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Purchasing power parity under the European Monetary System

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Using reduced rank cointegration analysis, this study examines whether exchange rate realignments are effective in extenuating the deviations from purchasing power parity (PPP) under the European Monetary System (EMS). In contrast to previous studies, more positive evidence for the PPP hypothesis is found. The difference in findings can be attributed partly to the statistical technique used, the correction of the finite sample bias, and the adjustment for realignment effects. In general, the results of this study support that currency realignments of the EMS have been effective in maintaining PPP among its member countries. (JEL F31, E58).

A major purpose of the European Monetary System (EMS) is to foster monetary stability and trade among its members. At the heart of the system is the quasi-fixed Exchange Rate Mechanism (ERM), under which intra-EMS rates are allowed to fluctuate within narrow bands around some mutually agreed upon central rates among the member countries. Significant changes in relative price levels can prompt exchange rate realignments, which are designed to maintain the competitiveness of the EMS members. Since the inception of the EMS in March 1979, the ERM has survived but through a number of realignments. An issue of interest is whether the member countries have been making efforts to coordinate monetary policies so as to maintain purchasing power parity (PPP) among them.

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Several arguments for a target zone arrangement like the EMS have been suggested. They include that the EMS is an effective disciplinary device for inflation-prone countries (Giavazzi and Pagano, 1988) and that the EMS can institute a short-run stabilizing effect on intra-EMS real and nominal exchange rates (Artis and Taylor, 1988; Diebold and Pauly, 1988; Ungerer *et al.*, 1986). The issue of welfare gains from the decrease in short-run volatility is still under debate (Artis and Taylor, 1988; Melitz, 1985). MacDonald and Taylor (1991) observe, however, that it may be more interesting to examine long-run exchange rate stabilization. Based on multivariate cointegration analysis, MacDonald and Taylor (1991) present evidence of long-run convergence in both nominal and real exchange rates for major EMS countries but not for non-EMS countries.

In the earlier EMS years, the ERM offered little anti-inflationary discipline, with Italy and France undergoing regular devaluations to offset higher inflation than in West Germany. By December 1991, values of the EMS currencies had been realigned 13 times despite heavy central interventions (see Table 1). Without currency realignments, those EMS countries with high inflation would lose competitiveness to the other low inflation countries. Furthermore, if each realignment did not fully offset the loss of competitiveness on the part of high inflation countries, deviations from PPP would not disappear. As a result, an issue to be examined is whether these realignments can be justified to maintain competitiveness (*ie* to maintain PPP) or whether these exchange rate adjustments only partially offset relative price changes due to purely political considerations.

Empirical studies on PPP for the EMS countries document conflicting results. Edison and Fisher (1991) report that relative prices and exchange rates are not cointegrated during the 1979–88 EMS period, suggesting that deviations from PPP are persistent under the EMS. Edison and Fisher (1991) conclude that the realignments of the EMS have not served fully to offset the inflation differentials

TABLE 1. Dates of realignments.

No.	Realignment date
0.	March 13, 1979
1.	September 24, 1979
2.	November 30, 1979
3.	March 23, 1981
4.	October 5, 1981
5.	February 22, 1982
6.	June 14, 1982
7.	March 21, 1983
8.	May 18, 1983
9.	July 22, 1985
10.	April 7, 1986
11.	August 4, 1986
12.	January 12, 1987
13.	January 8, 1990

No. 0 indicates the date of the initial formation of the EMS.

among the member countries. Artis and Nachane (1990) also fail to detect cointegration of bilateral exchange rates against the German mark with their relevant price differentials. Fisher and Park (1991), using the null hypothesis of cointegration, present evidence that rejects cointegration in the EMS and non-EMS countries, thus not supporting PPP. Analyses by Fung and Lo (1992) and MacDonald and Taylor (1991), on the other hand, find that real exchange rates in the EMS are cointegrated as a system.

The mixed findings on PPP in the EMS may reflect several problems that are encountered in testing for PPP in the literature. First, because exchange rates are found to have a unit root (Meese and Singleton, 1982), recent tests for PPP are commonly conducted using cointegration analysis. Various statistical methods, apparently of different statistical power, have been employed to detect cointegration. For example, some studies (Artis and Nachane, 1990; Edison and Fisher, 1991) apply Engle and Granger's (1987) residual-based cointegration analysis while others (Artis and Taylor, 1989; MacDonald and Taylor, 1991) use Johansen's (1991) multivariate cointegration method. The optimality of the Johansen estimation technique has been demonstrated by Gonzalo (1994) and Phillips (1991). Second, previous empirical studies using cointegration analysis are typically based on asymptotic tests. Hakkio and Rush (1991) have raised issues concerning the sample size for cointegration analysis. This is particularly critical for testing PPP in the relatively short EMS sample period, which began in March 1979. Finally, values of the EMS currencies have been realigned many times since March 1979. These realignments represent shifts in the EMS exchange-rate bands, and such shifts can distort statistical tests that do not account for the realignments. An explicit recognition of the realignments is thus needed to avoid the potential bias in inference and to provide a proper evaluation of whether the realignments are effective in extenuating the deviations from PPP.

Using Johansen's (1991) reduced rank cointegration analysis, this study investigates whether the EMS realignments are effective in maintaining PPP. Unlike previous empirical analyses, special attention is paid to address the small sample size problem inherent to EMS studies. Appropriate finite sample critical values obtained from response surface analysis are used to minimize the problem. The results of this study indicate that the realignments can be justified in offsetting inflation differentials and so maintaining PPP.

The paper is organized as follows. Section I briefly discusses the PPP relationship. Section II outlines Johansen's (1991) test for the cointegration analysis. Data and empirical results are described in Section III, followed by the conclusion.

I. The PPP relationship

The PPP doctrine suggests that currencies are valued for the goods they can buy and, in equilibrium, a given basket of goods should cost the same at home and abroad in the presence of international arbitrage. This implies a long-run equilibrium relationship between national price levels expressed in common

currency units. For the purpose of empirical testing, the PPP relationship is written as

$$\langle 1 \rangle \qquad fp_t = \alpha_0 + \alpha_1 p_t + e_t,$$

where α_0 is some constant, fp_t is the foreign price index converted to domestic currency units, p_t is the domestic price index, and e_t is an error term capturing deviations from PPP. All variables are in logarithms. A similar PPP specification has been considered by, *eg*, Frenkel (1981). Under the usual long-run proportionality condition, α_1 is equal to unity. Taylor (1988) and Taylor and McMahon (1991) observe that since observed price indices are imperfect proxies at best for the theoretical price variables, the proportionality condition is not necessarily consistent with empirical data. Consequently, α_1 should be estimated rather than imposed a priori to be unity (Cheung and Lai, 1993a).

A necessary condition for PPP to hold in the long run is that the deviation from PPP, e_t, should be a stationary process. This forms the basis for a cointegration test of long-run PPP. If fp_t and p_t are found to be cointegrated, deviations from a linear combination of the variables will be mean-reverting, implying that fp_t and p_t are tied together in the long run. Relationship $\langle 1 \rangle$ can in general be expressed as

$$\langle 2 \rangle \qquad \alpha' X_t = \alpha_0 + e_t,$$

where X_t is a vector time series given by $(fp_t, p_t)'$ and $\alpha = (1, -\alpha_1)$. When the series in X_t are I(1), *ie*, integrated of order one, e_t is generally also I(1). However, if there exists α such that e_t is stationary or I(0), as implied by long-run PPP, X_t is said to be cointegrated and $\alpha' X_t$ represents a long-run equilibrium relationship (Engle and Granger, 1987). A test for long-run PPP can thus be undertaken based on the theory of cointegration. The cointegration approach is useful since it allows data to determine the underlying long-run relationship and its short-run deviations.

II. Statistical methodology

Johansen (1991) develops a multivariate test for cointegration based on the method of reduced rank regression. The optimality of the Johansen estimation technique has been shown by Phillips (1991) in terms of symmetry, unbiasedness, and efficiency properties. A Monte Carlo study by Gonzalo (1994) supports the superior properties of the Johansen estimation technique relative to several other techniques.

Consider in general an $n \times 1$ time series vector $X_t = (x_{1t}, \ldots, x_{nt})'$. Regress ΔX_t on a constant and $\Delta X_{t-1}, \ldots, \Delta X_{t-k+1}$, giving the residual $\hat{u}_{1t}$. Regress X_{t-k} on a constant and $\Delta X_{t-1}, \ldots, \Delta X_{t-k+1}$, giving the residual $\hat{u}_{2t}$. Define the product moment matrices of the residuals as $S_{ij} = \sum_{t=1}^{T} \hat{u}_{it}\hat{u}'_{jt}/T$, $i, j = 1, 2$. The following gives a likelihood ratio test statistic for the hypothesis of at most r cointegrating vectors:

$$\langle 3 \rangle \qquad -2 \ln Q = -T \sum_{j=r+1}^{n} \ln(1 - \lambda_j),$$

where $\lambda_{r+1}, \ldots, \lambda_n$ are the $n-r$ smallest eigenvalues from $|\lambda S_{22} - S_{21}S_{11}^{-1}S_{12}|$ using the normalization $V'S_{22}V = I$ with V being the matrix of corresponding eigenvectors. This test is often referred to as the trace test. An alternative statistic, given by

$$\langle 4 \rangle \qquad -2 \ln Q_{r|r+1} = -T \ln(1 - \lambda_{r+1}),$$

and called the maximal eigenvalue statistic, examines the null hypothesis of r cointegrating vectors against the alternative of $r+1$ cointegrating vectors. Asymptotic critical values for both the trace and maximal eigenvalue tests are tabulated in Johansen and Juselius (1990). Cheung and Lai (1993b) examine the finite sample properties of these two tests and illustrate the individual roles of the sample size (T), the number of system variables (n), and the lag order (k) in determining the size of finite sample bias of the tests. Using response surface analysis, Cheung and Lai (1993b) provide finite sample critical values for the Johansen tests.

The use of proper finite sample critical values is particularly important for our analysis with the EMS data, for which the sample length available is not long. To the extent that the appropriate finite sample critical values are different from the asymptotic ones, asymptotic tests can be biased toward finding cointegration too often. To obtain reliable test results, it is thus important to adjust for any finite sample bias of the cointegration tests.

III. Data and empirical results

The data studied are monthly series taken from the IMF's *International Financial Statistics* data tapes. The data include price levels measured by wholesale price indices and month-end spot exchange rates used to convert price series into a common currency unit. Bilateral intercountry relations are considered among five EMS countries, which are Belgium (BE), France (FR), Germany (GE), Italy (IT), and the Netherlands (NL). The two major EMS countries, France and Germany, are considered alternatively as the home country. Following equation $\langle 1 \rangle$, all price series are expressed in either German mark (DM) or French franc (FF). All the data series are in natural logarithms. The data sample covers the period from March 1979 to December 1991, except for the price series for France that runs from March 1979 to December 1986.

The series of price indices were each first checked for a unit root using the augmented Dickey–Fuller (1979) or ADF test with a linear trend. Table 2 contains the results. According to the test results, for all the series examined the hypothesis of a unit root cannot be rejected at the 10 percent significance level. Unit root tests are applied also to the first-differenced series, and the null hypothesis of a unit root could be statistically rejected for all the series. The findings on the whole suggest that each of the price series contains a unit root.

The Johansen test for cointegration is next performed. Since Germany and France are considered alternatively as the home country, there are altogether seven bilateral relationships examined, namely, BE/GE, FR/GE, IT/GE, NL/GE, BE/FR, IT/FR, and NL/FR. In choosing the lag length k for the cointegration

test in each case, an unrestricted vector autoregressive (VAR) model is fitted to the data. The lag order was first estimated using a model selection procedure based on the Akaike information criterion. The maximum lag length considered is $k = 8$. The corresponding residuals were then tested for serial correlation using the Ljung–Box test. The estimated lag length would be used if the residuals could pass the serial correlation test. If they could not, the lag length would be increased until the serial correlation in the residuals were removed. In most cases, a lag of $k = 4$ is required to remove serial correlation in the residuals for the DM-based data; whereas, a lag of $k = 2$ is enough for the FF-based data. The residual diagnostic statistics are reported in Table 3. The results appear satisfactory and support the adequacy of the lag specifications.

Table 4 reports the values of both the trace and the maximal eigenvalue test statistic for the null hypothesis of no cointegrating vector. When Germany serves as the home country, in three out of four cases (Belgium, Italy, and the Netherlands) can the hypothesis of no cointegrating vector (*ie*, the hypothesis of $r = 0$) be rejected at the 5 percent or 10 percent level, indicating that the series p_t and fp_t are cointegrated, as suggested by long-run PPP. In contrast, results for the bilateral relations using France as the home country are less favorable. The hypothesis of no cointegrating vector can be rejected at the 10 percent level in only one case (Netherlands) based on the trace test. The supportive evidence for

TABLE 2. Testing for unit roots in individual price series.

		Level series		Differential series	
Country	T	ADF(2)	ADF(4)	ADF(2)	ADF(4)
Series in German mark:					
BE	154	−1.822	−1.973	−7.009**	−4.339**
FR	82	−1.868	−1.888	−4.179**	−4.016**
GE	154	−3.108	−2.702	−3.328**	−3.161*
IT	154	−2.846	−2.882	−5.792**	−4.452**
NL	154	−2.900	−3.095	−3.328**	−3.361**
Series in French franc:					
BE	82	−2.103	−2.276	−4.639**	−3.416**
FR	82	−0.084	−0.595	−3.417**	−3.211*
GE	82	−0.083	−0.211	−4.305**	−3.766**
IT	82	−0.890	−1.341	−5.569**	−4.538**
NL	82	−0.266	−0.026	−4.931**	−4.114**

Note: Five EMS countries are considered—Belgium (BE), France (FR), Germany (GE), Italy (IT), and Netherlands (NL). France and Germany are used alternatively as the home country. All data are in natural logarithms. The column beneath 'ADF(q)' gives the statistic for the Augmented Dickey–Fuller test with q lags and a time trend. The ADF test examines the null hypothesis of a unit root against the stationary alternative. T represents the sample length of the price series. To adjust for possible effects of the lag order on the ADF test, critical values for the test are based on Cheung and Lai (1995). Statistical significance is indicated by * at the 10% level and by ** at the 5% level.

TABLE 3. Residual tests for unrestricted VAR.

Country pair	Lag k	Test	Equation for p		Equation for fp	
			Statistic	[p-value]	Statistic	[p-value]
BE/GE	4	LB(24)	11.611	[0.770]	8.726	[0.924]
		LB(36)	19.559	[0.880]	5.515	[1.000]
FR/GE	2	LB(24)	11.488	[0.778]	8.787	[0.275]
		LB(36)	13.334	[0.991]	19.131	[0.894]
IT/GE	4	LB(24)	11.130	[0.801]	18.731	[0.283]
		LB(36)	24.420	[0.659]	22.325	[0.776]
NL/GE	4	LB(24)	13.750	[0.617]	14.293	[0.577]
		LB(36)	22.412	[0.762]	17.255	[0.943]
BE/FR	2	LB(24)	18.633	[0.481]	7.806	[0.993]
		LB(36)	19.155	[0.895]	8.895	[1.000]
IT/FR	2	LB(24)	21.095	[0.392]	14.060	[0.827]
		LB(36)	27.778	[0.680]	15.346	[0.994]
NL/FR	2	LB(24)	22.239	[0.328]	17.772	[0.606]
		LB(36)	16.856	[0.987]	18.755	[0.970]

Note: Five EMS countries are considered, namely, Belgium (BE), France (FR), Germany (GE), Italy (IT), and Netherlands (NL). The column beneath 'Lag k' gives the lag order selected in each corresponding case. The LB(m) statistic represents the Ljung–Box test statistic with m lags. The Ljung–Box test examines the null hypothesis of no serial correlation in the respective equation of the VAR system for (fp_t, p_t).

DM-based PPP is consistent with the usual view that the EMS has been a German mark currency zone.

In studies based on the EMS data, an issue concerns the potential effects of exchange rate realignments on statistical analysis. The alignments imply the EMS rates move within different specified bands. Such shifts in the stochastic processes may bias the cointegration test toward finding no cointegration too often. To adjust for the possible bias, realignment dummy variables are added in the reduced rank regressions. The results of cointegration tests are summarized in Table 5. In general, after controlling for the realignment effect on the tests, the results provide more positive evidence for cointegration than those reported in Table 4. In six out of seven cases can the hypothesis of no cointegration be rejected statistically, supporting that the series p_t and fp_t are cointegrated.

A caveat is in order, nonetheless. While the shifts associated with currency realignments may bias empirical tests, using dummy variables to capture them creates another problem. The currency realignments are not fully exogenous, and the dummy variables for these realignments may capture non-stationarity in real exchange rates. Hence, the results obtained using dummy variables should be interpreted with such qualification in mind.

TABLE 4. Testing for cointegration.

Country pair	Lag k	Eigenvalue		Maximum eigenvalue		Trace	
		λ_2	λ_1	Statistic	Critical value	Statistic	Critical value
BE/GE	4	0.0306	0.0831	13.016	13.421 (10%) 15.341 (5%)	17.675*	16.378 (10%) 18.750 (5%)
FR/GE	2	0.0383	0.0940	7.700	13.378 (10%) 15.306 (5%)	10.745	16.327 (10%) 18.691 (5%)
IT/GE	4	0.0312	0.0963	15.191*	13.421 (10%) 15.341 (5%)	19.940**	16.378 (10%) 18.750 (5%)
NL/GE	4	0.0481	0.1003	15.855**	13.421 (10%) 15.341 (5%)	23.253**	16.378 (10%) 18.750 (5%)
BE/FR	2	0.0183	0.1273	10.895	13.378 (10%) 15.306 (5%)	12.377	16.327 (10%) 18.691 (5%)
IT/FR	2	0.0241	0.0936	7.859	13.378 (10%) 15.306 (5%)	9.809	16.327 (10%) 18.691 (5%)
NL/FR	2	0.0710	0.1400	12.068	13.378 (10%) 15.306 (5%)	17.956*	16.327 (10%) 18.691 (5%)

Note: The five EMS countries considered are Belgium (BE), France (FR), Germany (GE), Italy (IT), and Netherlands (NL). The finite sample critical values for both the maximal eigenvalue test and the trace test for cointegration are computed using response surface analysis (Cheung and Lai, 1993b). Statistical significance is indicated by * at the 10% level and by ** at the 5% level.

TABLE 5. Testing for cointegration with adjustments for realignments.

Country pair	Lag k	Eigenvalue		Maximal test		Trace test	
		λ_2	λ_1	Statistic	Critical value	Statistic	Critical value
BE/GE	4	0.0026	0.2458	42.324**	30.523 (10%) 34.118 (5%)	42.718*	40.220 (10%) 44.652 (5%)
FR/GE	2	0.0068	0.6387	81.436**	28.147 (10%) 31.408 (5%)	81.985**	36.662 (10%) 41.184 (5%)
IT/GE	4	0.0176	0.2227	37.785**	30.523 (10%) 34.118 (5%)	40.445*	40.220 (10%) 44.652 (5%)
NL/GE	4	0.0200	0.2653	46.236**	30.523 (10%) 34.118 (5%)	49.264**	40.220 (10%) 44.652 (5%)
BE/FR	2	0.1550	0.3696	36.907**	28.147 (10%) 31.408 (5%)	50.383**	36.662 (10%) 41.184 (5%)
IT/FR	2	0.1551	0.2380	21.746	28.147 (10%) 31.408 (5%)	35.227	36.662 (10%) 41.184 (5%)
NL/FR	2	0.1617	0.4911	54.039**	28.147 (10%) 31.408 (5%)	68.150**	36.662 (10%) 41.184 (5%)

Note: Five EMS countries are considered—Belgium (BE), France (FR), Germany (GE), Italy (IT), and Netherlands (NL). The possible currency realignment effects on the Johansen cointegration test are allowed for using dummy variables. The finite sample critical values are obtained based on simulation in 25,000 replications. Statistical significance is indicated by * at the 10% level and ** at the 5% level.

IV. Conclusion

Using monthly data from March 1979 to December 1991, this study examines the empirical relevance of the PPP hypothesis under the EMS. Unlike previous EMS studies on PPP, this study addresses the small sample problem inherent in EMS studies and accounts for the realignments of exchange rates among the EMS countries. In contrast to the previous studies, our results based on reduced rank cointegration analysis are shown to be more favorable to the cointegration hypothesis and they provide a wider and more significant support for PPP. The difference in results with those of the previous studies may be attributed partly to the statistical technique used, the correction for the small sample bias, and the adjustment for currency realignment effects.

Although it has been argued that EMS has exerted a stabilizing effect on exchange rates among its members, the issue of welfare gains is still inconclusive (Artis and Taylor, 1988; Ungerer *et al.*, 1986). One argument against the EMS is that the EMS countries with high inflation have lost competitiveness to other low inflation countries, implying that deviations from PPP are persistent. In view of the supportive evidence for PPP, the realignments of the EMS appear to have been justified with reference to underlying inflation rates in order to maintain competitiveness among the member countries.

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