WP 43

REAL EXCHANGE RATES AND FUNDAMENTALS: EVIDENCE FROM 15 OECD COUNTRIES

Annika Alexius and Jonny Nilsson

October 1997

Abstract

Two variables that can be expected to affect equilibrium real exchange rates are relative productivity and terms of trade. We present evidence of systematic long run relationships between these fundamental variables and real exchange rates in a data set covering 15 OECD countries from 1960 to 1996. According to the Johansen's maximum likelihood approach to cointegration, high relative productivity and favourable terms of trade developments are associated with real exchange rate appreciations in most cases. Panel cointegration tests confirm that while the fundamental variables have the predicted average effects on equilibrium real exchange rates, the sizes of the effects differ between the countries.

1. Introduction

The empirical literature on real exchange rates focus mainly on the hypothesis that equilibrium real exchange rates are constant in the long run, i.e. purchasing power parity. PPP is usually rejected in empirical tests, implying that equilibrium real exchange rates change over time. Relative productivity in the tradable and non-tradable sectors has long been recognised as a potential determinant of time-varying equilibrium real exchange rates (Balassa 1964, Samuelson 1964). According to this model, real exchange rates of countries with high relative productivity in the tradable sector appreciate. The Balassa-Samuelson model has been extended by De Gregorio and Wolf (1994) to include terms of trade. Improved terms of trade then induce an appreciation of the equilibrium real exchange rate.

Empirical attempts to relate real exchange rates to the development of fundamental variables have been at best partly successful. Rogoff (1996) and Froot and Rogoff (1995) provide surveys of this literature. In the Balassa-Samuelson model, relative productivity in the tradable and non-tradable sectors affects real exchange rates through the relative prices on tradable and non tradable goods. Engels (1995) finds no relation between US relative non-tradable prices and real exchange rate on any horizon between one month and thirty years. Similarly, Asea and Mendoza (1994) find a strong relationship between relative non-tradable productivity and relative non-tradable prices but no significant relationship between either of these variables and real exchange rates in their study of 14 OECD countries. In one of the few papers that do document a relationship between real exchange rates and (any) fundamental variables, De Gregorio and Wolf (1994) find that real exchange rates are systematically related to either terms of trade or productivity (but not both simultaneously). Hsieh (1982) and Marston (1990) also report significant effects of productivity changes on real exchange rates.

The papers discussed above focus on changes in real exchange rate, i.e. use differenced data. The possibility of long run relationships between real exchange rates and the fundamental variables is then excluded. Real exchange rates appear to have trends in the medium to long run, as do the relevant fundamental variables. To answer the question whether these variables are related in the long run, methods designed to handle non-stationary data are needed. In one of the few cointegration studies of equilibrium real exchange rates determination, Strauss (1995) confirms the existence of cointegration among real exchange rates and relative productivity variables in 10 of 14 bilateral Deuschemark rates. However, he does not report estimates of the cointegrating vectors, which makes it difficult to evaluate whether his results are consistent with the effects expected from theory.

In this paper, we investigate how real exchange rates are related to relative growth and terms of trade using data on 15 OECD countries from 1960 to 1996. If PPP is rejected in the long run, equilibrium real exchange rates must be non-stationary. Since relative growth and terms of trade also found to be non-stationary, cointegration techniques are well suited to study how these variables are related. The main contribution of this paper compared to previous studies is that we focus explicitly on the long run relationship between real exchange rates and fundamental variables.

The paper is organised as follows. In section 2, the Johansen's maximum likelihood approach to cointegration is applied to the real exchange rate, terms of trade and domestic and foreign GDP of each country. First, the presence of systematic long run relationships among the variables is investigated. If they are cointegrated, various linear restrictions on the cointegrating vectors are tested. For instance, theory implies that domestic and foreign productivity growth should have symmetric effects on the real exchange rate. Restricted and unrestricted estimates of the cointegrating vectors are also presented. The results differ between countries, which makes it difficult to draw unambiguous conclusions. In section 3, we proceed to study the pooled data set using the panel cointegration techniques discussed by Pedroni (1995, 1996). Within this framework, the hypothesis that the fundamental variables have the same effect on the real exchange rates in all countries can be tested. Section 4 concludes.

2. Cointegration of time series data

The long run relationship between real exchange rates and the fundamental variables in each country can be investigated using Johansen's maximum likelihood cointegration approach. In contrast to other cointegration tests, the Johansen procedure is multivariate and estimates the number of cointegrating vectors in the data set conditional on the short run dynamics. Furthermore, linear restrictions on the cointegrating vectors can be tested within this framework.

The data set covers 15 OECD countries (OECD16 excluding Belgium) between 1960:1 and 1996:1.[1] Quarterly data on nominal exchange rates and CPI have been

[1] OECD16 includes Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Spain, Sweden, Switzerland, United Kingdom and the United States. Belgium is excluded from the study since we have been unable to find data that corresponds to the rest of the data set.

collected from the OECD data base Main Economic Indicators. Terms of trade are constructed from export and import prices available on the IFS data tape 1996:08. In a few cases where quarterly data are missing but monthly data are available, quarterly averages have been constructed from the monthly observations (see Appendix A for details). Effective real exchange rates are constructed using the IMF MERM weights. Logarithms are used throughout.

The Balassa-Samuelson model predicts a relationship between real exchange rates and total factor productivity in the tradable and non-tradable sectors. If GDP growth in steady state is driven by productivity growth and productivity growth is concentrated to the tradable sector, a relationship between relative GDP and real exchange rates emerges.[2] Given the problems involved in obtaining data on total factor productivity in the tradable and non-tradable sectors, we have chosen to use relative real GDP as a proxy for this variable.[3] Real GDP is available in the OECD data base Main Economic Indicators. The relevant foreign GDP series is constructed for each country using the same weights as in the effective real exchange rates.

The Johansen approach focuses on the Π-matrix in (1). Here, the x-variables are the real exchange rates, domestic GDP, foreign GDP and terms of trade of each country.

$$(1) \qquad \Delta x_t = \sum_{i=1}^{p-1} \Gamma_i \Delta x_{t-i} + \Pi x_{t-1} + \varepsilon_t$$

The appropriate number of lags p in (1) is determined using information criteria (AIC, BIC and LIL). In addition, residual tests may indicate misspecification. In particular, a VAR-model produces biased estimates in the presence of autocorrelation. This procedure results in two to four lags for all countries except Switzerland and Canada, where eight and nine lags are needed, respectively (see Table 1 for details). The cointegrating rank of the system in (1) can then be estimated using the trace test and the λ-max test developed by Johansen (1992). The results, shown in Table 2, indicate one cointegrating vector in most cases. Denmark and possible France have two

---

[2] The same prediction may also be reached from a model where wages depend on the capital-labour ratio and production of non tradable goods is more labour intensive than production of tradables. See for instance Bhagwati (1994).

[3] Data on total factor productivity in the tradable and non-tradable sectors are available on a yearly basis since 1970. Most studies focus on relative labour productivity, which may not be a good proxy. Furthermore, the crucial distinction between tradable and non-tradable sectors is rather arbitrary given the high level of aggregation of sectoral data.

cointegrating vectors and the time series do not appear to be cointegrated in the cases of Italy, Norway and Switzerland.

The presence of cointegration in 12 of the 15 countries studied confirm that there are long run relationships between the variables. Theory predicts not only that real exchange rates should be cointegrated with relative productivity and terms of trade, but also that favourable developments should be associated with stronger real exchange rates. Domestic GDP is then expected to enter with a positive sign, foreign GDP to enter with a negative sign and terms of trade to enter with a positive sign.

Unrestricted estimates of the cointegrating vector(s) are shown in Table 3. The effects expected from theory are found in about two thirds of the cases. Four of the eleven point estimates of the effect of domestic GDP are negative, while foreign GDP and terms of trade have the wrong sign in three cases. At least two of the three parameter estimates are of the opposite sign for Austria, Canada, Japan and Germany, while all three parameters have the expected signs in the cases of Finland, France, Spain, Sweden, the United Kingdom and the USA. Hence, the results in Table 3 lend some support to our hypothesis.

A second observation from Table 3 is that many of the estimated parameters are very large. For instance, one percents increase in domestic GDP appears to appreciate the Spanish equilibrium real exchange rate by ten percent and the French real exchange rate by six percent. In previous studies, the estimated effects of productivity changes on real exchange rates typically fall in the range 0.1-0.8.[4]

More information about the long run relationships between real exchange rates and the fundamental variables can be extracted from the data by investigating various linear restrictions on the cointegrating vectors. For instance, it may be the case that the single stationary cointegrating vector is [1, 0, 0, 0] , i.e. the first variable of the system is stationary. Since the first variable is the real exchange rate, this amounts to a test of purchasing power parity. If PPP holds, the equilibrium real exchange rate is time-varying and the estimated effects of the fundamental variables are not significantly

[4] For instance, the parameters estimated by Hsieh (1982) are 0.362, 0.516 and 0.538. In Marston (1990), they vary between 0.714 and 1.244. Rogoff (1992) report estimates of 0.6-0.7 while De Gregorio and Wolf document smaller effects, between 0.1 and 0.3. The panel cointegration results of Chinn and Johnston fall in the range 0.1-0.9.

different from zero. As evident from the second column in Table 4, PPP is rejected in all cases except Denmark, Finland and the UK.[5]

PPP may hold as a special case of any model of time-varying equilibrium real exchange rates. Here, where it is non-stationarity of terms of trade or relative growth that drive the equilibrium real exchange rate, PPP is expected to hold if the terms of trade and relative growth are stationary. In the case of Finland, the terms of trade are stationary but there exists no stationary combination of the two real GDP series. For the United Kingdom, neither terms of trade nor relative GDP are stationary.[6] Since PPP holds only barely for both countries, we continue to look for more stationary relationships between the real exchange rate and the non-stationary fundamental variables also in these two cases. It may be noted that Finland was one of three cases where the terms of trade showed up with the wrong sign in the unrestricted estimates of the cointegrating vector in Table 3.

Since PPP is rejected in all cases except Denmark, Finland and the United Kingdom, there are significant long run relationships between real exchange rates and at least one of the fundamental variables for the remaining countries. Next possibility to be investigated is that at either term of trade or the two real GDP series are needed in the equilibrium relationship while the other are not significant. Columns three and four of Table 4 show the results from testing if real exchange rate is related to growth but not terms of trade and vice versa. It turns out that terms of trade can be excluded from the cointegrating relationship in five cases and the two GDP variables can be excluded in four cases.

A third linear restriction of interest is whether domestic and foreign GDP enters into the cointegrating relationship with coefficients of equal size but opposite signs, i.e. whether it is <u>relative</u> productivity growth that matter. As shown in the final column of Table 4, the symmetry restriction on the effects of domestic and foreign GDP is not rejected by data in seven cases.

The cointegrating vectors may be more efficiently estimated if the relevant restrictions are imposed. Table 5 shows the resulting restricted estimates. In the cases where terms

---

[5] The tests are known to be oversized. Taking this into consideration, the results may be interpreted as indicating stationarity also for the real exchange rates of France, Germany and Spain.

[6] The test statistics are 14.90 and 14.20 for the terms of trade and the most stationary combination of the two GDP series for the United Kingdom. The corresponding results for Finalnd are 6.45 and 9.00. Stationarity tests of the remaining fundamental variables reject the null.

of trades may be excluded from the cointegrating relation, all point estimates have the expected signs. Hence, high domestic growth is associated with an appreciation of the real exchange rate and high foreign growth is associated with a depreciation. Of the seven cases where relative GDP matters, the estimates have the expected sign in five. Finally, there are four cases where both domestic and foreign GDP can be excluded to leave us with a relationship between the real exchange rate and terms of trade. Three of these estimates are positive, implying that improved terms of trade are associated with an appreciation of the real exchange rate.

When comparing the results in Tables 3 and 5 for individual countries, we see that domestic and foreign GDP for Canada and Germany get the expected sign with restrictions imposed, while the effects are still the opposite for Austria and the signs are now reversed for France. There are also fewer really large parameter estimates in Table 5 than in Table 3. On the whole, there appears to be substantially more evidence in favour of our hypothesis that high relative growth and improved terms of trade appreciate real exchange rates in Table 5, when the relevant restrictions are imposed, than in Table 3.

We conclude that according to the Johansen approach, there is cointegration among real exchange rates, domestic GDP, foreign GDP and terms of trade for all countries except Norway, Italy and Switzerland. Hence, real exchange rates are systematically related to the development of fundamental variables in the long run. High domestic growth, low foreign growth and improved terms of trade are associated with an appreciation of the real exchange rate in 60-80 percent of the cases.

From cointegrating individual country time series, different results are obtained for the different countries. This makes it difficult to evaluate our hypothesis about how equilibrium real exchange rates are related to terms of trade and productivity. It would be more satisfying if the fundamental variables had the same effects in every case. However, the point estimates from data on 15 countries cannot be expected to coincide exactly. Within the Johansen framework, it is not possible to investigate whether the effects in the different countries differ significantly or not. We therefore turn to panel tests where this hypothesis is testable.

3. Single equation estimation and panel data

Until recently, there was a choice between cointegrating single country time series and studying stationary transformations of multicountry panel data. The power of unit root tests is often low when applied to single country time series since the available series are fairly short. Turning to panel data vastly increases the number of observations and the variance of the dependent variable, thereby improving the power and precision of the tests. However, if the true relationship is between the levels of the variables, much information is lost by differencing. Tests for cointegration and restrictions on cointegrating vectors in panel data have recently been developed by Pedroni (1995, 1996). An advantage of these procedures is that hypotheses may be tested across the panel of countries, whereby a single result for the whole data set can be obtained.

The panel cointegration tests are based on single equation estimation as opposed to the systems approach of the Johansen procedure. Although the cointegrating vectors may be estimated by OLS, Phillips and Hansen's fully modified OLS-estimator (FMOLS) is more appropriate since it takes the short run dynamics and possible endogeneity of the regressors into account. Pedroni develops a panel estimator of the potentially common cointegrating vector based on the FMOLS estimator as well as tests of whether this vector is common to all countries in the sample. Since single equation estimation may yield other results than the Johansen system approach, it is necessary to reestimate the cointegrating vectors of the individual countries with FMOLS. Table 6 shows the results. The null hypothesis of the panel tests is that these parameters (and not the ones in Table 3) are identical for all countries and equal to the parameters estimated on the panel data set.

In contrast to the Johansen cointegration rank tests, the ADF-test for unit roots indicate cointegration among real exchange rates, domestic and foreign GDP and terms of trade for all countries. The panel unit root test discussed by Im, Pesharan and Shin (1995) also reject the null. Hence, there is more evidence of long tun relationships between real exchange rates and the fundamental variables in Table 6 than in Table 2.

The cointegrating vectors estimated by FMOLS differ substantially from the Johansen estimates. 9 of the domestic GDP coefficients, 10 of the foreign GDP coefficients and 13 of the terms of trade coefficients have the expected signs. The magnitudes also appear more reasonable in Table 5 than in Table 3 since we do not expect a one percentage GDP change to have double digit effects on the equilibrium real exchange rate. Domestic and foreign GDP now enter with the expected signs for France and Germany but not for the US. On the whole, single equation estimation on individual country data provides considerably more support to our hypothesis about the relationship between real exchange rates, domestic and foreign GDP and terms of trade than the Johansen approach in the preceding section.

The parameters estimated on the panel data set imply that one percent domestic GDP growth appreciates the equilibrium real exchange rate with 0.657 percent. Foreign GDP growth depreciates the equilibrium real exchange rate by 0.572 percent, while one percents improvement of the terms of trade is associated with an appreciation of 0.346 percent. These parameters have the expected signs and also reasonable magnitudes in comparison to previous results. Since the diversity of the individual country estimates may be a consequence of the small sample, we proceed to investigate whether all parameters are in fact equal to this panel vector.

Pedroni (1996) discusses two tests of whether the cointegrating vector is the same in all countries: The panel *t*-ratio and the group mean *t*-ratio. The latter test is similar to the panel data unit root test discussed in Im, Pesaran and Shin (1995). Both tests can be constructed either from an asymptotic estimator or from small sample counterpart. Pedroni shows that the former are standard normals. Monte Carlo simulations by Pedroni (1996) and Canzoneri, Cumby and Diba (1996) show that the small sample tests are relatively well behaved. Since the sample only includes 15 countries, we stick to the small sample versions of the tests.

The null hypothesis of both tests is that $\beta_i = \beta_0$ for all countries *i*. The panel *t*-ratio is defined as $T\sqrt{N}(b-\beta_0)$ where b is the small sample panel cointegration estimator. The group mean t-ratio is defined as

$$\bar{t}_b = N^{-1/2}\sum_{i=1}^{N} L_{11i}^{-1}\left(\sum_{t=1}^{T}(x_{it}-\bar{x}_i)^2\right)^{-1/2}\left(\sum_{t=1}^{T}(x_{it}-\bar{x}_i)y_{it}^{*}-T\gamma_i\right)$$

where

T is the number of observations

N is the number of countries

L_i is the lower triangular decomposition of the estimated long run covariance matrix Ω_i

$y_{it}^{*}=(y_{it}-\bar{y}_i)-L_{21i}L_{22i}^{-1}(\Omega_{22i})$ and

$\gamma_i = \Omega_{21i} - L_{21i}L_{22i}^{-1}\Omega_{22i}$

The two panel test statistics investigate the null hypothesis that all cointegrating vectors are jointly equal to the estimated panel vector. In order to check how the restriction fairs with the individual countries, we also test whether the cointegrating vector of each country coincides with the one estimated on the panel. The test of linear restrictions on cointegrating vectors based on the FMOLS estimator discussed by Phillips and Hansen (1990) appears appropriate to use here. Table 7 shows the results.

The hypothesis that the panel cointegrating vector coincides with the individual country estimates is rejected in all cases except Germany. Furthermore, the joint tests of whether all the cointegrating vectors coincide with the one estimated on the panel data set also reject the null. Hence, although the average effects of domestic GDP, foreign GDP and terms of trade have the expected signs and reasonable magnitudes, we find little support for the hypothesis that there is a common cointegrating vector for all the countries.

4. Conclusions

Purchasing power parity implies that equilibrium real exchange rates are constant in the long run. This hypothesis has been tested numerous times and usually rejected. Hence, equilibrium real exchange rates appear to be time varying. The most popular model of why they would vary over time is the Balassa (1964) and Samuelson (1964) model where real exchange rates are driven by the relative productivity in the tradable and non tradable sectors. The model has also been extended to include terms of trade, in which case improvements appreciate the equilibrium real exchange rate. Given that steady state GDP growth is driven by productivity and productivity growth is concentrated to the tradable sectors, the model predicts a relationship between equilibrium real exchange rates and real GDP.

Models of time varying equilibrium real exchange rates have previously been tested on differenced data, whereby the possibility of long run equilibrium relations between the levels of the variables is excluded. Here, we focus on the long run relationship between real exchange rates and fundamental variables. According to the Johansen approach, 12 of 15 OECD countries have cointegration among real exchange rates and domestic GDP, foreign GDP and terms of trade. Hence, there are systematic long run relationships between real exchange rates and the fundamental variables in the individual country time series data. From the theory, favourable developments in relative productivity and terms of trade are expected to be associated with stronger real exchange rates. The estimated parameters of the unrestricted cointegrating vectors have the expected signs in about two thirds of the cases. When linear restrictions like exclusion of insignificant variables or symmetry of domestic and foreign GDP are imposed, around 80 percent of the parameters have the expected signs.

Single equation cointegration tests confirm that real exchange rates are related to relative productivity and terms of trade in the long run. The estimated parameters have the expected signs in most cases. Cointegration of individual country time series data thus provides considerable support for our hypothesis that high relative GDP growth and improved terms of trade result in stronger equilibrium real exchange rates.

When each country is studied in isolation, different results are obtained for different countries. In some cases, the parameters have the expected signs and in other case, the signs are the opposite. The magnitude of the effects also differs drastically between the countries. However, this could be a consequence of the small sample. With panel cointegration procedures, hypotheses may be tested across the panel of countries. For instance, the restriction that the fundamental variables have the same effect in all countries is testable within this framework.

The parameters of the estimated panel cointegrating vector have the expected signs and reasonable magnitudes compared to previous studies. If the single country results were random, they would average out in the panel tests. While this does not happen, the hypothesis that the cointegrating vector is common to all the countries in the panel is rejected. Single country tests of whether the estimated panel vector coincides with the individual country cointegrating vector also reject the null in all cases but one. Hence, there does not appear to exist a common cointegrating vector for the panel of countries.

We conclude that there are systematic long run relationships between real exchange rates and relative GDP growth but that the effects of the fundamental variables on the equilibrium real exchange rates differ between the countries.

Appendix A: Data

The last observation on export and import prices of Finland is 1994:4. There are no monthly data on the IFS data tape. Hence, the sample for Finland is 1960:1 to 1994:4. The same applies to Austria, where 1994:1 is the last observation.

In the case of Sweden, quarterly data on export and import prices are available until 1994:4. Quarterly averages of monthly data have been used from 1995:1 to 1995:3, which is the last observation in the sample.

In the case of Switzerland, export and import price indices are available up to 1987:4. Thereafter, the IFS data base instead report unit values of exports and imports. We link the two types of series together, hence using price indices up to 1987 and unit values thereafter.

Table 1: Information criteria for choice of lag lengths and residual tests

Country	AIC	BIC	LIL	Box-Ljung	Bera-Jarque	Preferred lags
Austria	3	1	1	505.25	23.92	3
				(0.51)	(0.00)	
Canada	2	1	2	479.19	82.43	9
				(0.05)	(0.00)	
Denmark	1	1	1	525.77	48.69	3
				(0.70)	(0.00)	
Finland	2	1	1	572.01	54.72	3
				(0.09)	(0.00)	
France	2	1	2	515.15	138.68	5
				(0.27)	(0.00)	
Germany	2	1	2	600.66	77.32	2
				(0.06)	(0.00)	
Italy	2	1	1	543.61	163.21	2
				(0.69)	(0.00)	
Japan	3	1	3	532.39	73.11	3
				(0.80)	(0.00)	
Netherlands	2	1	1	553.68	51.35	3
				(0.38)	(0.00)	
Norway	1	1	1	564.63	44.67	5
				(0.06)	(0.00)	
Spain	2	1	1	586.38	82.91	4
				(0.05)	(0.00)	
Sweden	1	1	1	595.82	114.45	2
				(0.08)	(0.00)	
Switzerland	2	1	1	473.94	44.54	8
				(0.08)	(0.00)	
UK	1	1	1	601.87	120.29	3
				(0.06)	(0.00)	
USA	2	1	1	608.22	18.48	2
				(0.08)	(0.02)	

Table 2: Tests for cointegrating rank

	tr(1)	tr(2)	tr(3)	tr(4)	$\lambda_{max}(1)$	$\lambda_{max}(2)$	$\lambda_{max}(3)$	$\lambda_{max}(4)$	rank
Critical values	36.58	21.63	10.47	2.86	21.58	15.59	9.52	2.86	1
Austria	48.20	16.04	6.28	0.00	32.16	9.76	6.27	0.00	1
Canada	47.36	14.15	5.63	2.30	33.20	8.52	3.33	2.30	1
Denmark	55.02	25.18	11.05	1.94	31.84	12.13	9.11	1.94	2
Finland	42.96	22.58	7.13	2.48	20.38	15.45	4.65	2.48	1
France	44.33	22.28	8.21	1.09	22.06	14.06	7.13	1.09	1
Germany	47.63	22.99	10.34	2.40	24.64	12.66	7.93	2.40	1
Italy	36.32	19.35	5.38	1.00	16.98	13.97	4.38	1.00	0
Japan	49.62	15.86	1.94	0.00	33.76	13.92	1.94	0.00	1
Netherlands	58.31	22.57	7.39	3.07	35.74	15.18	4.32	3.07	1
Norway	31.83	12.99	5.31	0.16	18.83	7.68	5.15	0.16	0
Spain	40.54	13.05	4.82	0.00	27.49	8.23	4.81	0.00	1
Sweden	52.77	22.23	10.55	0.04	30.54	11.68	10.51	0.04	1
Switzerland	38.60	15.96	6.46	0.49	22.64	9.50	5.97	0.49	0
UK	49.66	16.90	5.94	0.03	32.77	10.93	5.94	0.03	1
USA	73.54	18.28	5.63	0.13	55.26	12.65	5.50	0.13	1

tr(1) tests H_0: r=0 against H_A: r=1 and so on.

Table 3: Unrestricted estimates of the cointegrating vector(s)

Country	Real exchange rate	Domestic GDP	Foreign GDP	Terms of trade
Austria	1.00	-3.703	3.803	9.688
Canada	1.00	-0.045	-0.235	0.231
Denmark	1.00	0.073	0.108	1.391
	1.00	-46.762	36.405	-4.935
Finland	1.00	0.330	-0.369	-0.750
France	1.00	6.429	-8.267	1.446
Germany	1.00	-0.488	0.320	1.698
Japan	1.00	-2.060	9.327	-0.076
Netherlands	1.00	2.453	-2.323	-2.104
Spain	1.00	10.142	-11.793	0.275
Sweden	1.00	4.647	-3.509	0.506
UK	1.00	0.065	-0.001	1.116
USA	1.00	0.613	-1.211	1.357

Table 4: Tests of linear restrictions on the cointegrating vectors

Country	PPP	Terms of trade excluded	GDP excluded	GDP symmetry
R	[1, 0, 0, 0]	[1, 0, 0, 0 0, 0, 1, 0 0, 0, 0, 1]	[1, 0, 0, 0 0, 0, 0, 1]	[1,.0, 0, 0 0, 1, -1, 0 0, 0, 0, 1]
Australia	33.11 (0.00)	3.86 (0.05)	23.89 (0.00)	20.01 (0.00)
Austria	24.18 (0.00)	20.03 (0.00)	2.55 (0.28)	0.07 (0.28)
Canada	27.55 (0.00)	3.07 (0.08)	22.52 (0.00)	14.57 (0.00)
Denmark	2.28 (0.32)			
Finland	6.60 (0.09)	0.92 (0.34)	0.52 (0.77)	0.45 (0.50)
France	13.23 (0.00)	4.48 (0.03)	7.41 (0.02)	3.00 (0.08)
Germany	13.60 (0.00)	11.81 (0.00)	1.53 (0.47)	0.49 (0.48)
Japan	27.74 (0.00)	1.23 (0.27)	26.61 (0.00)	19.24 (0.00)
Netherlands	29.65 (0.00)	11.42 (0.00)	19.66 (0.00)	2.39 (0.12)
Spain	12.37 (0.01)	0.06 (0.81)	12.36 (0.00)	2.10 (0.15)
Sweden	24.70 (0.00)	0.50 (0.48)	14.94 (0.00)	16.82 (0.00)
UK	7.08 (0.07)	7.05 (0.01)	2.01 (0.37)	0.19 (0.67)
USA	51.22 (0.00)	4.41 (0.04)	10.20 (0.01)	6.21 (0.01)

Table 5: Estimates of restricted cointegration vectors

Country	Real exchange rate	Domestic GDP	Foreign GDP	Terms of trade
Exclusion of the terms of trade				
Australia	1.00	2.967	-3.526	
Canada	1.00	0.131	-0.472	
Finland	1.00	1.029	-1.555	
Japan	1.00	1.452	-0.839	
Spain	1.00	12.135	-14.25	
Sweden	1.00	4.161	-3.388	
UK	1.00	0.193	-0.130	
Symmetry of domestic and foreign GDP				
Austria	1.00	-6.733	6.733	15.191
Finland	1.00	0.376	-0.376	-1.175
France	1.00	-0.385	0.385	-0.365
Germany	1.00	0.369	-0.369	1.472
Netherlands	1.00	1.971	-1.971	-3.055
Spain	1.00	2.297	-2.297	0.211
UK	1.00	0.114	-0.114	1.094
Exclusion of domestic and foreign GDP				
Austria	1.00			102.54
Finland	1.00			-1.480
Germany	1.00			1.165
UK	1.00			1.048

Table 6: Estimated FMOLS cointegrating vectors, ADF-test statistics

Country	Real exchange rate	Domestic GDP	Foreign GDP	Terms of trade	ADF
Austria	1.00	**1.110**	**-0.827**	**0.595**	-3.248***
		(5.339)	**(-4.172)**	**(3.202)**	
Canada	1.00	-0.293	0.088	**0.311**	-2.966***
		(-0.780)	(0.188)	**(1.909)**	
Denmark	1.00	-0.620	**0.854**	**0.487**	-2.379**
		(-1.544)	**(2.465)**	**(2.681)**	
Finland	1.00	**0.817**	**-0.892**	**0.663**	-2.700***
		(4.407)	**(-4.820)**	**(3.746)**	
France	1.00	0.689	**-1.079**	**0.417**	-3.189***
		(1.513)	**(-1.812)**	**(2.066)**	
Germany	1.00	**0.599**	**-0.498**	**0.444**	-2.024**
		(2.092)	**(-2.047)**	**4.589**	
Italy	1.00	**0.643**	**-0.722**	**0.587**	-3.542***
		(1.844)	**(-1.835)**	**(7.378)**	
Japan	1.00	**-1.163**	**6.328**	**0.106**	-2.860***
		(-7.195)	**(10.819)**	**(2.724)**	
Netherlands	1.00	**1.989**	**-1.757**	**-0.664**	-2.368**
		(6.955)	**(-6.415)**	**(-3.368)**	
Norway	1.00	**-0.505**	**0.724**	0.113	-2.315**
		(-3.299)	**(4.526)**	(1.571)	
Spain	1.00	**0.417**	-0.065	0.157	-3.316***
		(2.489)	(-0.324)	(1.689)	
Sweden	1.00	**1.630**	**-1.312**	0.319	-2.106**
		(7.604)	**(-8.249)**	(1.267)	
Switzerland	1.00	**-1.197**	**1.336**	-0.070	-2.034***
		(-2.738)	**(4.216)**	(-0.411)	
UK	1.00	0.035	-0.087	**0.943**	-3.362***
		(0.099)	(-0.356)	**(5.831)**	
USA	1.00	-0.174	-0.216	0.199	-2.501**
		(-0.815)	(-0.784)	(1.504)	
Panel	1.00	**0.657**	**-0.572**	**0.346**	-6.266***
		(2.187)	**(1.953)**	**(1.731)**	

t-values as suggested by Phillips and Hansen (1990) within parenthesis

***Significant at 1 percent (the critical value is -2.582)

**Significant at 5 percent (the critical value is -1.942)

Table 7: Tests of the hypothesis that the estimated common cointegrating vector [0.572, -0.657, 0.346] is the cointegrating vector in each country

Country	test statistics
Austria	39.20
Canada	245.07
Denmark	104.75
Finland	25.92
France	214.44
Germany	0.85*
Italy	50.63
Japan	143.77
Netherlands	128.07
Norway	61.48
Spain	46.39
Sweden	12.75
Switzerland	238.09
UK	21.25
USA	53.20
$\bar{t}_b$	-5.78
panel *t*-ratio	-6.02

*Significant at the 5 percent level. The Phillips and Hansen test statistics has a $\chi^2(\mathrm{J})$ distribution, where J is the number of restrictions. Hence, the 5 percent critical value is 7.81. The panel cointegration test statistics are normally distributed.

REFERENCES

Asea, P. and Mendoza, E., (1994), "The Balassa-Samuelson model: A general equilibrium appraisal", Review of International Economics 2, 244-67

Bhagwati, J., (1984), "Why are services cheaper in poor countries?", Economic Journal 94, 279-86

Balassa, B., (1964), "The purchasing power parity doctrine: A reappraisal", Journal of Political Economy 72, 584-596

Canzoneri, M., Cumby, R and Diba, B., (1996), "Relative labour productivity and the real exchange rate in the long run: Evidence for a panel of OECD countries", NBER Working Paper No. 5676

De Gregorio, J. and Wolf, H, (1994), "Terms of trade, productivity and the real exchange rate", NBER Working Paper No. 4807

Engel, Charles (1995), "Accounting for US real exchange rate changes", NBER Working Paper 5394

Froot, K. and Rogoff, K., (1994), "Perspectives on PPP and long-run real exchange rates", in Grossman, G. and Rogoff, K. eds., *Handbook of International Economics*, Elsevier Science B.V., Amsterdam

Im, K., Pesaran, H. and Shin, Y., (1995), "Testing for unit roots in heterogeneous panels", Working Paper, Department of Applied Economics, Georgetown University

Jacobson, T., Vredin, A and Warne, A., (199?), "Common trends and hysteresis in unemployment", forthcoming in European Economic Review

Oh, K., (1996), "Purchasing power parity and unit root tests using panel data", Journal of International Money and Finance 15, 405-418

Pedroni, P., (1995), "Panel Cointegration: Asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis", Working Paper, Department of Economics, Indiana University

Pedroni, P., (1996), "Fully modified OLS for heterogeneous panels", Working Paper, Department of Economics, Indiana University

Phillips, P. and Hansen, B., (1990), "Statistical inference in instrumental variables regressions with I(1) processes", Review of Economic Studies 57, 99-125

Rogoff, K., (1996), "The purchasing power parity puzzle", Journal of Economic Literature 34, 647-668

Samuelson, P., (1964), "Theoretical notes on trade problems", Review of Economics and Statistics 46, 145-154

Strauss, J., (1995), "Real exchange rates, PPP and the relative price of non-traded goods", Southern Economic Journal 61, 991-1005