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Real Disturbances, Relative Prices and Purchasing Power Parity*

This paper tests a modified version of purchasing power parity which hypothesizes that real shocks that alter equilibrium relative prices between tradables and non-tradables are responsible for the deviations from purchasing power parity. Using cointegration/error-correction methods and quarterly data from the post Bretton Woods period, we find supportive evidence that productivity, government spending and real world oil price might account for deviations from purchasing power parity.

1. Introduction

Purchasing power parity hypothesis (PPP) remains a controversial issue, both as a building block of theoretical exchange rate determination models and as an equilibrium exchange rate relation by itself. There have been numerous studies, theoretical and empirical, which specify the circumstances of its validity as a description of exchange rate behavior. It is well known that temporary deviations from PPP can arise as an outcome of different speeds of adjustment in assets and goods markets (Dornbusch 1976). Accordingly, after a permanent shock in the money supply, the nominal exchange rate moves more than proportionately to clear the money market. A movement in the nominal exchange rate translates into a movement in the real exchange rate because of sticky commodity prices. This result is referred to as "overshooting" and is an example of short-run purchasing power disparity. Moreover, within the context of the "overshooting model," imperfect substitutability between domestic and foreign goods implies that permanent real aggregate supply and demand disturbances can cause permanent changes in the real exchange rate, which is the relative price of foreign goods. At the extreme, there is no substitutability between domestic and foreign goods in the case of non-traded goods. In this case permanent changes in the real exchange rate can arise due to real disturbances that change equilibrium relative prices between tradables and non-tradables. The Samuelson-Balassa hypothesis singles out productivity differentials between tradables and non-tradables as the determinant of relative prices (Samuelson 1964; Balassa 1964). Extensive empirical studies on the validity of PPP have

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not resolved the issue completely as the evidence is mixed.[1] Baillie and Selover (1987), Taylor (1988), Baillie and Pecchenino (1991), among others, provide evidence that the nominal exchange rate and national price levels are not even cointegrated.

Given the increasing evidence that real exchange rates are non-stationary, recent studies have focused on identifying disturbances that cause deviations from PPP. Huizinga (1987) decomposes the real exchange rate series into transitory and permanent components using the Beveridge and Nelson (1981) technique, and finds an important transitory (mean-reverting) component. On the other hand, using an approach along the lines of Blanchard and Quah (1989), Lee and Enders (1991) and Lastrapes (1992) decompose real and nominal bilateral exchange rate movements into components induced by real and nominal factors. The studies try to identify the shocks by imposing a long-run neutrality restriction on the bivariate moving average representation of real and nominal exchange rates. In particular, nominal shocks are restricted to have no long-run effect on the level of real exchange rates. Both studies find that a dominant proportion of nominal *and* real exchange rate movements have been due to real shocks in all cases and at all horizons.

The primary objective of this study is to re-examine the empirical validity of PPP. Given the focus in the recent empirical exchange rate literature on real factors as primary sources of disturbances that cause deviations from PPP we use a theoretical framework in which PPP is augmented by real supply (productivity in the tradables sector, and real world oil price) and demand (real government spending) disturbances and test for the existence of *systematic* departures from PPP. To that end, we use Johansen (1988) and Johansen and Juselius (1990) methodology to test for cointegration between the bilateral nominal exchange rates, national price levels, productivities, government spending and real world oil price. Different versions of the PPP hypothesis will be tested as restricted versions of the cointegrating vectors. Specifically, we will test the proposition that international differences in productivity, government spending and changes in the real oil prices can account for the deviations from PPP. We will also use a Vector Error Correction Model and Variance Decomposition Analysis to test the relative importance of biases, if any, introduced by these real disturbances. Section 2 describes the model and methodology. Section 3 reports

[1]Earlier evidence provided by Frenkel (1981) shows that PPP does not hold, whereas Davutyan and Pippenger (1985) find supportive evidence. More recently an increasing number of studies found evidence that real exchange rates are integrated stochastic processes (e.g., Corbae and Ouliaris 1988; Enders 1988; Mark 1990), whereas Abuaf and Jorion (1990) dispute this evidence.

empirical results pertaining to Germany, Italy and Japan vs. the United States. Section 4 concludes.

2. The Theoretical Framework and Methodology

The absolute version of PPP is based on the presumption that in an integrated competitive market, the law of one price would prevail and as such, the price of a given good would be the same when quoted in the same currency. If price indexes are constructed in the same manner and are comprised of the same goods in different countries, then absolute PPP holds:

$$s_t = p_t - p_t^* , \tag{1}$$

where s_t is the logarithm of the nominal exchange rate defined as the number of units of domestic currency per unit of foreign currency; p_t and p_t^* are the logarithms of the domestic and foreign price levels. Since there are transportation costs as well as some impediments to trade, the weak or the relative form of PPP restates the relationship between the exchange rate and national price levels in terms of changes. The logarithm of the real exchange rate r_t, can be defined as $r_t = s_t - (p_t - p_t^*)$ and it gives the price of foreign goods in terms of domestic goods. It is evident from Equation (1) that the real exchange rate is unity if absolute PPP holds at each point in time, and constant if relative PPP holds. Since PPP can be taken as an equilibrium relationship and deviations from equilibrium are possible, the empirical implication is that real exchange rate series must be stationary if PPP holds.

If there are non-tradable goods, one can no longer apply the law of one price in deriving PPP. However, as long as there are no relative price changes between traded goods and non-traded goods, relative PPP will hold. In other words, if the law of one price applies to traded goods, the real exchange rate is determined by the relative price of traded goods in the two countries.

A significant component of goods and services does not enter the price indexes that are used to test for PPP. The case of non-traded goods has long been recognized in economic analysis (for references, see Dornbusch 1980, 94–97). Due to transportation costs and some impediments to trade, some goods might not be traded internationally. Let the domestic price level be a weighted average of the prices of traded goods and non-traded goods:

$$\begin{aligned} p_t &= \theta\, p_t^T + (1-\theta)\, p_t^N \\ &= p_t^T + (1-\theta)\, \rho_t , \end{aligned} \tag{2}$$

where

$$\rho_t \equiv p_t^N - p_t^T ,$$

p^T is the logarithm of the price of traded goods; p^N is the logarithm of the price of non-traded goods; ρ is the logarithm of the relative price of the non-traded good; and θ is a share parameter. It is assumed that a similar relationship exists for prices in the foreign country.

If the law of one price prevails in the traded goods, then

$$p_t^T = p_t^{*T} + s_t \,, \tag{3}$$

where s_t, p_t, and p_t^* are as defined in Equation (1) above.

If we combine Equations (2) and (3) assuming that the price indexes are constructed in the same manner for the two countries (i.e., $\theta = \theta^*$):

$$s_t = p_t - p_t^* - (1 - \theta)(\rho_t - \rho_t^*) \,. \tag{4}$$

Equation (4) is the modified-PPP relationship; as long as there are no relative price changes between tradables and non-tradables, PPP will hold.[2] However, relative price changes (i.e., changes in ρ or ρ^* that are not offsetting) can cause deviations from PPP.

Balassa (1964) and Samuelson (1964) singled out productivity differentials between tradables and non-tradables as an important source of change in relative prices and the exchange rate. Both studies have argued, within the context of a Ricardian model, that the price of domestic goods relative to foreign goods (the reciprocal of the real exchange rate) will increase in fast growing, innovative economies. If prices equal marginal costs, and labor is internally mobile so that wages are equal across sectors, the relative price of non-traded goods will be determined by relative productivity between traded goods and non-traded goods. Assuming that international differences in productivity are smaller in the production of non-traded goods such as services, non-traded goods will be relatively more expensive in countries with higher levels of productivity: "The greater are productivity differentials in the production of traded goods between two countries, the larger will be differences in wages and in the prices of services and, correspondingly, the greater will be the gap between purchasing power parity and the equilibrium exchange rate" (Balassa 1964, 586).[3] Gartner and Urpsrung (1980), and Gartner (1993) use a structural goods market and an exchange rate which is determined in an asset market a la Dornbusch (1976). They assume collective wage formation and mark-up pricing so that relative prices of non-traded goods are determined by relative productivities. Other studies such as Dornbusch (1974) relax the assumption of constant costs and introduce dimin-

[2]Equation (4) provides the basis for the definition of the real exchange rate as the relative price of tradables (i.e., $-\rho$). See, for example, Krugman (1988) and Edwards (1989).

[3]Different variants of the Ricardian framework where prices are determined by unit labor costs have been used to explain changes in equilibrium relative prices of traded goods. See, for example, Dornbusch, Fisher and Samuelson (1977).

ishing returns with perfect wage and price flexibility. Assuming internal and external balance (the market for non-traded goods clears and expenditure equals income), the study considers the effects of various shocks on relative prices of traded goods. A uniform rise in the productivity level in the tradables, for example, implies increased wages in tradables and non-tradables alike. But without productivity gains in non-tradables, costs and prices in non-tradables increase, and the relative price of the non-tradables (ρ) increases.[4] Given the nominal price level of non-traded goods and commodity arbitrage in traded goods, a relative price change can only come through a change in the nominal exchange rate.

The foregoing framework can be extended to include a number of real disturbances that can lead to changes in the relative price of non-tradables. Consider, for example, the effect of a demand side shock such as government spending on relative prices. We can incorporate the government by using a simple optimizing framework. The government provides public goods which enter the utility function of domestic residents. In this framework, government activities may influence the private sector through two channels. First, government spending financed through *lump-sum* taxes absorbs resources which otherwise would be available for private consumption. Second, government spending may influence the marginal evaluation of private goods.[5]

To best understand the relationship between government spending and relative prices, consider Figure 1. To simplify the analysis, we assume that there is no production, government spending enters the utility function in a separable way (so that government spending does not influence the marginal evaluations of private goods) and the utility function is homothetic (optimal consumption decisions are invariant to income distribution). We also assume that the economy is initially in equilibrium at the *endowment* point *K*, where the marginal rate of substitution equals relative price of non-tradables, ρ_0. The Engel curve is given by the ray *OK*. Consider a rise in government spending on both goods, G^T on tradables and G^N on non-tradables. Since this represents withdrawal of resources from the private sector, the new private sector endowment is given by point *H*. Note that in the Figure, government's spending is biased towards non-traded goods relative to the endowment. At the prevailing relative price ρ_0, the optimal consumption bundle is indicated by point *J*. It is obvious that with the case represented in the Figure, there is excess supply of the traded good and an excess demand for the non-traded good at point *J*. Thus, the relative price of non-traded goods ρ must rise and the Engel curve rotates to the left. The new equilibrium must lie on the line

[4]A sufficient condition for technological progress in the traded goods sector to increase the relative price of non-traded goods is assuming homothetic preferences.

[5]Details of the effects of government spending can be found in Frenkel and Razin (1992).

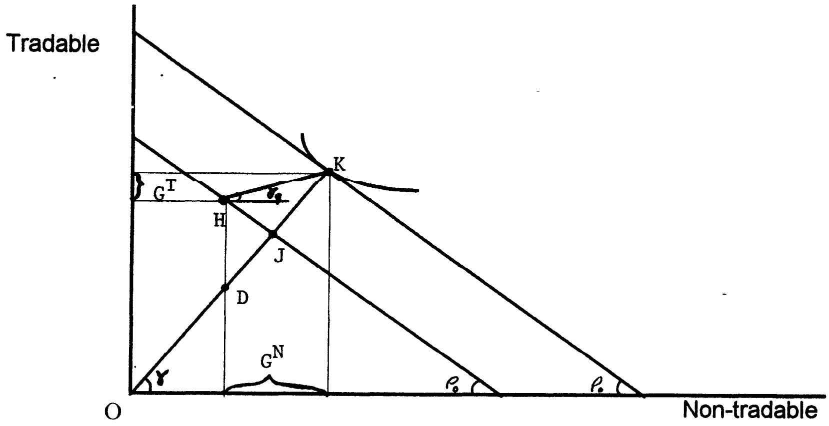

Figure 1.
Government Spending and Relative Prices

segment *HD* so that the market for non-traded goods clears. Define the marginal share of non-tradables in government spending as $\beta_g = \rho G^N/(G^T + \rho G^N)$. Similarly β can be defined as the marginal share of non-tradables in private sector spending. If β_g exceeds β (equivalently $\gamma_g < \gamma$ so that line *HK* is flatter than *OK*), then a rise in government spending induces a rise in the domestic relative price of non-traded goods. The converse holds when β_g falls short of β. Again, for a given value of the nominal price of non-traded goods, an increase in the relative price of non-traded goods brings about a domestic currency appreciation.

It should be noted that supply side disturbances such as an increase in the real world oil price might influence the relative prices. An oil price shock can be incorporated into the analysis as a negative endowment shock. To the extent that it affects sectors asymmetrically, it can lead to a relative price change. However in reality, an oil price shock can have complex effects. Oil prices are likely to have demand deflationary effects due to rising imports (depending on dependency on oil), as well as inflationary effects due to rising production costs. Secondary effects include increase in substitutes for oil, and increasing imports by oil exporting countries. The final outcome depends on how these factors affect traded versus non-traded goods sectors.

Changes in tastes, and factor endowments have been cited as other factors that influence relative prices and cause purchasing power disparities (Kravis and Lipsey 1983; Bhagwati 1984).

Given this theoretical framework, it is important to test whether the real disturbances outlined above have caused deviations from PPP. This can be done by augmenting PPP with productivity differentials in tradables, a demand side variable, real government spending on non-traded goods and real world oil price. An important issue in empirical implementation is whether the measures of these variables are non-stationary, in which case standard tests and statistical inference might not be meaningful. In this paper the possibility of non-stationarity will be handled by utilizing unit root and cointegration techniques. Moreover, a cointegrating vector has the interpretation of a "long-run" equilibrium relationship (Engle and Granger 1987). Specifically, consider the following equation:

$$s_t = \beta_0 + \beta_1(p_t - p_t^*) + \beta_2(pr_t - pr_t^*) + \beta_3(g_t - g_t^*) + \beta_4 rop_t + u_t \,, \qquad (5)$$

where pr_t and pr_t^* are logarithms of domestic and foreign productivity levels in the traded goods, g_t and g_t^* are domestic and foreign government spending on non-traded goods; rop_t is the real world oil price; β_i are coefficients, and u_t is an error term.

If Equation (5) represents an equilibrium for the exchange rate in the long run, then s_t, $(p_t - p_t^*)$, $(pr_t - pr_t^*)$, $(g_t - g_t^*)$ and rop_t must be cointegrated. Different versions of PPP place restrictions on the cointegrating vector(s). For example, if Equation 5 represents the normalized cointegrating relation and PPP holds up to a stationary error term, then we should expect $\beta_1 = 1$, $\beta_2 = 0$, $\beta_3 = 0$, and $\beta_4 = 0$. In this case the resulting relationship might be interpreted as a stable real exchange rate. However, if productivity in the tradables rises relatively faster than the non-tradables in the home country, or government spending on non-tradables increases relatively faster than tradables, equilibrium relative prices $(\rho - \rho^*)$ can be expected to increase, and β_2 and β_3 should be negative. The sign of β_4 depends on how the increase in real world oil price affects the tradable and non-tradable sectors.

We will use the full information maximum likelihood method to test whether variables in Equation (5) are cointegrated.[6] This method can detect multiple cointegrating vectors and allows for testing various restrictions on the parameter vector. The implications outlined above will be tested using bilateral data for Germany, Japan, and Italy vs. the United States. We then estimate a Vector Error Correction Model for the real exchange rate and examine the relative importance of biases introduced to PPP. The data are quarterly, pertain to the modern floating period and are taken from the International Financial Statistics.

[6]Pioneering work in the area of cointegration is due to the Granger Representation Theorem. See Granger (1983) and Engle and Granger (1987).

3. Empirical Results

Before applying the cointegration framework, we investigate the stochastic properties of the variables to see if they have unit roots. We measure s_t by nominal, period average exchange rate (e.g., Marks per U.S. Dollar); p_t, by the GNP deflator, except for Italy, where it is measured by the GDP deflator. This measure of the price index includes a wider range of goods that are reflected in the tradables/non-tradables specification of the model. We realize that there is no satisfactory measure of pr_t, the productivity index of traded goods; we proxy the productivity in tradables by productivity index of the manufacturing sector; g_t is real government expenditure on non-tradables, and again it is not possible to decompose government expenditure into spending on tradables versus non-tradables; we use general government expenditure in national accounts as a proxy; rop_t is world real oil price deflated by OECD consumer price index; an asterisk denotes U.S. counterparts, and all variables are measured in logarithms.

The results of Augmented Dickey-Fuller tests with and without a linear time trend for the data in levels and first differences are presented in Table 1. Appropriate lag lengths are determined by starting with a lag length of 4 for the data in levels (since the data is quarterly), and 1 for the data in the first difference, and then including additional lags depending on whether residuals approximate white noise. Box-Pierce Q-Statistics, residual ACF's and residual plots were used in determining the appropriate lag length.

Table 1 indicates that the null hypothesis of a unit root cannot be rejected for all series, with the exception of Japanese government spending when a linear time trend is not included. However, when a linear trend is included, the null hypothesis of a unit root is not rejected for the Japanese relative government spending. To complete the tests, we performed ADF unit root tests to first differenced series. With the exception of the price series for Germany and Italy which are on the borderline when a linear trend is not included, all series reject a unit root. Hence the tests are broadly consistent with the series being integrated of order one.

MacDonald (1993), and Cheung and Lai (1993) have recently emphasized that imperfections in observed price series as proxies for theoretical price variables imply that proportionality between the nominal exchange rate and prices under PPP is not necessarily consistent with empirical data. Hence, the validity of proportionality between the nominal exchange rate s_t, and relative prices $(p_t - p_t^*)$, should be tested as a restriction on the cointegrating vector(s). If proportionality holds, then cointegration tests can be carried out using the real exchange rate, r_t.

Next, we test whether the exchange rate, prices, productivities, real government spending, and the real world oil price are cointegrated using the maximum likelihood cointegration technique. Different values of the lag

TABLE 1. *Augmented Dickey-Fuller (ADF) Tests*

Variables	Germany No Trend	Germany Trend	Italy No Trend	Italy Trend	Japan No Trend	Japan Trend
s_t	−1.47	−1.96	−1.90	−1.22	−0.87	−2.56
$(p_t - p_t^*)$	−2.23	−0.73	0.48	−2.78	−0.42	−2.95
r_t	−1.96	−1.75	−1.19	−1.75	−1.98	−2.57
$(pr_t - pr_t^*)$	−2.31	−3.38	−0.14	−1.97	−0.14	−1.87
$(g_t - g_t^*)$	−0.48	−2.08	−1.54	−1.06	−3.69	−2.52
rop_t	−1.30	−1.36				
First Differences						
Δs_t	−4.59	−4.61	−3.77	−4.11	−4.50	−4.52
$\Delta(p_t - p_t^*)$	−2.90	−3.70	−2.84	−4.19	−4.48	−4.31
Δr_t	−3.83	−3.94	−4.26	−4.39	−4.40	−4.43
$\Delta(pr_t - pr_t^*)$	−4.83	−4.93	−4.98	−4.94	−4.55	−4.51
$\Delta(g_t - g_t^*)$	−5.84	−6.62	−5.42	−5.39	−6.49	−6.99
Δrop_t	−5.47	−5.42				

NOTES: (1) Definition of the Variables: s_t, nominal, period average exchange rate (e.g., Marks per U.S. Dollar); p_t, price level as measured by the GNP deflator, except for Italy where it is measured by the GDP deflator; pr_t, productivity rate of tradables as measured by productivity index of the manufacturing sector; g_t is real government expenditure; rop_t is world real oil price deflated by OECD price index; an asterisk denotes U.S. counterparts, and all variables are measured in logarithms.

(2) The critical value for 70 degrees of freedom at the 0.05 significance level is −2.90 for the no-trend case, and −3.47 for the trended case, respectively. Sample period is 1974.I–1990.IV.

length from 1 to 6 were considered to remove serial correlation from the residuals of the VAR. In Germany and Japan 4, and in Italy 5 lags were required for residuals to approximate white noise. Likelihood ratio tests based on the maximal eigenvalue (λ_{max}), and trace (λ_{tr}) of the stochastic matrix are given in Table 2. In reporting critical values, we take into account the possibility of linear trends.

Table 2 indicates that the null hypothesis of no cointegration ($r = 0$) is rejected for all countries by the trace statistic. Moreover, the hypothesis that there is at most one cointegrating vector ($r \leq 1$) is rejected by the trace statistic for Germany and Japan, but not for Italy. Note also that we fail to reject $r \leq 2$ for Germany and Japan. The maximal eigenvalue statistic indicates a unique vector for Italy and Germany, and two vectors for Japan. In the following discussion we assume two cointegrating vectors for Germany and Japan and one vector for Italy. Table 2 also reports tests of restrictions on the

TABLE 2. *Cointegration Tests of the Nominal Exchange Rate*

	λ_{tr}					λ_{max}					Restrictions		
Null	$r = 0$	$r \leq 1$	$r \leq 2$	$r \leq 3$	$r \leq 4$	$r = 0$	$r = 1$	$r = 2$	$r = 3$	$r = 4$	H_1	H_2	H_3
Germany	89.61	53.56	28.57	13.99	4.02	36.05	24.98	14.57	9.97	4.02	0.085	0.000	0.000
Italy	95.07	43.56	25.88	10.72	1.68	51.50	17.68	15.15	9.04	1.68	0.000	0.000	0.000
Japan	100.13	59.76	31.26	13.02	0.09	40.36	28.50	18.23	12.90	0.09	0.279	0.000	0.000

NOTES: 1) Variables included in the VAR st, $(p_t - p_t^*)$, $(pr_t - pr_t^*)$, $(g_t - g_t^*)$, and rop_t.

2) Maximum lag in the VAR is 4 for Germany and Japan, 5 for Italy.

3) Sample period is 1974.I–1990.IV.

4) Critical values for the λ_{tr} statistic at 5% significance level are 70.59 ($r = 0$), 48.28 ($r \leq 1$), 31.53 ($r \leq 2$), 17.95 ($r \leq 3$), and 8.18 ($r \leq 4$), where r is the number of cointegrating vectors. The critical values for the λ_{max} statistic are 33.31 ($r = 0$), 27.14 ($r = 1$), 21.07 ($r = 2$), 14.90 ($r = 3$), 8.18 ($r = 4$).

5) H_1 tests the proportionality between nominal exchange rate and prices ($\beta_1 = 1$ in Equation 5), H_2 tests strict PPP ($\beta_1 = 1$, $\beta_2 = 0$, $\beta_3 = 0$, and $\beta_4 = 0$ in Equation 5), H_3 tests modified PPP ($\beta_2 = 0$, $\beta_3 = 0$, and $\beta_4 = 0$ in Equation 5), and the entries under H_i in the table indicate marginal significance levels (i.e., p-values).

cointegrating vectors. Note that the proportionality restriction between the nominal exchange rate and prices (H_1: $\beta_1 = 1$ in Equation 5) is not rejected at the 5% significance level except for Italy. The normalized cointegrating relationship for Italy is given by:

$$s_t = 1.850\,(p_t - p_t^*) - 2.167\,(pr_t - pr_t^*) - 0.868\,(g_t - g_t) + 0.045\,rop_t\,, \qquad (6)$$
$$(0.000)\quad(0.000)\qquad\qquad(0.000)\qquad\qquad\qquad(0.002)\qquad\qquad(0.033)$$

where marginal significance levels (p-values) are given in parentheses. Equation (6) implies that all estimated coefficients have theoretically plausible signs. An increase in productivity in tradables relative to the foreign country is associated with an appreciation of home currency. Similarly, government spending on home goods is associated with appreciation of domestic currency.[7] On the other hand, an increase in the real oil price is associated with depreciation of home currency. Note that all coefficient estimates are significant for Italy. Table 2 also indicates that strict PPP (H_2) is rejected for all countries. Moreover, productivity, government spending, and real oil price (H_3) are jointly significant for all countries. This implies that the data is not favorable to a mean reverting, stable real exchange rate, and productivity, government spending and real world oil price shocks might have caused systematic deviations from PPP in the post-Bretton Woods period.

Since the proportionality between the nominal exchange rate and prices is not rejected for Japan and Germany, we impose the proportionality restriction[8] and perform cointegration tests with the real exchange rate r_t, productivity $(pr_t - pr_t^*)$, government spending $(g_t - g_t^*)$, and the real world oil prices rop_t. The results are given in Table 3.

Both λ_{tr} and λ_{max} statistics indicate a single cointegrating vector for Germany and Japan. Normalizing with respect to the real exchange rate,

$$\text{Germany:}\quad r_t = -1.654\,(pr_t - pr_t^*) - 2.042\,(g_t - g_t^*) + 0.143\,rop_t, \qquad (7)$$
$$(0.000)\quad(0.003)\qquad\qquad(0.027)\qquad\qquad(0.023)$$

$$\text{Japan:}\quad r_t = -0.778\,(pr_t - pr_t^*) - 1.874\,(g_t - g_t^*) + 0.086\,rop_t, \qquad (8)$$
$$0.000\quad(0.026)\qquad\qquad(0.009)\qquad\qquad(0.021)$$

where numbers in parentheses indicate marginal significance levels. The estimated speed of adjustment coefficients $[\alpha_1\ \alpha_2\ \alpha_3\ \alpha_4]$ from the error

[7]Strictly speaking, since we proxy government spending on home goods by general government spending, its coefficient can be of either sign.

[8]This is likely to reduce the number of cointegrating vectors, which circumvents the problem of interpreting multiple cointegrating vectors.

TABLE 3. *Cointegration Tests of the Real Exchange Rate*

	λ_{tr}				λ_{max}			
Null	$r = 0$	$r \leq 1$	$r \leq 2$	$r \leq 3$	$r = 0$	$r = 1$	$r = 2$	$r = 3$
Germany	59.42	23.48	9.03	0.04	35.94	14.45	8.99	0.04
Japan	53.93	24.37	7.38	0.07	29.56	16.99	7.31	0.07

NOTES: 1) Variables included in the VAR: r_t, $(pr_t - pr_t^*)$, $(g_t - g_t^*)$, rop_t. Maximum lag is 4 for Germany, 8 for Japan. Sample period is 1974.I–1990.IV.

2) Critical values for the λ_{tr} statistic at 5% significance level are 48.28 (r=0), 31.53 ($r \leq 1$), and 17.95 ($r \leq 2$), and 8.18 ($r \leq 3$) where r is the number of cointegrating vectors. The critical values for the λ_{max} statistic are 27.14 (r=0), 21.07 (r=1), 14.90 (r=2), and 8.18 (r=3).

correction model corresponding to $[\Delta r_t \ \Delta(pr_t - pr_t^*) \ \Delta(g_t - g_t^*) \ \Delta rop_t]$ are given by

$$\text{Germany:} \quad [-0.133 \ -0.037 \ -0.101 \quad 0.143]\,;$$
$$\text{Japan:} \quad [-0.017 \ -0.034 \ -0.121 \quad -0.252]\,.$$

An interesting question is whether productivity, real government spending and the real oil price are jointly "weakly exogenous" with respect to the long-run parameters. This hypothesis can be tested as the joint significance of the last three speed of adjustment coefficients[9], that is, testing H_0: $\alpha_2 = \alpha_3 = \alpha_4 = 0$ is a test for the joint weak exogeneity of productivity, real government spending and real oil price. The likelihood ratio test statistic for this hypothesis is distributed as χ^2 with 3 degrees of freedom under the null. Performing the test, we get a value of 9.42 for Germany and 10.63 for Japan. Since the critical value at the 5% significance level $\chi^2(3) = 7.81$, the hypothesis is rejected in both cases. This has important implications for the interpretation of the long-run parameters.

The estimated coefficients in Equations (7) and (8) are all significant. Increases in productivity in tradables and government spending on non-tradables at home relative to the foreign country are associated with appreciation of the real exchange rate. Particularly, a 10% increase in productivity growth in Germany and Japan relative to the U.S. tends to be associated with an increase in the real value (purchasing power) of the Mark by 16.5% and the real value of the Yen by 7.8%. On the other hand, a 10% increase in relative government spending in Germany and Japan is associated with an increase in the real Mark and Yen rates by approximately 20% and 19%.

[9]The implication is that productivity, government spending, and real oil price are not "error correcting"; that is, the cointegrating vector does not appear in the equations for these conditioning variables. Details on weak exogeneity within the context of cointegration and error correction can be found in Urbain (1992).

This is compatible with the productivity bias hypothesis. Accordingly, increases in productivity in tradables in Japan and Germany can be expected to decrease the relative price of traded goods in those countries and due to an increase in demand for tradables, currencies of both Germany and Japan appreciate relative to PPP. We noted that when the marginal propensity of government spending on non-tradables exceeds private sector spending, there can be increases in the relative price of non-tradables. In reality, it is plausible to assume that most government purchases are on services which are predominantly non-tradable. On the other hand, increases in government spending can have an impact on the intertemporal terms of trade (real interest rates) as well. Within a simple inter-temporal optimization framework, a current transitory increase in domestic government spending, for example, creates an excess demand for current period goods. Given that lump-sum taxes have risen by an amount equal to government spending, and private sector's marginal propensity to spend is smaller than unity, the private sector lowers its demand for current period goods less than the increase in government spending. This excess demand for current period goods induces an increase in the relative price of present goods in terms of future goods, that is, the real interest rate increases. An increase in domestic real interest rate can be expected to increase the real value of domestic currency due to capital mobility. This is another channel through which government spending can influence the real exchange rate. Indeed many authors attributed the appreciation of the dollar in the 1980s to the increase in U.S. government spending (Masson and Blundell-Wignall 1985; Friedman 1992). If increases in domestic government spending are associated with a real exchange rate appreciation, which means a reduction in competitiveness and perhaps persistent current account deficits, then this has important implications for macro-policymaking, since there tend to be increasing pressures for protection in response to external deficits. Notice also that the normalized coefficient of government spending is relatively high, which means increases in domestic government spending are associated with a greater change in competitiveness as compared to other variables.

Equations (7) and (8) indicate that increases in the real world oil price are associated with real depreciation of both Mark and Yen rates (a decrease in the relative price of German and Japanese goods in terms of U.S. goods) in the long run. This can be partly attributed to the various degrees of dependency on oil by these three countries. Whereas the U.S. imports about 40% of its oil, Japan is totally dependent on imported oil, which means, among other things, the demand deflationary effect of an oil price increase varies across countries. Second, there are differences in real wage responses to oil shocks in import competing and export industries in these three countries and the subsequent exchange rate depreciations that take place to offset these increases (Corden 1985). Third, there are various degrees of exchange rate intervention in these three countries.

Short-Run Dynamics

We have noted that cointegrating relationships have the interpretation of "long run equilibrium" relationships. The interrelationships among variables can best be understood by examining short-run dynamics characterized by a Vector Error Correction Model (VECM). Consider the dynamic specification:

$$\Delta X_t = A(L)\Delta X_{t-1} + \alpha z_{t-1} + \mu + \epsilon_t , \quad (9)$$

where X_t is a column vector of variables in the system, $A(L)$ is a matrix whose elements are k-order polynomials in the lag operator L, z_t is a column vector of the deviations from the long-run equilibrium (error correction terms) and ϵ_t is a column vector of disturbances. In this section we estimate a VECM for Japan and Germany and proceed with conventional innovation accounting (variance decompositions) typical of vector autoregressions.[10] We estimate the VECM with 8 lags imposing one cointegrating vector for Germany and Japan; Table 4 reports Variance Decompositions for a 16 quarter forecasting horizon using Choleski decomposition. The order of the variables is that implied by the table; real oil price, productivity, government spending, and the real exchange rate. The table also reports results for the reverse order.

Estimation results in Table 4 indicate that real oil price and relative productivity explain the preponderance of their forecast error variance for Germany. Perhaps the most important finding is that real oil price, government spending and productivity innovations account for over 85% of the forecast error variance of the real exchange rate for both Germany and Japan. Second, of the three factors relative government spending innovations seem to be the most important source accounting for roughly 64% of the real Yen/Dollar rate variability, and 33% of the Mark/Dollar variability. This is compatible with the earlier finding of a higher long-run "elasticity" of real exchange rate with respect to relative government spending. Notice that real oil price, relative productivity, and government spending all seem to be important in explaining the real Mark/Dollar rate. However, the effect of relative productivity on the real Yen/Dollar rate is minimal, and it is relative government spending that seems to be the most important source of variability in the real Yen/Dollar rate. Given the U.S. trade deficit with Japan and increasing pressures for protection in the U.S., this result seems to suggest that relative government spending is the most important source of changing competitiveness in the Japan/U.S. case. In order to check the robustness of

[10]For innovation accounting with cointegrated variables see Lütkepohl and Reimers (1992).

TABLE 4. *Variance Decompositions (16 quarters)*

		Innovation In		
	rop	(*pr* − *pr**)	(*g* − *g**)	*r*
Germany:				
rop	82.16	11.76	4.71	1.36
(*pr* − *pr**)	6.66	83.41	8.08	1.83
(*g* − *g**)	34.63	23.55	26.83	14.97
r	26.05	27.65	33.13	13.16
		Reverse Order		
rop	80.10	11.99	4.38	3.52
(*pr* − *pr**)	4.04	86.96	5.40	3.60
(*g* − *g**)	29.11	17.91	30.60	22.37
r	31.04	20.93	32.36	15.66
Japan				
rop	75.09	1.84	17.78	5.27
(*pr* − *pr**)	20.15	11.80	51.79	16.24
(*g* − *g**)	7.46	1.78	56.77	33.97
r	16.82	6.50	64.12	12.54
		Reverse Order		
rop	74.43	1.84	13.69	10.03
(*pr* − *pr**)	16.14	12.20	47.35	24.29
(*g* − *g**)	7.96	2.90	55.55	33.57
r	17.54	3.72	62.86	15.85

the results to the ordering in Choleski decomposition, we also report results from a reverse order in the Choleski decomposition. Reversing the order does not significantly alter the main results; real shocks, particularly real government spending shocks, still account for a sizable proportion of the real exchange rate forecast error variance.

4. Concluding Discussion

An important question in empirical international finance is whether purchasing power parity holds or there exists a stable real exchange rate. The importance of PPP is that it makes international real purchasing power comparisons possible using a common currency and nominal exchange rates. Second, since the real exchange rate is a relative price which is a measure of competitiveness, its movement has important resource allocation effects.

It has long been recognized that if there are non-traded goods, and if the relative price of non-traded goods changes, a bias will be introduced to PPP. There are many potential disturbances that can cause changes in the equilibrium price of non-traded goods. This paper attempts to test the biases caused by several real disturbances. First, using quarterly data from the post-Bretton Woods-period for Germany, Italy, and Japan vs. the United States and nominal exchange rates, the evidence is generally supportive of the hypothesized biases introduced by relative productivity, government spending, and real world oil price. Our results seem to be inconsistent with the findings of Cheung and Lai (1993) who report favorable evidence to long-run PPP for a number of countries including Germany. The study uses monthly data and two different price indices, the wholesale price index, and consumer price index, which might account for the discrepancy in the findings. We then estimate a real exchange rate equation for Germany and Japan. The results indicate that increases in productivity in tradables and real government spending at home relative to the U.S. are associated with appreciation of the real Yen and Mark rates in the long run whereas increases in real oil price is associated with depreciation of these rates. We also estimate a Vector Error Correction Model for Germany and Japan with real oil price, productivity, government spending and the real exchange rate to characterize short-run dynamics. Variance decompositions based on the VECM indicate that real shocks account for a sizable proportion of real exchange rate forecasting error variance and government spending shocks seem to be the most important source in real exchange rate movements particularly in the Japan/U.S. case. There seems to be a growing evidence that productivity, government spending, and oil price shocks influence the purchasing power of currencies. Using a model based on uncovered interest parity and accounting for productivity, fiscal, and oil price shocks, Throop (1993) outperforms the random walk in in-sample and out-of-sample forecasting. These results imply that real shocks identified to be empirically important in determining the equilibrium value of the dollar should be taken into account in macroeconomic policy in addition to monetary policy instruments. Moreover, assuming the conventional link between the real exchange rate and trade flows, these results have an important bearing on trade policy since the persistent U.S. trade deficit, particularly with Japan, is often accompanied by calls for increased protection.

It should be noted that the empirical part of this paper is limited to testing deviations from PPP and accounting for real biases introduced to PPP. In particular, we investigated sources of real exchange rate movements accounting for several real disturbances. However, the real exchange rate may respond to a number of real factors in the long run, and nominal factors in the short run. Following a modeling strategy similar to Dibooğlu and

Enders (1995), one can obtain a rich set of dynamics by incorporating long-run properties with short-run dynamics and by incorporating nominal shocks into the analysis.

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