence in favor of the monetary model.[1] Moreover, this positive evidence of a long-run monetary model also contrasts with the findings of some other researchers such as Gardeazabal and Regúlez (1992), Sarantis (1994) or Cushman, Lee and Thorgeirsson (1995).

The second line of research has evolved around the idea of purchasing power parity (PPP). As noted by Froot and Rogoff (1994), researchers have found significant evidence in favor of PPP when they use sufficiently long spans of data. This is a particularly confusing result, since it is precisely over such long periods of time that we would expect gradual shifts in industrial structure, relative productivity growth and other factors to alter real equilibrium exchange rates.[2]

1. Recent Monte Carlo studies (see for example, Toda 1994, Gonzalo and Pitarakis 1994, and Godbout and van Norden 1995) have found that the systems approach to cointegration, an approach often used in this literature, will tend to find evidence of cointegration where none exists in systems with many variables (as is the case with the monetary model of exchange rate determination).
2. For example, see the discussion on Balassa-Samuelson effects in Froot and Rogoff (1994).

Third, structural time-series work on the determinants of real exchange rate fluctuations indicates that real shocks or permanent components play a major and significant role in explaining real exchange rate fluctuations. Univariate and multivariate Beveridge-Nelson decompositions by Huizinga (1987), Baxter (1994) and Clarida and Gali (1994) find that, even though real exchange rates may not follow a random walk, most of their movements are due to changes in the permanent components. Lastrapes (1992) and Evans and Lothian (1993), using the Blanchard and Quah (1989) decomposition, find that much of the variance of both real and nominal exchange rates from a number of countries over both short and long horizons is due to real shocks. The conclusions from the structural time-series literature therefore seem to be robust to both decomposition methods and currencies. This has led some to suggest that an unidentified real factor may be causing persistent shifts in real equilibrium exchange rates.[3]

In this paper, we try to identify this real factor by examining the ability of real domestic oil prices to account for permanent movements in the real effective exchange rate of Germany, Japan and the United States over the post-Bretton Woods period. The potential importance of oil prices for exchange rate movements has been noted by, *inter alios*, McGuirk (1983), Krugman (1983a, 1983b), Golub (1983) and Rogoff (1991). Although these models are intuitively appealing, the empirical work in this area has several important gaps. There have been several studies on the link between oil prices and U.S. macroeconomic aggregates (see for example, Hamilton 1983, Loungani 1986, Dotsey and Reid 1992), but exchange rates were not included and evidence for other nations is lacking. There has also been some analysis with calibrated macromodels (see McGuirk 1983 and Yoshikawa 1990) that suggests that oil price fluctuations play an important role in exchange rate movements, but these studies lack econometric rigour and consider a data sample limited either in length (McGuirk) or number of currencies (Yoshikawa). Some recent papers such as Throop (1993), Zhou (1995) and Dibooglu (1995) find evidence of a long-run relationship

3. Many investigating the failure of real interest rate parity relationships have already tried to identify this factor, without much success (see, for example, Meese and Rogoff 1988, Edison and Pauls 1993, Baxter 1994.) Their research has focussed on the explanatory power of fiscal policy and external indebtedness. Other studies (mentioned below) have used a broader range of explanatory variables. The extent to which other variables cause persistent changes in expected real exchange rates may help to explain the failure of real interest rate parity.

between exchange rates and a number of macroeconomic factors, including oil prices. However, the tests used in these papers tend to produce false evidence of cointegration when several variables are included in the system.[4] In addition, they do not examine the causal relationship between these variables, so it is not clear whether these are models of exchange rate determination or whether they simply capture the influence of exchange rates on a variety of other macroeconomic variables.

The organization of the paper is as follows. The next section describes a possible rationale for the existence of a simple relationship between real exchange rates and oil prices. Section 3 describes the data used and examines whether or not a stable relationship exists between oil prices and real exchange rates. Section 4 presents and discusses the exogeneity and causality results. The final section offers some concluding remarks.

2. The Terms of Trade and Exchange Rates

As mentioned above, many papers have previously suggested that oil prices may have an important influence on exchange rates. The suggestion, however, that oil prices might be sufficient to explain all long-run movements in real exchange rates appears to be new. In this section, we examine the motivation for such a hypothesis. We begin with a simple model of a small open economy in which the exchange rate is determined by exogenous changes in the terms of trade. Thereafter, we discuss the potential role of productivity differentials in exchange rate determination and also consider the evidence linking oil prices to terms-of-trade shocks. Finally, we briefly comment on the extent to which our results might reasonably be attributed to data mining.

2.1 A Simple Long-Run Model

Consider a small open economy with two sectors, one which produces a traded good T, and the other producing a non-traded good N. Suppose that each sector produces its good using a constant returns to scale (CRS) technology with a non-traded factor L and a traded factor M as

4. For references, see footnote 1.

inputs. Since our analysis will be long-run, we will assume that factors are mobile between sectors and that both sectors make zero economic profits.

Let T be the numeraire. This means that P_M, the price of M, will determine the country's terms of trade, with increases in P_M implying an improvement (deterioration) in the terms of trade if the country is a net exporter (importer) of M. We will interpret the price of non-traded goods P_N as the real exchange rate, with an increase in P_N corresponding to a real appreciation of the domestic currency.

The assumption of CRS implies that the cost function for each industry will be homogeneous of degree one in output, so that per-unit production costs will be a function of factor prices only. The assumption that economic profits are zero in both sectors then implies that average production costs will equal output prices. This leads to the pricing equations

$$\begin{aligned} 1 &= T(P_M, P_L) \\ P_N &= N(P_M, P_L) \end{aligned} \tag{1}$$

So long as T is produced from both M and L, we see that the first equation in (1) defines a relationship between P_M and P_L. We can solve this relationship for $P_L(P_M)$ and (so long as N is produced from both M and L) substitute this into the second equation to obtain

$$P_N = f(P_M) \tag{2}$$

which states that the real value of the exchange rate will be determined by the terms of trade.

The intuition behind this result is straightforward. Both sectors compete for the same inputs. An increase in the price of one of these inputs implies an increase in the average cost of both industries. However, costs will rise more in the industry that is the more intensive user of the input whose price has increased. If these industries produce no profits, this change in relative costs must be reflected in equilibrium by a change in the relative price of outputs. However, this change in the relative price of traded and non-traded goods in turn implies a change in the real exchange rate.

One might wonder how such an economy would balance its external sector when the exchange rate is independent of demand-side factors. The important point to notice is that since both sectors of the economy have a CRS technology, the scale of these sectors is not determined by the price structure derived above. Instead, given prices, the production of traded and non-traded goods will adjust to clear the market for non-traded goods, which in turn implies that any budget constraints on external trade will be respected.

2.2 Productivity Growth and the Balassa-Samuelson Effect

Like the model presented in Section 2.1, models of the Balassa-Samuelson effect also produce the result that the (long-run) real exchange rate is determined solely by the supply side of the economy.[5] These models can differ from the above model in some important respects, however. First, they typically (although not necessarily) assume that the two factors of production are called capital (M) and labour (L). Second, Balassa-Samuelson models consider the effects of differential rates of productivity growth across sectors while sometimes ignoring the effects of factor price changes. A model that allows for both differential rates of sectoral productivity growth and factor price changes would find that these factors will jointly determine the real exchange rate in the long run.

The question of whether relative productivity growth alone can explain the behaviour of real exchange rates has been previously examined.[6] Generally speaking, however, movements in relative productivity are sufficiently small and gradual that they explain little of the overall movements in real exchange rates over the last 20 years. Most published studies that focus on relative productivity as a determinant of exchange rates have relied on cross-sectional regressions rather than time-series analysis, but even so their results have been mixed.[7]

5. See Froot and Rogoff (1994), Section 3.2, for a lucid exposition of the Balassa-Samuelson effect.
6. See Froot and Rogoff (1994), Sections 3.3 and 3.4.

One possible reason for these mixed results is the omission of terms-of-trade shocks as another factor driving exchange rates. Some cross-sectional evidence supporting this view is presented by De Gregorio and Wolf (1994). In a time-series study, it would be interesting to see the degree to which exchange rate movements in the post-Bretton Woods period can be jointly explained by relative productivity and terms-of-trade shocks. Because of the problems inherent in constructing accurate time series on relative sectoral productivity levels, we focus instead on the degree to which exchange rate movements can be explained by terms-of-trade shocks alone.[8] One risk that this approach presents is that some of the explanatory power of relative productivity shocks might inadvertently be attributed to terms-of-trade shocks. We return to this possibility in our concluding remarks. For the time being, we simply note that since relative productivity shocks seem to be small, the omission of relative productivity may not be a serious problem.

2.3 Oil Prices and the Terms of Trade

The model presented in Section 2.1 suggests a unique relationship between the terms of trade and the real exchange rate. This will be a causal relationship if the terms of trade are set independently of domestic conditions by world markets. We think that the latter is unlikely to be the case for industrial economies as large as the United States, Japan and Germany, however. In the empirical work we present in subsequent sections, we use the real price of oil as a proxy for exogenous changes in the terms of trade. While we do not claim that oil prices would be a useful proxy for all nations, we feel that the price of oil is a good approximation for some industrialized nations, such as the United States, Japan

7. Exceptions are the positive results for the yen-dollar exchange rate reported by Marston (1987) and Yoshikawa (1990), but these relied on calibrated rather than estimated models, so formal tests of statistical significance are not available.
8. Amano and van Norden (1995) show that long-run movements in the Canada-U.S. real exchange rate seem to be caused by movements in components of Canada's terms of trade.

and Germany.

If we examine the behaviour of real oil prices over the most recent floating exchange rate period, we see that the series is dominated by major persistent shocks around 1973-74, 1979-80 and 1985-86, with another large but transitory shock in 1990-91. The historical record offers us a very plausible explanation for these shocks: they were supply-side shocks that were themselves the result of political conflicts specific to events in the Middle East. Note that we are not arguing that oil prices (or even the stability of price 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. Instead, we feel that there is ample reason to believe that such demand-side factors have been small relative to the supply-side shocks experienced over the last 20 years, and that the supply shocks have been exogenous in the sense of most macroeconomic models. Furthermore, comparing domestic real oil prices with the terms-of-trade series for each of the United States, Japan and Germany in Figure 1 shows that oil prices shocks, indeed, appear to account for most of the major movements in the terms of trade.[9] In fact, the point correlation between the terms of trade and the one-period-lagged price of oil is -0.57, -0.78 and -0.92 for the United States, Japan and Germany, respectively.

However, for those skeptical of the use of oil prices as a proxy for exogenous changes in the terms of trade, the appendix presents additional results that use terms-of-trade data rather than real oil prices. These results are broadly similar to the results that we present below using oil prices data. Because we feel that the case for exogeneity of the terms of trade is less convincing than that for the real price of oil, we will henceforth consider oil prices rather than the terms of trade. However, we are comforted by the fact that broadly similar results are found using aggregate terms-of-trade data.

3. Unit-Root and Cointegration Results

In this section, we present evidence of a stable long-run relationship between real exchange

9. The terms-of-trade variables are calculated as the ratio between the unit value of exports and the unit value of imports. These data are taken from the *International Financial Statistics* (International Monetary Fund).

rates and real oil prices. The data we use are the Morgan Guaranty 15-country real effective exchange rate series of Germany (Deutsche mark), Japan (yen) and the United States (dollar), and the domestic price of oil, defined as the U.S. price of West Texas Intermediate crude oil converted to the respective currency deflated by the respective country consumer price index. The data are observed monthly and cover the period 1973M1 to 1993M6.[10] Figure 2 plots each country's real exchange rate with its respective real price of oil. From the figure, it is readily apparent that the real exchange rate and the price of oil for each country are related over the sample period. In the remainder of this section we examine these relationships in some detail.

Our first step is to examine the time-series properties of each variable using the augmented Dickey and Fuller (1979) and Phillips and Perron (1988) tests. As shown in the appendix, we found that the real effective exchange rates for the United States, Japan and Germany show no strong evidence of long-run PPP.[11]

Our approach to testing for a long-run relationship between the real effective exchange rate and the price of oil is to look for evidence of cointegration between the two variables. Assuming that each series has a unit root in its autoregressive time-series representation, a stable long-run equilibrium relationship between the variables requires that they be cointegrated in the sense of Engle and Granger (1987).[12] This also allows us to gauge the adequacy of specifying the real exchange rate simply as a function of the price of oil. If the long-run real exchange rate is determined by nonstationary factors other than

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10. Although other measures of the real exchange rate are available, we chose the Morgan Guaranty 15-country measure simply because it gave us the longest span of data. We should note that the results appear robust to different price deflators and measures of the real effective exchange rate. The latter is not surprising, as the different measures are very highly correlated (> 0.98).
11. In additional work not reported here, we also found that real interest rate differentials alone cannot explain the failure of PPP, and structural decompositions suggest that real shocks are an important source of persistent real exchange rate movements. These results are available from the authors.
12. We emphasize that the assumption that the data are I(1) is not crucial to our conclusions concerning the stability or causality of the relationship we uncover between the price of oil and real exchange rates. For example, one might believe that the data are truly stationary and that our failure to reject the null hypothesis of a unit root is simply due to a lack of power (perhaps owing to an insufficiently long sample.) Under this alternative assumption, the cointegration test results presented in this section will be of limited interest. However, the evidence which we then present on the measure of this relationship and its apparent Granger causality should still be meaningful.

those associated with the price of oil, then their omission should prevent us from finding significant evidence of cointegration. Evidence of cointegration, on the other hand, suggests that asymptotically, the price of oil can adequately capture all the permanent innovations in the real effective exchange rate.

We test for cointegration between exchange rates and oil prices using the two-step single-equation approach developed by Engle and Granger (1987). The results presented in Table 1 yield strong evidence of cointegration between the price of oil measures and the real effective exchange rates for Germany and Japan but not for the United States. Specifically, the augmented Dickey and Fuller (1979) and Phillips and Ouliaris (1990) tests reject the null hypothesis of no cointegration at the 1 per cent level for the mark, and the 5 and 1 per cent level for the dollar. We then compare these conclusions using an efficient (and therefore more powerful) cointegration test developed by Johansen and Juselius (1990). These results are reported in Table 2. The Johansen-Juselius (JJ) tests find evidence consistent with cointegration for all three currencies, which suggests that the price of oil captures the permanent innovations in the real exchange rate for Germany, Japan and the United States.

Having found evidence consistent with a long-run relationship, we turn to estimating the long-run response of real effective exchange rates to changes in the price of oil. Cointegration implies that least-squares (LS) estimates will be super-consistent; however, it is important to note that the rate T-convergence result does not, by itself, ensure that parameter estimates will have good finite-sample properties. The reason is that LS estimates are not asymptotically efficient, in the sense that they have an asymptotic distribution that depends on nuisance parameters. This problem is due to serial correlation in the error term and endogeneity of the regressor matrix that is induced by Granger causation. To control for these problems we use three recently developed estimators—Stock and Watson's (1993) dynamic LS, the prewhitened Phillips and Hansen (1990) fully modified LS, and Park's (1992) canonical cointegrating regression estimators. All three estimators are designed to eliminate nuisance parameter dependencies and possess the same limiting distribution as full-information-maximum-likelihood estimates, a fact which implies that the estimates are asymptotically optimal. The application of the three different estimators also allows us to determine the robustness of the parameter estimates.

Table 3 reports these results along with those from simple LS for the sake of comparison. As we can see the LS estimator tends to underestimate the response of real exchange rates to oil price shocks. Dynamic LS (DLS), prewhitened Phillips and Hansen fully modified LS (FMLS) and Park's canonical cointegrating regression (CCR) estimators give us long-run estimates that are statistically significant. Regardless of the method used, we find that a rise in oil prices (for example, of 10 per cent) causes a depreciation of the mark (of roughly 0.9 per cent), an even larger depreciation of the yen (of roughly 1.7 per cent), and an appreciation of the dollar (of roughly 2.4 per cent).

To interpret these elasticities it is important that the long-run parameters estimates be structurally stable over the sample period. To test for structural stability of the parameter estimates, we use a series of parameter constancy tests for I(1) processes recently proposed by Hansen (1992)—the *Lc*, *MeanF* and *SupF* tests. All three tests have the same null hypothesis of parameter stability but differ in their alternative hypothesis. Specifically, the *SupF* is useful if we are interested in testing whether there is a sharp shift in regime, while the *Lc* and *MeanF* tests are useful for determining whether or not the specified model captures a stable relationship. The results presented in Table 4 suggest that we are unable to reject the null hypothesis for any of the tests, even at the 20 per cent level. We note that Hansen (1992) suggests that these tests may also be viewed as tests for the null of cointegration against the alternative of no cointegration. Thus the test results also corroborate our previous conclusion of cointegration among the variables under study.

Some may argue that because our measure of domestic oil prices uses the bilateral exchange rate with the United States to convert U.S. dollar oil prices into a domestic price, any evidence of cointegration is simply a result of a common trend between the effective and bilateral exchange rates. We investigated this possibility by using the bilateral rate as the explanatory variable in the place of the real domestic price of oil. With this change, we find no evidence of cointegration, even at the 10 per cent significance level. Moreover, such an explanation cannot explain the evidence of cointegration found between real U.S. dollar oil prices and the U.S. real exchange rate. Finally, if we are simply capturing a relationship between bilateral and effective exchange rates, we should not find unidirectional causality in our systems. We address this point in the next section.

4. Causality and Exogeneity

From Engle and Granger (1987) we know that cointegration in a two-variable system implies that at least one of the variables must Granger-cause the other. However the results presented above do not indicate whether the long-run relationship we have found reflects the endogeneity of the domestic price of oil or the determination of the exchange rate, or both. While understanding the causal links between these variables may be interesting in its own right, we note that if causality runs from the price of oil to the exchange rate, this would also imply that exchange rate changes are forecastable, and therefore that semi-strong market efficiency is rejected.

Our first step in testing for causality is to test for "long-run causality," or more accurately, to test whether any of our variables are weakly exogenous in the sense of Engle, Hendry and Richard (1983). This can be tested using the likelihood-ratio test described in Johansen and Juselius (1990). The results shown in Table 5 imply that the price of oil is weakly exogenous, while the real exchanges are not. This implies that deviations from the long-run relationship between oil prices and exchanges significantly influence exchange rates, but do not significantly affect domestic oil prices.

Next we test for more general Granger causality using standard tests on the vector autoregression level representation of our system. As demonstrated in Sims, Stock and Watson (1990), standard inference procedures are valid in this case under the maintained hypothesis of one cointegrating vector, provided that we test the exclusion restrictions on one variable at a time. These results are reported in Table 6.[13] They indicate strong evidence that the price of oil Granger-causes the real exchange rate, whereas there is no evidence of the reverse.

If we accept the conclusion that exchange rates do not Granger-cause oil prices as our empirical evidence suggests, what other interpretation can we offer for the apparent long-run relationship between these two variables? An important possibility to consider is that oil prices and exchange rates are jointly determined by some third (omitted) macroeconomic variable. This would imply that we have a reduced-form relationship, but not one that should be thought of as a structural or causal link. Without a specific alternative, this is not a criticism that we can test. Nonetheless, we feel that this is unlikely to be the case. As we argued in Section 2.3, the behaviour of oil prices over our sample period is dominated by major persistent supply shocks that have been exogenous in the sense of most macroeconomic models. Accordingly, few macroeconomic insights are likely to be gained from a search for a co-determinant of exchange rates and oil prices.

Previous formal analysis of this question in the case of the United States would seem to support our view. In particular, Hamilton's (1983) claim that major oil price increases preceded almost all post–World War II recessions in the United States is accompanied by an extensive search for a variable that was Granger-causally-prior to domestic U.S. oil prices. After exploring a wide range of variables, including aggregate prices, wages, real output, monetary aggregates, bond yields and a stock-price index, Hamilton finds that almost none seemed to cause oil prices and none could explain their effect on output.[14] As for the monetary and fiscal variables that have been the mainstay of modern exchange rate modelling, we have already cited studies which show that the explanatory power of these variables for exchange rates is limited. Furthermore, even

13. Since all results are based on asymptotic approximations we use the limiting chi-square critical values instead of their more common F-distributed counterparts.
14. Apparently causal-prior variables were import prices (weak evidence that is sensitive to the lag-length used), coal prices and the ratio of person-days idle due to strike to total employment. The first two could simply reflect the same external energy supply shocks, but might response to these shocks more quickly than domestic energy prices. The latter variable may simply reflect the influence of strikes by U.S. coal miners on domestic energy prices in the 1950s.

supposedly exogenous measures of monetary policy such as that recently proposed by Romer and Romer (1989) for the United States may capture a considerable amount of endogenous policy reaction to exogenous external oil prices. Indeed, Dotsey and Reid (1992) show that Romer and Romer's measure of monetary policy is coincident with several major oil price shocks and that its explanatory power for output variables vanishes when oil prices are included in the system. We therefore think it is unlikely that oil prices are simply acting as a proxy for some other macroeconomic determinant of long-run exchange rates.

5. Concluding Remarks

We have documented what we think is a robust and interesting relationship between the real domestic price of oil and real effective exchange rates for Germany, Japan and the United States. We have also explained why we think the real oil price captures exogenous terms-of-trade shocks, and why such shocks could be the most important factor determining real exchange rates in the long run. Given the ongoing debate over the determination of exchange rates and the other work we have cited examining relationships between exchange rates and the terms of trade for other industrialized countries, we think that this is an area that deserves further research.

This research could be usefully extended in several directions. Obviously, more evidence could be gathered, perhaps for additional currencies, for additional measures of the terms of trade, or from additional testing methods. As we noted earlier, it would also be reasonable to see whether our results are robust to the inclusion of sectoral differentials in productivity growth, although we have suggested that this is likely to be the case.

More structural work on the relationship between oil prices and exchange rates would also be useful. The terms-of-trade model we presented is only one of many which predict that oil prices will have important effects on industrial-country exchange rates. More detailed testing and comparison of these competing models may be warranted.

Finally, attempts to relate the size of the long-run elasticities reported in Table 3 to sectoral factor intensities would also be of interest.

Table 1:
Augmented Dickey-Fuller (ADF) and Phillips-Ouliaris (PO) Tests for Cointegration[a]

Regression	Lags	AEG t-statistic	PO Z_α-statistic
mark	9	-3.98**	-41.75**
yen	8	-3.82*	-34.79**
dollar	12	-2.19	-11.204

a. ADF and PO Z_α critical values are taken from MacKinnon (1994). The lag length for the ADF test is selected on the basis of a data-dependent method suggested by Ng and Perron (1994) using a 5 per cent critical value. The initial number of ADF lags is set equal to the seasonal frequency plus 1 or 13. The PO test statistic is calculated using the prewhitened QS kernel estimator with the automatic bandwidth parameter advocated by Andrews and Monahan (1992). For Tables 1 and 2, ** and * indicate significance at the 1 and 5 per cent levels.

Table 2:
Johansen and Juselius Tests for Cointegration[a]

		Trace Statistic		λ Max. Statistic	
Equation	Lags	$r \leq 1$	$r \leq 0$	$r \leq 1$	$r \leq 0$
mark	5	19.81*	3.84	15.98*	3.84
yen	4	20.60*	2.61	17.99*	2.61
dollar	4	21.89*	4.76	15.123*	4.76

a. We performed the tests under the assumption that the cointegrating vector annihilates any drift terms in the exchange rate or price of oil. Tests of this restriction are available from the authors. The critical values are taken from Johansen and Juselius (1990). Lag lengths are determined using standard likelihood ratio tests. We begin with 13 lags and use a 5 per cent critical value. r denotes the number of cointegrating vectors.

Table 3:
Estimation of the Static Equation[a]
The Estimated Effect of Oil Prices on Exchange Rates

Estimation Method	mark	yen	dollar
LS	-0.079	-0.156	0.141
FMLS	-0.086 (0.011)	-0.170 (0.029)	0.276 (0.089)
DLS	-0.083 (0.010)	-0.158 (0.022)	0.174 (0.059)
CCR	-0.092 (0.014)	-0.201 (0.047)	0.258 (0.058)

a. Standard errors are in parentheses. The FMLS estimates are based on the VAR(2) prewhitening procedure of Andrews and Monahan (1992), as this gave us serially uncorrelated residuals. The DLS estimates are based on sixth-order leads and lags and Newey and West (1987) standard errors calculated using a truncation parameter equal to the seasonal frequency or 12. The CCR estimates are from the third stage of estimation as suggested by Park and Ogaki (1991).

Table 4:
Hansen Stability Tests of the Cointegrating Vector[a]

Equation	Lc	MeanF	SupF
mark	0.380 (> 0.09)	2.493 (> 0.20)	4.447 (> 0.20)
yen	0.111 (> 0.20)	1.334 (> 0.20)	3.087 (> 0.20)
dollar	0.260 (> 0.19)	2.421 (> 0.20)	5.451 (> 0.20)

a. We use the FMLS estimates from Table 3 to calculate these test statistics. The reported values in parentheses are p-values.

Table 5:
Johansen Weak Exogeneity Tests[a]

Equation	Lags	H_0: Price of oil is weakly exogenous	H_0: Exchange rate is weakly exogenous
mark	5	0.414	< 0.000
yen	4	0.158	< 0.000
dollar	4	0.901	0.001

a. Reported numbers are p-values (the lowest significance level at which we can reject the null hypothesis).

Table 6:
Granger-Causality Tests[a]

Equation	Lags	H_0: Price of oil does not cause exchange rates	H_0: Exchange rates do not cause oil prices
mark	5	0.002	0.239
yen	4	0.012	0.422
dollar	4	0.017	0.857

a. Reported numbers are p-values (the lowest significance level at which we can reject the null hypothesis).

Statistical Appendix

Unit-Root Tests

Unit-root test results for the real exchange rate and real oil price series are reported in Table A1. We are unable to reject the null hypothesis of a unit root for any of the series, with the exception of the German exchange rate. For the latter, the test statistics are between the 1 per cent and 5 per cent critical values. Since we feel that there may be some doubt about this conclusion, we choose to include this series in our cointegration analysis nonetheless.

Table A1: Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) Tests
"*" indicates significance at the 5 per cent level

Nation	Series	ADF τ [a]	PP Z_{α} [b]
U.S.	Exchange Rate	-1.68 (1)	-5.82
	Oil Price	-2.22 (2)	-12.87
Germany	Exchange Rate	-3.06* (9)	-14.00*
	Oil Price	-1.88 (2)	-8.85
Japan	Exchange Rate	-2.51 (4)	-10.73
	Oil Price	-1.22 (7)	-5.50

a. All test regressions include a constant term. The lag selection procedure is that suggested by Ng and Perron (1994). The number of lags used is shown in parentheses.
b. The long-run variance is estimated using an AR(1) prewhitened quadratic spectral kernel estimator and a data-dependent bandwidth parameter, as suggested by Andrews and Monahan (1992).

Tests Using Terms-of-Trade Data

At an earlier stage of our research, we examined the relationship between the real effective exchange rate and the terms of trade. The data we used were the Morgan Guaranty 40-country real effective exchange rate series for the United States, Germany and Japan, and the same nations' terms of trade, defined as the ratio of export to import unit values in U.S. dollars and taken from the IMF data base (lines 74d and 75d). The data are quarterly and cover the period 1973Q3 to

1992Q1.[15]

Table A2 shows that both the German and the Japanese terms of trade appear to be I(1), while the U.S. series seems to be I(0). If correct, this would imply that there could be no long-run relationship between the U.S. terms of trade and the U.S. real effective exchange rate. Therefore, the cointegration analysis we present below considers only the data for Germany and Japan.

Table A2: Unit Root Tests on Terms of Trade
"*" indicates significance at the 5 per cent level[a]

Nation	ADF τ	PP Z_{α}
U.S.	-3.88*	-19.25*
Germany	-1.87	-8.72
Japan	-2.45	-11.27

a. See footnotes for Table A1.

Next, we used the Johansen-Juselius tests to look for evidence of cointegration, as shown in Table A3. For the mark, both test statistics indicate the presence of at least one cointegrating vector at the 5 per cent level, whereas for the yen, the trace and λ Max. statistics find evidence of cointegration at the 5 and 10 per cent level. Neither test finds any significant evidence of a second cointegrating vector for either currency. Accordingly, we conclude that there seems to be a long-run relationship between the real effective exchange rate and the terms of trade for Japan and Germany. The results of tests for weak exogeneity are shown in Table A5. They accept the null hypothesis that the German terms of trade are weakly exogenous but reject the same null for the mark. Evidence for Japan is more ambiguous, but shows that the terms of trade are more consistent with weak exogeneity than the exchange rate.

15. The raw Morgan Guaranty data are monthly. To convert them to quarterly frequency, we simply select the value for the mid-quarter month.

Table A3: Johansen-Juselius (JJ) Test for Cointegration
Estimation under Assumption of Restricted Drift
"*" indicates significance at the 5 per cent level

		Trace Statistic	λ Max. Statistic	JJ Lags[a]
Mark	$r \leq 1$	20.925*	16.536*	2
	$r \leq 0$	4.389	4.389	
Yen	$r \leq 1$	21.484*	14.871	2
	$r \leq 0$	6.613	6.613	

a. Appropriate lag lengths are determined using standard likelihood ratio tests with a finite-sample correction.

Table A4: Weak Exogeneity Tests

Nation	Variable under the Null of Weak Exogeneity	Significance Level
Germany	Terms of Trade	0.682
	Exchange Rate	0.001
Japan	Terms of Trade	0.102
	Exchange Rate	0.066

Table A5 shows the results of tests for Granger causality using standard tests on the vector autoregression level representation of the systems. Since this does not require evidence of cointegration, results for the United States are included once more. The evidence for the United States and for Germany allow us to conclude that the terms of trade appear to Granger-cause the real exchange rate, whereas the reverse is not true. The conclusions for Japan are somewhat more difficult to interpret. If we use the 5 per cent significance levels, then neither variable appears to Granger-cause the other. However, we should recall that the presence of cointegration implies that Granger causality should exist in at least one direction. With this in mind, we simply note that there is more evidence of the terms of trade Granger-causing the real exchange rate than the reverse.

Table A5: Granger Causality Results

Dependent Variable	Independent Variable	Number of Lags[a]	Significance Level
U.S. Exchange Rate	U.S. Terms of Trade	1	0.020
U.S. Terms of Trade	U.S. Exchange Rate	3	0.857
German Exchange Rate	German Terms of Trade	1	0.003
German Terms of Trade	German Exchange Rate	2	0.719
Japanese Exchange Rate	Japanese Terms of Trade	2	0.129
Japanese Terms of Trade	Japanese Exchange Rate	4	0.301

a. Lag lengths were selected on the basis of the Akaike information criteria.

In summary, we found evidence of cointegration between the German and Japanese real effective exchange rates and their corresponding terms of trade. We rejected the hypothesis of a unit root in the U.S. terms of trade, which therefore implies the absence of cointegration with the U.S. real effective exchange rate. The results also show no evidence of Granger-causality from the exchange rate to the terms of trade but significant evidence of the reverse for two of the three nations.

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Figure 1: (Inverse of) the Terms of Trade (1985=100) and the Price of Oil

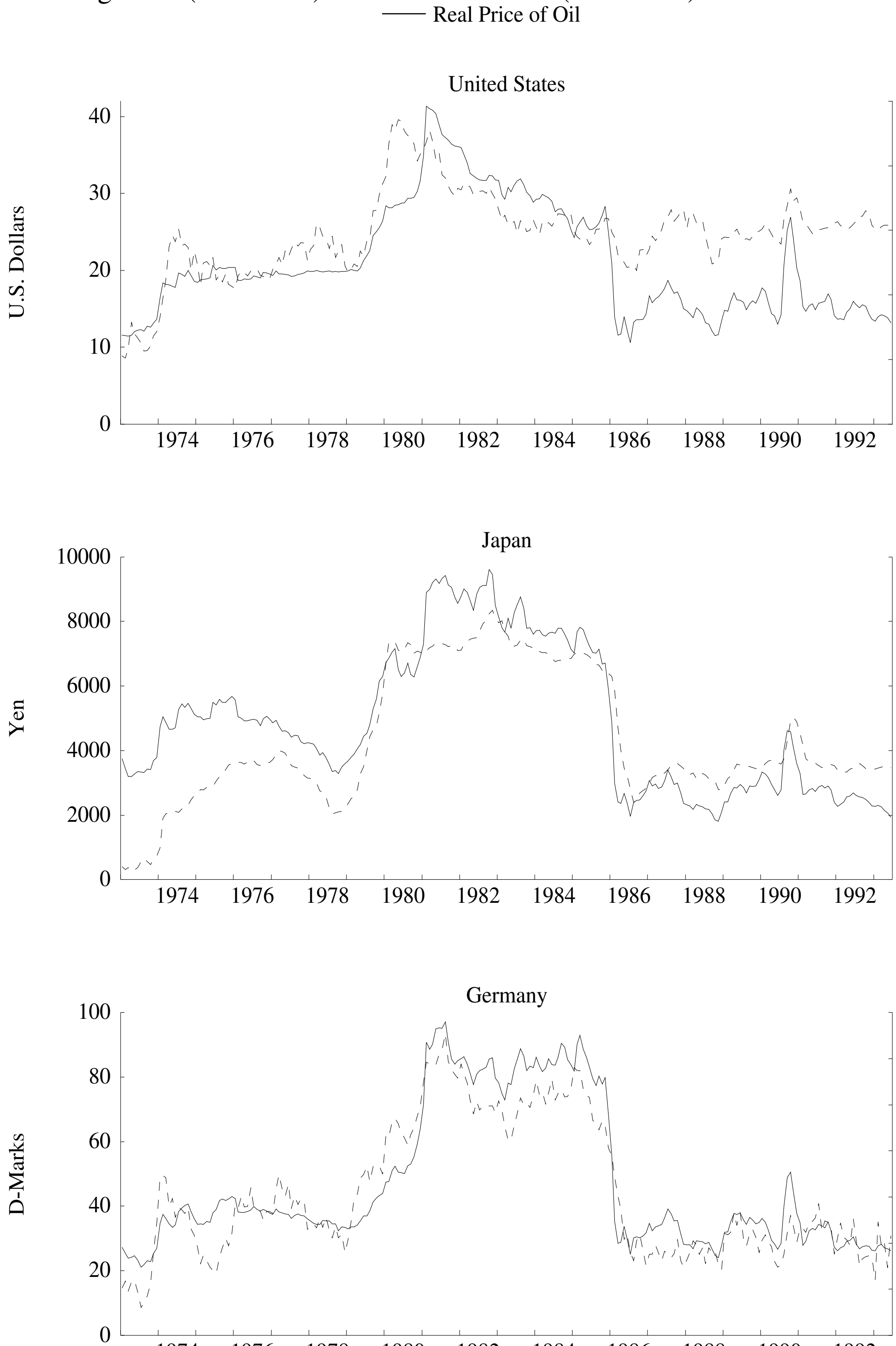
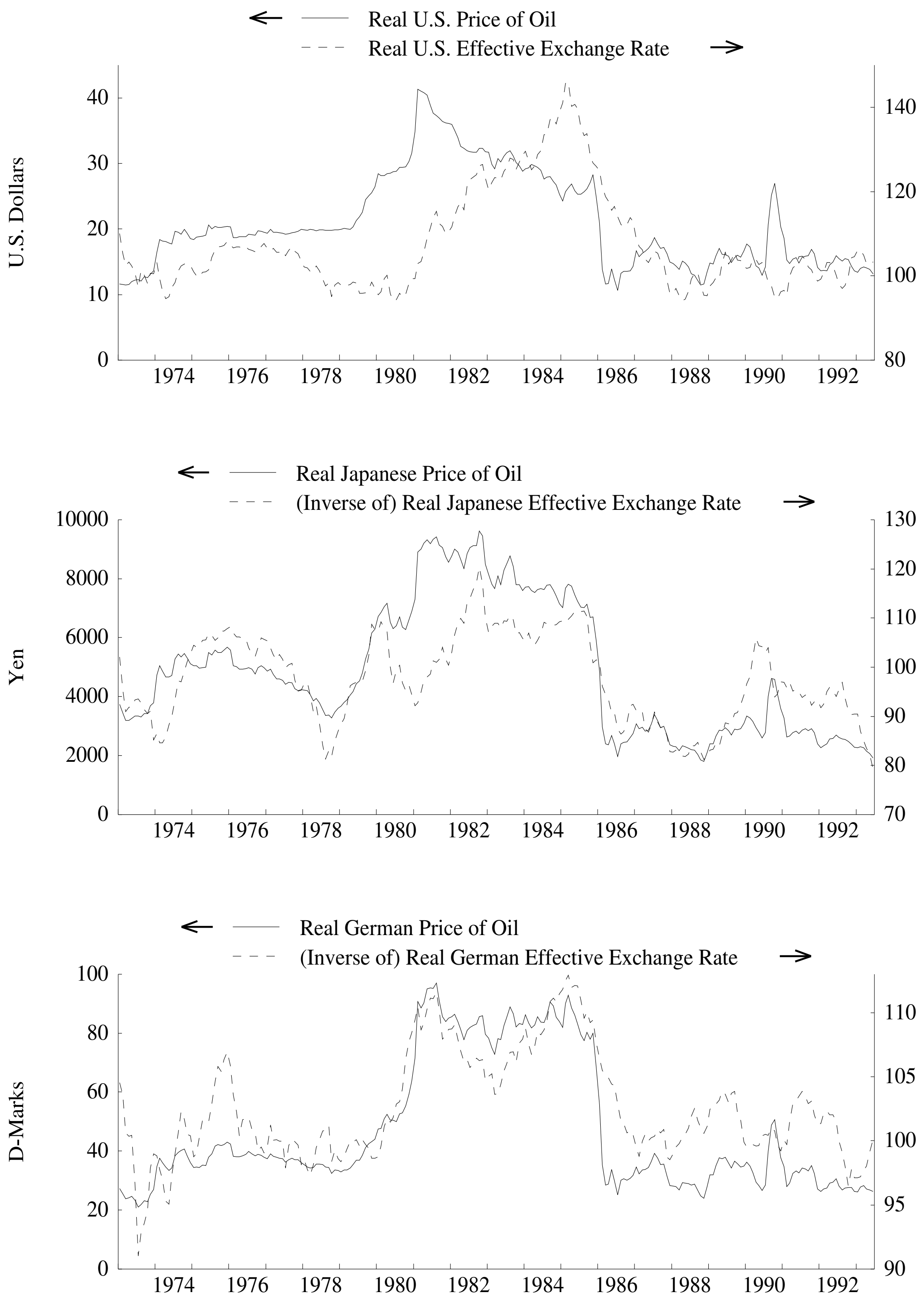


Figure 2: Effective Exchange Rates and the Price of Oil



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