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ABSTRACT

The present paper tests for the validity of long-run purchasing power parity (PPP) for the three key currencies of the recent floating exchange rate period, the US dollar, the German mark and the Japanese yen. The novelty of the paper is that the validity of the PPP conditions relating the economies of the US, Germany and Japan is tested in a system framework, which allows for possible interactions in the determination of the exchange rates and the prices of the three economies. Some form of causality among the variables of the system is also assessed empirically with the aid of weak exogeneity tests. The results illustrate the importance of the multilateral testing. Positive evidence for PPP is found: long-run PPP is supported for the US and Germany but also for the US and Japan, in contrast to evidence of earlier empirical studies. In addition, causality is found running from the US prices to the exchange rates and German and Japanese prices.

Keywords: PPP, cointegration, causality.
JEL Classification: C32, C52, F31.

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1. Introduction

Purchasing power parity (PPP) states that the exchange rate between two currencies is determined by the change in the relative prices of the two countries. The notion underlying this is that deviations from the parity represent profitable commodity arbitrage opportunities, which, if exploited, will tend to force the exchange rate towards the parity. PPP has been viewed as an equilibrium condition as well as an exchange rate determination theory. Since the return to a floating exchange rate regime in the early 1970s, it has been used as at least a long-run relationship in most of the international economic models (for a survey, see *inter alia* Froot and Rogoff (1995)).

As a consequence, the empirical verification of PPP has been the purpose of a large number of applied papers. According to Froot and Rogoff (1995), there are three different stages of empirical studies (grouped based on the different types of the empirical tests they perform): (a) the correlation - based studies, (b) the unit root testing studies, which test for stationarity of real exchange rates and (c) the cointegration - based studies, which test for cointegration between relative prices and exchange rates. The correlation - type studies (performed mainly in the 1980s) found little or no support for long-run PPP, whereas the unit root and cointegration based studies (performed from the late 1980s and on) provided mixed results for the validity of PPP.

The recent papers, which mainly test for PPP using the concept of stationarity and cointegration (i.e. belong to the (b) and (c) stages of studies) further advocate the use of larger data sets and more advanced econometric techniques (see MacDonald (1999) and references therein). Larger data sets can be obtained by making use of long historical time series (see Froot and Rogoff (1995), Lothian and Taylor (1996), Cuddington and Liang, (2000)) or by analysing time series data from a large number of countries, using panel data techniques (Abuaf and Jorion (1990), Jorion and Sweeny (1996), Papell (1997), Koedijk, Schotman and Van Dijk (1998), Papell and Theodoridis (1998), Bayoumi and MacDonald (1999), Fleissig and Strauss (2000)). Advanced econometric techniques contain the use of unit root tests with improved power, which may also account for possible structural breaks (Lothian and Taylor (1997), Michael, Nobay and Peel (1997), Sarno and Taylor (1998), Cheung and Lai (1998), (2000), (2001), Kuo and Mikkola (1999), Salehizadeh and Taylor (1999), Baum, Barkoulas and Caglayan (1999), (2001)) and the use of multivariate cointegration – mainly the Johansen technique (MacDonald (1993), Juselius (1995), MacDonald and Moore (1996), Edison, Gagnon and Melick (1997)).

In the present paper, we argue that testing for PPP should be done in a system context, which models the dynamic interactions of exchange rates and prices of more than two countries simultaneously[1]. In other words, we state that the standard bilateral testing for PPP is not adequate. The argument is based on two ideas. The first idea is that the bilateral setting ignores the links that may exist between the short-run movements of the exchange rates and may therefore produce misleading results. Actually, this idea lies also behind the testing for PPP using panel techniques (see Abuaf and Jorion (1990)). However, in contrast with the present paper, the panel studies assume that PPP holds equally well for all currencies. They assume equal slope coefficients relating relative prices to exchange rates or equal mean reversion parameters for the exchange rate, for all the cases they analyse, whereas in the present study each possible PPP relationship is investigated as an individual case.

The second idea is that testing in a system context also allows domestic prices to be influenced by the prices (expressed in domestic currency) of more than one trading partner. Studies, which test for PPP using effective exchange rates and effective (trade weighted) foreign prices, adopt the same rationale. However, the use of effective series has been criticised as being arbitrary in terms of the choice of weights. It also has the drawback that it implies that the relative importance of different countries' prices in determining domestic prices changes if and only if, the trade pattern changes. In the present work, we do not restrict the influence of foreign prices to domestic prices to be measured by fixed trade weights but we allow the influence of the foreign prices to be estimated and determined by the data series.

In the analysis, we also investigate empirically whether prices or the exchange rate is the weakly exogenous variable in the PPP relationship. As a parity or arbitrage condition, PPP does not imply any direction of causality, but as an exchange rate determination theory it clearly assumes exogenous prices. Contrary to most of the previous PPP empirical studies, we allow the endogeneity/ exogeneity status to be evaluated statistically, rather than imposed *a priori*. In addition, the weak exogeneity

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[1] This idea is first developed in Sideris (1997), in an analysis for the Greek drachma.

tests we perform, further reveal causality directions among the economies under consideration.

Finally, and in contrast to a number of previous works, the present study does not pre-impose but tests for the validity of the hypotheses of symmetry and proportionality implied by the weak and strong PPP forms, respectively.

The paper investigates the validity of long-run PPP for currencies that are frequently chosen for testing the PPP hypothesis. The currencies are the three key currencies of the recent floating exchange rate period, the US dollar, the German mark and the Japanese yen. Providing support for PPP between the US and Japan is of further interest, given that previous studies rejected the parity hypothesis for the two countries (Kim (1990), Patel (1990), Koedijk, Schotman and Van Dijk (1998)). In two recent studies, Xu (Xu (1999), (2003)) provides evidence for cointegration between the yen-dollar rate and the prices of the two countries (a result, which can be interpreted as providing some support for PPP), but fails to accept PPP in either the weak or the strong form as expressed by the economic theory. In addition, Cheng (Cheng (1999)) provides evidence for a cointegrating relationship including the yen-dollar rate, relative prices and the interest rate ratio of the two countries (and interprets it as a long-run PPP relation), but he does not test for a more theoretically accurate PPP specification.

Long-run PPP is tested as an equilibrium relationship using the Johansen multivariate cointegration technique (Johansen (1988), Johansen and Juselius (1990)). The model specification used for cointegration allows for different long-run relations and short-run dynamics and for adjustment for specific regime shifts. If the short-run dynamics are different from the long-run relations, the explicit specification of the former is probably crucial for a successful estimation of the latter and of the time path to equilibrium (see Juselius (1995)). This is of particular relevance when the adjustment is very slow, as is the adjustment to PPP. Applied in the present work, the methodology allows us to account for more complex short-run dynamics, which may link the exchange rates with the prices of the three countries. In addition, taking into account possible regime shifts is important since such shifts can distort statistical tests that do not account for them. The technique also allows for possible interactions in the determination of the variables (no variable is pre-considered exogenous) and for testing for the alternative versions of PPP.

The rest of the paper is organised as follows: Section 2 describes briefly the theory underlying the PPP doctrine and outlines the methodology we apply for the testing, whereas section 3 presents the data set and describes the applied work. The final section summarises and concludes.

2. Theoretical and methodological issues

2.1 The economic background

Recent work on PPP has concentrated on the application of cointegration methods to an equation of the form:

$$e_t = \gamma_0 + \gamma_1 p_t + \gamma_2 p_t^* + u_t \qquad (1)$$

where p_t, p_t^* indicate the logs of the price levels of the domestic and the foreign economy respectively, e_t the log of the exchange rate denominated in the currency of the domestic economy and u_t is the error term.

Strong PPP is implied by the proportionality restriction $\gamma_1=1$, $\gamma_2=-1$

$$e_t = \gamma_0 + p_t - p_t^* + u_t \qquad (2)$$

and states that, whatever the monetary or real disturbances in an economy, under the assumption of instantaneous costless arbitrage, the prices of a common basket of goods in the two countries measured in a common currency will be the same.

However, even though there cannot be any objection to strong PPP as a theoretical statement, it cannot be expected to hold always as an empirical proposition. The prices of a given commodity will not necessarily be equal in different locations, because of transportation costs, possible tariff barriers and information costs. Moreover, measurement error problems, arising from published price indices which do not coincide with the theoretical prices, should also be taken into account when PPP is tested empirically[2]. Therefore, the relationship is more likely to have the weak PPP form implied by the restriction of symmetry: $\gamma_1=-\gamma_2$

$$e_t = \gamma_0 + \gamma_1(p_t - p_t^*) + u_t \qquad (3)$$

[2] An implicit assumption for PPP to hold when tested using aggregate price indices is that each good is equally weighted in the indices of the different economies. International differences in consumption patterns, variations in product qualities and differences between listed and transaction prices are some of the reasons for different weighting of the price indices.

with γ_1 being a constant factor which accounts for assumed constant transportation, information costs and measurement errors. γ_1 is allowed to differ from unity, implying that long-run proportionality between the exchange rate and relative prices may not be exactly one-to-one (see Taylor (1988), for the derivation of (2) in a model allowing for transportation costs and measurement errors).

However, even in the weak form, PPP does not necessarily hold in the long run: Changes in tastes causing shifts in exports demand, the different relevant importance of the tradeable to the nontradeable sectors, as well as the difference in more fundamental factors such as productivity, government spending and strategic pricing decisions by firms would cause exchange rate movements beyond the PPP level (see Froot and Rogoff (1995) for a survey of the structural models that explain deviations from PPP).

2.2 The econometric methodology

The empirical analysis is consistent with the General to Specific methodology (see *inter alia* Hendry (1995)). Equation (3) defines the long-run equilibrium relationship in the goods market, in a very simplified world. Following the ideas of the methodology, when (3) is used as a basis for empirical modelling, it has to be modified, so that the stochastic properties of the data are taken into account. In addition, there might be other factors not specified by the theory that are relevant to understand the variation in the series i.e. policy changes, exogenous shocks, or structural breaks. In order to take into account such problems presented in applied work, the General to Specific methodology advocates as an initial step, the construction of a congruent unrestricted vector autoregression (VAR), which can be considered as an adequate representation of the joint distribution of the observed series (see *inter alia*, Hendry and Mizon (1993)).

In the VAR framework, the number of the cointegrating relationships between the variables can be defined following the Johansen procedure. The procedure suggests reparameterisation of the initial VAR, in the familiar vector error correction (VEC) form:

$$\Delta x_t = \sum_{\iota=1}^{p-1} \Pi_i \Delta x_{t-i} + \Pi x_{t-p} + \psi D_t + v_t \qquad (4)$$

where x_t is an N×1 vector of the time series of interest ν_t~IN(0,Σ) and D_t contains a set of conditioning variables (e.g. constant, seasonal dummies, specific regime shift dummies). The order of the VAR, p, is assumed finite and the parameters Π_i, Π and ψ are assumed constant. Π is the matrix of the long-run responses and if there exist r cointegrating relationships between the variables, is of reduced rank r < N. In this case, Π can be expressed as the product of two N×r matrices α and β' : Π = α β' where β contains the r cointegrating vectors and α is the loadings matrix, which contains the coefficients with which the cointegrating relationships enter the equations modelling Δx_t .

Johansen and Juselius (1990) and Johansen (1995) provide the test statistics to define the rank r of the matrix Π and show that testing for linear restrictions on either the parameters of the cointegrating vectors or their loadings is allowed given that the matrices α and β' are not unique. Therefore, specific meaningful economic restrictions concerning the elements of the matrices α and β can be tested and not imposed *a priori*. In the present case, certain linear restrictions on the elements of the matrix β test for the theoretical hypotheses of symmetry and proportionality for the long-run behaviour of e, p and p*. On the other hand, certain restrictions on the elements of the matrix α may imply weak exogeneity of the variables with respect to the long-run parameters. In particular, zero restrictions on the elements of the matrix α test whether or not the cointegrating vectors enter the equations of the system[3] (i.e. whether or not the variables are error-correcting).

3. The Empirical Analysis

PPP is tested between the US and the economies of Germany and Japan. Quarterly seasonally unadjusted data for the post-Bretton Woods period 1973(1) to 2002(4) are used. The two bilateral nominal exchange rates of the Japanese yen and the German mark[4] against the US dollar, and the consumer price indices of the three countries are all taken from the International Financial Statistics (IFS) database. All variables are

[3] For a presentation of the concept of weak exogeneity see *inter alia* Ericsson (1994); for testing for weak exogeneity in the cointegration framework, see Johansen (1995).

expressed in logs. The exchange rates yen / US dollar and mark / US dollar are denoted as e_J and e_G,, respectively. The consumer price indices are denoted as p_{US}, p_G and p_J where the subscripts US, G, and J stand for the US, Germany and Japan, respectively. Effective estimation periods are reduced so as to accommodate the lag structure of the estimated models.

The first step in the econometric analysis is the estimation of an unrestricted fifth-order VAR of the form of (4) for the vector $x' = (e_J\ ,\ p_G,\ e_G,\ p_{US},\ p_J)$ using multivariate least squares. The VAR is initially estimated using five lags of the variables, with a constant and seasonals included in the conditioning variables set D_t. However, likelihood ratio tests indicated the number of lags to be 4 in the final model.

While lack of residual correlation and heteroscedasticity was accepted by this first VAR specification, the normality of the residuals was not, possibly due to non-constant parameters as indicated by the plots of the relevant Chow tests. In addition, visual examination of the graphs of the series revealed fluctuations in specific time periods. These features supported the inclusion of two dummies to account for the structural breaks observed in the sample period[5]. The impulse dummy ID741 (takes the value 1 in 1974 (Q1)) was included to account for the first oil price shock whereas the step dummy SD901 (takes the value 1 in 1990(Q1) - 2002(Q4)) was included to account for the German unification. They both turned out to be significant in the system, whereas their absence would mean non normal residuals. The statistical properties of the residuals of the final VAR specification are reported in Table 1. The diagnostics do not indicate any serious mis-specification and therefore the VAR can be considered as a congruent statistical representation of the data[6].

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[4] For the period 1998(1) - 2002(4), the mark/dollar rate is calculated using the rate by which the mark was converted to euro and the euro/dollar rate.

[5] Inclusion of dummies is preferable to an enlargement of the system, as advocated by Clements and Mizon (1991).

[6] The tests indicate a non-normality problem at a 5% level for the residuals of the p_J equation, which cannot be solved by inclusion of any dummy. Based on the findings of Gonzalo (1994) on the robustness of the Johansen procedure with respect to non-normality, we make no further modeling changes.

Table 1: Misspecification tests for the VAR

Autocorrelation	
e_J	AR 1- 5 F(5, 83) = 0.94793 [0.4547]
p_G	AR 1- 5 F(5, 83) =0.80491 [0.5494]
e_G	AR 1- 5 F(5, 83) =0.56443 [0.7270]
p_{US}	AR 1- 5 F(5, 83) =0.92644 [0.4682]
p_J	AR 1- 5 F(5, 83) = 1.3791 [0.2405]
Normality	
e_J	X^2 (2) = 3.4907 [0.1746]
p_G	χ^2 (2) =0.48514 [0.7846]
e_G	χ^2 (2) = 1.8194 [0.4027]
p_{US}	χ^2 (2) =1.8664 [0.3933]
p_J	χ^2 (2) =7.4745 [0.0238] *
Conditional heteroscedasticity	
e_J	ARCH 4 F(4, 80) =0.1794 [0.9484]
p_G	ARCH 4 F(4, 80) =1.0302 [0.3969]
e_G	ARCH 4 F(4, 80) =1.0896 [0.3674]
p_{US}	ARCH 4 F(4, 80) =2.4852 [0.0501]
p_J	ARCH 4 F(4, 80) =0.23984 [0.9150]
VAR residuals	
Autocorrelation	AR 1-5 F(125,295) = 1.0193 [0.4415]
Normality	χ^2 (10) = 19.112 [0.0389] *
Cond. Hetero/city	F(600,530) =0.60268 [1.0000]

Note: * and ** indicate rejection of the null hypothesis at the 5% and 1% level of significance, respectively.

The VAR satisfies the statistical assumptions required for the Johansen technique and thus we can go on with the cointegration analysis. Inspection of the graphs of the price series indicates that the series have an approximate linear trend. Therefore the model is estimated with the restriction of the constant to be included in the cointegration space. The outcomes of the maximum eigenvalue and trace statistics are reported in Table 2. According to both likelihood ratio tests, there is evidence for three cointegrating vectors. In addition, the plot of the recursively estimated maximum eigenvalues indicate cointegrating relationships with constant parameters.

The estimated coefficients of the three cointegrating vectors (reported in Table 2) indicate that the vectors do not necessarily express relationships with a well-specified economic meaning. As already stated, the initial scope of the present work was to test for the validity of two long-run relations (PPP between the US and

Germany and PPP between the US and Japan), simultaneously. Nevertheless, the analysis indicated the existence of three cointegrating vectors, thus providing evidence for a third equilibrium relationship among the variables, which has to be specified. A quick examination of the estimated coefficients of the cointegrating vectors indicates that the third vector could express a relationship which involves the behaviour of the yen /mark rate calculated as the e_J / e_G ratio. (This is based on the observation that in all three cointegrating vectors the coefficients of e_J and e_G obtain values opposite in sign and almost equal in magnitude). A natural candidate - theoretical relationship for the specification of the third vector linking the yen/ mark rate with prices, could well be PPP between Germany and Japan. Based on this observation indicated by the data, we go on with the formal specification of the three dimensional cointegrating space. Table 3 presents the outcomes of a number of likelihood ratio test statistics for alternative hypotheses concerning the specification of the three cointegrating vectors.

Table 2: Cointegration analysis: 1974 (1) to 2002 (4)

Testing for the cointegration rank.

Eigenvalues	*Max. Eigen. (Using T-nm)*	*Trace (Using T-nm)*
0.305338	34.98*	113.6**
0.292131	33.17*	78.58**
0.226837	24.7*	45.41**
0.169161	17.79*	20.0
0.0299902	2.923	2.923

Estimated cointegrating vectors β' s

E_J	p_G	e_G	p_{US}	p_J	*Constant*
1	-3.506	-1.063	3.274	-2.797	9.555
0.260	1	-0.2944	-0.1608	-0.228	-3.827
-1.069	-4.149	1	1.864	0.597	11.547

Estimated loadings α's

E_J	0.0100	-0.1326	0.0629
P_G	0.0132	-0.0305	0.00236
E_G	0.0974	0.6012	0.03334
p_{US}	0.0023	-0.0138	-0.00141
P_J	0.0105	-0.0267	-0.0062

Note: * and ** indicate rejection of the null hypothesis at the 5% and 1% level of significance, respectively.

Table 3: Restriction Testing

Hypothesis		e_J	p_G	e_G	p_{US}	p_J	$\chi^2(d\ o\ f)$	*p-value*
Testing for theoretical restrictions								
H_1:	β_1 :	1	0	0	a	-a	0.4018 (1)	0.5261
H_2:	β_2 :	b	1	-b	0	-1	3.3202 (1)	0.0684
H_3:	β_3 :	0	-d	1	d	0	0.1830 (1)	0.6688
H_4:	β_2 :	c	1	-c	0		Not a constr.	
H_5:	β_1 :	1	0	0	1	-1	4.4085 (2)	0.110
H_6:	β_2 :	1	1	-1	0	-1	0.2384 (2)	0.8876
H_7	β_3 :	0	-1	1	1	0	4.0017 (2)	0.1352
H_8	$H_1 \cap H_2 \cap H_3$						34.413 (3)	0.0000**
H_9	$H_1 \cap H_4 \cap H_3$						5.948 (2)	0.0510
H_{10}	$H_5 \cap H_7$						37.61 (6)	0.0000**
H_{11}	$H_5 \cap H_6 \cap H_7$						50.98 (9)	0.0000**
Testing for restrictions necessary for weak exogeneity								
H_{12}	$H_9 \cap$ w. exogeneity of p_G, e_G w.r.t. β_1						23.252 (4)	0.000**
H_{13}	$H_9 \cap$ w. exogeneity of p_J, e_J w.r.t. β_3						13.284 (4)	0.010**
H_{14}	$H_9 \cap$ w. exog. of p_{US} w.r.t. β_1, β_2, β_3						7.425 (5)	0.190
H_{15}	$H_9 \cap$ w. exog. of p_G w.r.t. β_1, β_2, β_3						22.451 (5)	0.004**
H_{16}	$H_9 \cap$ w. exogeneity of p_J w.r.t. β_1, β_2, β_3						19.94 (5)	0.001**
H_{17}	$H_9 \cap$ w. exogeneity of e_J w.r.t. β_1, β_2, β_3						14.55 (5)	0.012 *
H_{18}	$H_9 \cap$ w. exog. of e_G w.r.t. β_1, β_2, β_3						17.94 (5)	0.003 **
H_{19}	$H_9 \cap$ w. exog. of e_G w.r.t. β_1 ,β_2 ,β_3 $\cap$ w. exogeneity of e_J w.r.t. β_1 ,β_2 ,β_3						39.76 (8)	0.003**

Note: * and ** indicate rejection of the null hypothesis at the 5% and 1% level of significance, respectively.

Hypotheses on a single cointegrating vector framework are initially considered. The first three hypotheses test for the validity of weak PPP for the three pairs of the countries. H_1 assumes weak PPP between the US and Japan for the specification of the first vector β_1, H_2 assumes weak PPP between Germany and Japan for the second vector β_2 and H_3 assumes weak PPP between the US and Germany for the third vector β_3. H_4, which assumes a long-run relation linking the yen / mark exchange rate with the German and Japanese prices for the second vector, does not form a constraint. Hypotheses H_5 , H_6 and H_7 assume strong PPP between the US -

Japan, Germany - Japan and the US - Germany, for the specification of the first, second and third vector, respectively. All six hypotheses (H_1, H_2, H_3, H_5, H_6 and H_7) are accepted by the data; still, their acceptance is just indicative for the specification of the cointegration space, since the restrictions, which concern one cointegrating vector at a time, are not identifying restrictions for the structure of the system. Joint testing is needed.

Hypotheses H_8 - H_{11} test jointly restrictions already described for the specification of the individual vectors. (e.g. H_8 assumes that the three vectors express weak PPP relations, whereas H_{11} assumes that the three vectors express strong PPPs). All but hypothesis H_9 are rejected by the data set. As a consequence, the analysis was continued by assuming that the structure of the cointegrating space can be trustfully given by the specification implied by H_9. The three cointegrating vectors are of the form (standard errors in parenthesis):

β_1 : e_J - 1.471 (0.182)(p_J - p_{US}) - 3.025 (0.457)

β_2 : 0.417 (0.0327)(e_J – e_G) - 0.401 (0.071) p_J + p_G -4.394 (0.366)

β_3 : e_G - 0.536 (0.227)(p_G - p_{US}) - 1.0572 (0.436)

β_1 implies weak PPP between Japan and the US, whereas β_3 implies weak PPP between Germany and the US. β_2 expresses a relation between the yen/mark rate, p_G and p_J which could be interpreted as a PPP-type relationship between Germany and Japan.

Assuming that H_9 expresses a reliable specification for the three vectors, we can go on and perform weak exogeneity tests. These tests are essentially tests for the significance of the cointegrating vectors, when used as error correction terms in the equations which model the short-run dynamics of the variables. If, for example, the third cointegrating vector β_3 (which implies PPP between Germany and the US) enters significantly the equation modelling the short-run dynamics of the e_G rate, the e_G rate cannot be considered as weakly endogenous with respect to the parameters of β_3. Such a result would mean that the e_G rate adjusts in the short run, in a way to restore the long-run equilibrium relationship implied by β_3.

A large number of weak exogeneity tests have been performed[7]. Some selected results are reported in the lower part of Table 3. The test outcomes reveal the complex dynamics that govern the behaviour of the variables in the short run. The outcomes of the tests implied by H_{12} and H_{13} indicate the importance of the joint modelling. H_{12} tests for weak exogeneity of e_G and p_G with respect to the parameters of β_1 (the long-run PPP between Japan and the US) and is rejected by the data set. The result indicates that the adjustment to the long-run US-Japan PPP comes even *via* movements of variables, which are not directly involved in this equilibrium relationship such as the German variables (e_G and p_G). The rejection of H_{13} leads to similar conclusions. Stated differently, the rejections of H_{12} and H_{13} demonstrate that any disturbance causing deviations from the equilibrium relations has important consequences for the dynamics of the whole system.

Hypotheses H_{14} - H_{18} are easier to interpret. They test for weak exogeneity of the five variables with respect to the parameters of the full system of cointegrating vectors. In detail, H_{14}, H_{15}, H_{16}, H_{17}, H_{18}, test for weak exogeneity of p_{US}, p_G, p_J, e_J and e_G respectively, with respect to the parameters of the cointegrating space (the parameters of β_1, β_2 and β_3). Hypothesis H_{19} tests jointly for weak exogeneity of the exchange rates with respect to the parameters of the cointegrating space. All, but hypothesis H_{14} are rejected by the data set.

Therefore, the US price variable was found to be weakly exogenous for the system. This result implies that, in the event of a shock to US prices, which causes the PPP relations to move out of equilibrium, all variables but p_{US} will move in a way to restore equilibrium. The US price variable might thus be considered to be the driving variable of the system (a variable that "pushes" the system but is not "pushed" by it). In other words, in the short run the US prices are not affected by the equilibrium PPP relations between the US, Germany and Japan; however, the German and Japanese variables, move in order to establish the equilibrium PPP relations with the US prices[8]. The PPP relations thus dominate the short-run formation of exchange rates and prices in Germany and Japan, but not that of the US prices. Consequently, the results provide some evidence on the hypothesis that prices in Germany and Japan (small countries relative to the US) are affected by the monetary policy of the US. In

[7] We do not report the results of all the tests for space reasons, but they are available upon request.
[8] Enders (Enders (1988)) finds similar results for Japan for the period 1960-1971.

such a context, the exchange rate acts as a channel by which the US monetary policy is transmitted to the economies of Germany and Japan.

4. Conclusions

The present study extends the current literature by re-examining the validity of the PPP hypothesis for the three key currencies of the recent floating exchange rate period, in a multilateral framework. We argue that PPP testing is more adequate in a system context, which takes into account the dynamic interactions of exchange rates and prices of more than two economies, simultaneously. In this study, we apply the Johansen methodology, which allows for different long-run relations and short-run dynamics and for adjustment for structural breaks.

Considering interdependence effects in PPP testing, turned out to be crucial: The system analysis provided positive evidence for PPP and revealed causal influences among the economies under consideration. There was evidence for two weak PPP relationships, (a) between the US and Germany and (b) between the US and Japan, in contrast with previous studies which rejected weak PPP between Japan and the US. It also revealed that there exists a cointegrating relationship, which links the yen / mark rate with German and Japanese prices, and thus provides some support for PPP between Germany and Japan. The results probably imply that both Germany and Japan preserved constant competitiveness with the US for the period analysed, and this is reflected in the third Japan - Germany relationship, which can be considered as a secondary relationship.

The system analysis also provided interesting results concerning the weak exogeneity of the variables. It indicated that US prices are the weakly exogenous variable for the long-run relations and thus function as the driving variable in the system. This implies that any shocks that hit US prices are passed through to German and Japanese prices via the equilibrium real exchange rate. The results thus support the hypothesis that the US monetary policy is transmitted to the prices of Germany and Japan. In the event, for example, of a loosening of US monetary policy, which causes US prices to increase, we would also expect upward pressure on German and Japanese prices coming through the exchange rate channel, so that PPP with the US is maintained in the long run.

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