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Abstract:

This paper provides a bivariate and multivariate analysis of real interest rate parity on monthly data for the period 1970.1 to 1997.12. This period was selected to conform with the time span of existing studies of the G7. The analysis extends from the existing literature by providing both parametric and non-parametric tests for real interest parity. This approach accommodates the non-normality of real interest rate data and the low power of tests for cointegration in small samples. The parametric analysis indicates a long run relationship between real interest rates in the G7. The non-parametric Persaran-Timmermann test for statistical independence given non-normality of the residuals reveal a uniform North American capital market; and strong links between the US-Germany and the German -UK; an integrated Europe with the notable exception of the UK market. There are also important links between the major markets US-Japan and Japan-UK. There remain, however, several instances of non-integration which would allow these independent countries a degree of policy independence and provide a conduit for risk diversification for international transactions. A most significant finding is that the non-normality of the distributions governing real interest rate time series can distort tests for real interest parity and all such studies should accommodate the non-normality of the data.

1. Introduction

Perfect capital market integration is defined by Bekaert and Harvey (1995) as a situation in which identical expected returns apply to international assets of an equivalent class subject to a given level of risk. Tests for capital market integration are often hindered by the difficulties involved in assessing the degree of risk associated with the international exchange of financial assets. Further, all components of expected returns are not readily available, for example, dividend returns. These difficulties force researchers to seek general measures for determining the extent of capital market integration.

Mishkin (1984, a, b) argues that the appropriate generic basis for testing capital market integration is the real interest parity (RIP) condition. He argues thus, for if the RIP condition holds, then capital market integration also holds and international capital is perfectly mobile. There is also both a policy and theoretical dimension underpinning Mishkin’s view. In relation to policy, Feldstein (1983) argues that if RIP holds then there is no basis for country specific monetary policy strategies designed to stabilise national incomes. In a theoretical context, RIP holds only if two other international equilibria hold, namely, uncovered interest and purchasing power parity. RIP does not hold if either or both of these conditions fail. The case for tests of RIP as a basis for determining the presence of capital market integration hinges on these arguments.

The monetary authorities of the smaller nations are not the only transactors in the international markets who would find their opportunities restricted. There are the demands of transactors in the global private currency markets who readily seek out opportunities to diversify away at least some of their currency risks. Their capacity to achieve this risk diversification goal will depend upon the degree of capital market integration in the markets of interest to them, and for many small country transactors the focus is on the major countries in this respect. In an extreme case, if real interest parity was to hold among the G7, then the opportunities for risk diversification within individual G7 markets simply would no longer exist. This study should be quite informative in relation to this issue.

The purpose of this study is to test for the presence of RIP and consequently capital market integration among the G7 group of countries. This study differs from previous analyses of RIP among the G7 countries by focussing on the G7 as a group and not as a bivariate collection alone. Recent analyses of RIP among the G7 nations includes work by Dreger and Schumacher (2003), Wu and Fountas (2000). These recent studies are preceded by a plethora of related studies for various combinations of countries,[1] none of which find any conclusive evidence for the existence of RIP in its strictest form, namely that real interest rates are equal.

The analyses by Dreger and Schumacher and Wu and Fountas contain some novel features although both are concerned only with bivariate comparisons of real rates. In particular, the first named authors find that there are several cases where the difference between pairs of G7 real rates constitutes an I(0) stationary series and consequently satisfy a requirement for RIP. Wu and Fountas find that there is strong convergence of non US G7 real rates towards the comparable US real rate. Further, they find from the analysis of a structural break in the bivariate cointegrating vector that monetary policies stabilise the Canadian and UK economies while in the case of France and Germany long-term real interest rate changes are influenced by the US monetary policy stance.

The study contained in this paper extends from this literature in two ways: first, it augments Drager and Schumacher's study by conducting both bivariate and multivariate Johansen and Juselius [1990] tests for RIP; second, it recognizes the non-normality of the individual interest rate series in testing for RIP. The Pesaran-Timmermann non-parametric

[1] See for example studies conducted by Cumby and Mishkin (1986), Felmingham, Zhang and Healy (2000), Fountain and Wu (1999), Mark (1985), Miller (1993) and Mishkin (1984 b).

test for RIP takes non-normality into account and is applied to test the proposition that the G7 real rate series are statistically independent.

Why is the G7 chosen as the focus for this study? There are obvious answers to this question. The outstanding one is the sheer magnitude of this group of nations in world affairs. Collectively, the G7 account for almost 70 percent of global output and owns a commensurate proportion of the total value of global financial assets. The G7 is the engine room of the developed world and if anything is amiss with its machinery, then the rest of the world experiences the consequences. About the only caveat that might be entered about the representativeness of the G7 is the absence of the world's second largest economy China from the G7 and for that matter the G8 or G20.

The period chosen for this study dates from the first month of 1970 to December 1997. The data set does not include the full impact of the Asian currency crisis, the 9/11 tragedy, and the innovation of the Euro. Each of these will have disturbed the normal behaviour of the markets when the objective of this analysis was to study capital market integration in a period when the markets behaved normally. The two random shocks and the advent of the Euro are events warranting a further and distinctive analysis. This is beyond the scope of the current paper which sets the scene for these additional analyses. Further, it is appropriate to compare the results of this study with other G7 studies of real interest rate parity. This time series was selected with comparability in mind.

The following section of this paper includes discussion of the approach applied, key definitions including the form of the RIP condition in the multivariate case and the properties of the data set. The results of the analyses are presented in a third section and conclusions drawn in a final section along with policy implications.

2. Theoretical Basis and Properties of the Data Set

2.1 Theoretical Basis

Real Interest Rate Linkages

Following Mishkin (1984a), the real rate of interest for a country is given by,

$$r'_t = i_t - E_{t-1}\pi_t \tag{1}$$

where i_t = the nominal rate of interest

π_t = the rate of inflation

$r`_t$ = the real rate of interest

E = expectations operator conditional on information at time t -1

The real rate defined above, which is more precisely the *ex ante* real rate, is unobservable and, therefore, it is necessary to employ the *ex post* real rate which is defined as,

$$r_t = i_t - \pi_t = r'_t - \left(\pi_t - E_{t-1}\pi_r\right) = r'_t - e_t \tag{2}$$

where r_t = the one period ex post real rate at time t

π_t = the actual rate of inflation

$e_t = \pi_t - E_{t-1}\pi_t$ = the forecast error of inflation

A critical assumption underlying this model is rational expectations, which implies that the forecast error of inflation, $e_{t,}$ is unforecastable. Hence its expected value is zero as follows:

$$r'_t = E_{t-1}r_t \tag{3}$$

The equality of real interest rates across countries implies that,

$$r_t - r'_t = E_{t-1}\left(r_t - r^*_t\right) = 0 \tag{4}$$

where, r and r* are the interest rates for two different countries.

Equation (4) suggests that the ex post real rate differential between countries is unforecastable given any information at time t -1.

A test of real interest rate equality can be carried out by running the following regression,

$$r_t = a + br_t^* \tag{5}$$

In (5) $\hat{a} = 0$ and $\hat{b} = 0$ imply complete real interest rate convergence, while $\hat{b} = 0$ denotes absence of any interest rate linkage. Partial interest rate linkages are implied by $0 < \hat{b} < 1$.

Mishkin (1984b) has further shown that the equality of real interest rates is closely related to the uncovered interest parity and speculative efficiency conditions. The covered interest parity condition is given by the following:

$$f_t - s_t = i_t - i_t^* \tag{6}$$

The ex ante version of purchasing power parity (PPP) is expressed in the following relationship,

$$E_{t-1}\left(\pi_t - \pi_t^* - (s_t = s_{t-1})\right) = 0 \tag{7}$$

and the speculative efficiency condition follows from the above,

$$f_t = E_{t-1}s_t \tag{8}$$

Combining these three equations gives the UIP condition:

$$E_{t-1}\left(i_t - i_t^* - (s_t - s_{t-1})\right) = 0 \tag{9}$$

Subtracting the PPP condition from the above equation yields a basis for the RIP test,

$$E_{t-1}\left(r_t - r_t^*\right) = 0 = r_t' - r_t'^* \tag{10}$$

Wu and Fountas (2000) provide a useful distinction between weak and strong form versions of tests for RIP as follows:

- the weak form holds if r_t and r_t^* are cointegrated and their difference is stationary.
- the strong form holds if in addition to the above, a = 0 and b = 1 in estimates of equation (5).

These conditions may be extended to the multivariate case as follows:

- the weak form of the RIP for n real rates of interest in the n variable case is that there is some evidence of cointegration.
- the strong form requires perfect cointegration defined as n -1 cointegrating vectors for n variables and a unit slope coefficient in the relationship between all pairs of real rates.

It is this extension for the multivariate case which is developed in this paper. The weak form is determined from Johansen – Juselius (1990) VAR methodology in which case the weak form is satisfied, if there is any evidence of cointegration, however, the strong form requires a more specific definition. In particular, perfect cointegration must apply which means in the cointegrative analysis of the G7 real rates that there are six cointegrating vectors. An important contribution of the present analysis is recognition of the non-normal nature of the individual real rate series applied in the analysis. The Pesaran-Timmermann non-parametric test for statistical independence is applied to accommodate non-normality.

The approach adopted here is briefly summarised. The distributional and stationarity properties of the data set are examined first and following this analysis, a Johansen and Juselius VAR model is used to test for the presence of cointegration in both bivariate and multivariate cases. The results reveal a strong degree of cointegration. Bivariate cointegration holds in twenty of twenty-one bivariate comparisons while there is evidence of four cointegrating vectors in the multivariate study. The likelihood ratio statistics do not reveal any compelling evidence for the presence of RIP in its strong form. The generalized impulse responses of the rest of the countries to an interest rate shock in the US are then assessed. Such standard techniques are augmented by a non-parametric test of the G7 rates. The results of this indicate that RIP does hold for six of the bivariate relationships, but not for the twenty relationships identified in the standard analysis ignoring non-normality.

2.2 *Properties of the Data Set*

The data used are three-month treasury bill rates for all for all countries – the US, Japan, UK, Germany, France, Canada and Italy. All data are obtained from *Global Financial Data*. The data covers the period 1970.1 to 1997.12. Real interest rates are calculated as $i - \pi$, a representation which is consistent with the assumptions applied to the derivation of the real interest rate in Section 2.1. Table 1 presents the mean, skewness and kurtosis values and the Bera-Jarque (BJ) statistics for normality for each series.

Table 1: Statistics of the Interest Rates

	US	**Japan**	**Germany**	**Britain**	**France**	**Canada**	**Italy**
Mean	6.61	3.73	5.32	8.81	8.56	7.96	11.36
Skewness	1.2451	-.5380	.6718	.1655	-.5528	.6562	.0904
Kurtosis-3	1.5633	-.4966	.0216	-.9114	19.5856	.4318	-.5775
BJ Statistic	116.18	187.15	149.39	215.72	3868.25	116.45	179.64

The Bera-Jarque statistic for normality is asymptotically distributed as a χ^2 with 2 degrees of freedom. The critical $\chi^2_{(.01)}$ value at the one percent level is 9.21.

The mean value of real interest rates for Japan is the lowest while for Britain, France and Italy they are larger. The real rates for Japan and France appear to be skewed to the left while for the US, Germany, Britain, Canada and Italy the data series are skewed to the right. The kurtosis statistic for all series except France are below 3 in value indicating non-normality. For France the kurtosis statistic is 19.59 suggesting excess kurtosis beyond that of a normal distribution. The last line reports the Bera-Jarque (BJ) test for normality. This is calculated as:

$$BJ = n\left[\frac{s^2}{6} + \frac{(k-3)^2}{24}\right]$$

where s denotes skewness, k represents kurtosis and n is sample size. Under the null hypothesis of normality, the BJ statistic is distributed as χ^2 with 2 degrees of freedom. All the BJ values are greater than the $\chi^2_{(.01)}$ level of 9.21 suggesting that the errors in all series are non-normally distributed.

Table 2 presents results for unit roots. These suggest that all interest rate series are non-stationary except for the Japanese and UK series which appear to be I(0) according to the Phillips (1987) test and I(0) at the 10% and 5% levels under the ADF test. All data appear to be I(0) in first differences. Due to the discrepancy in the ADF and Phillips tests for the UK and Japanese series in the levels, cointegration tests are carried out on all seven series.

Table 2: Dickey-Fuller Test for Unit Roots for the Levels of the Series

Variable	**No Trend ADF**	**Zt**	**Trend ADF**	**Zt**
Interest Rates:				
US	-2.36	-1.69	-2.49	-1.74
UK	-2.85*	-4.45***	-2.91**	-4.40***
Canada	-2.10	-1.43	-2.11	-1.42
Japan	-2.79**	-3.83***	-2.93**	-5.13***
France	-2.32	-1.54	-2.23	-1.58
Italy	-2.18	-2.53	-2.18	-2.43
Germany	-2.19	-2.02	-2.16	-2.02

Note: Significance levels without trend are : 10%, -2.58: 5%, -2.90 and 1%, -3.51.
With trend 10%, -3.16; 5%, -3.46; 1%, -4.07 (Davidson and MacKinnon 1993).
A sixth order autoregressive model is used. Six lags on the Bartlett window are used for the Phillips (1987) test.
*, **, *** significant at the 10%, 5% and 1% levels respectively.

Table 3:Dickey-Fuller Test for Unit Roots for the First Differences of the Series

Variable	No Trend ADF	Zt	Trend ADF	Zt
Interest Rates:				
US	-17.43***	-7.59***	-17.41***	-7.58***
UK	-21.99***	-21.35***	-21.06***	-21.35***
Canada	-18.35***	-14.83***	-18.38***	-14.72***
Japan	-21.60***	-24.84***	-21.51***	-24.73***
France	-14.42***	-17.11***	-14.45***	-17.08***
Italy	-19.99***	-9.67***	-19.99***	-9.67***
Germany	-19.02***	-18.08***	-19.00***	-18.22***

Note: Significance levels without trend are : 10%, -2.58: 5%, -2.90 and 1%, -3.51
With trend 10%, -3.16; 5%, -3.46; 1%, -4.07 (Davidson and MacKinnon 1993)
A sixth order autoregressive model is used. Six lag on the Bartlett window are used for the Phillips (1987) test.
*, **, *** significant at the 10%, 5% and 1% levels respectively.

3. Methodology and Results

3.1 *The Johansen Methodology*

Cointegration tests are conducted by applying the standard trace and eigenvalue measures proposed by Johansen (1988) and Johansen and Juselius (1990). The non-parametric procedures applied below also accommodate the non-normality of the time series.

The Johansen Juselius Procedure

Johansen and Juselius (1990) consider the following model:

$$\Delta X_t = \Gamma_{k-1} \Delta X_{t-k+1} + ... + \Pi X_{t-k} + \upsilon + e_t \quad (11)$$

$t = 1, 2, \ldots,$

where υ is an intercept vector

e_t is a vector of Gaussian error terms.

The Johansen approach requires estimation of the above equation and the residuals are then used to compute two likelihood ratio tests for the determination of the number of cointegrated vectors: the trace test and the maximal eigenvalue test.

The maximal eigenvalue test evaluates the null hypothesis that there are at most r cointegrating vectors against the alternative of r+1 cointegrating vectors. The maximum eigenvalue statistic is given by,

$$\lambda_{max} = -T \ln(1 - \lambda r + 1) \qquad (12)$$

where $\lambda r + 1, ..., \lambda n$ are the n - r smallest squared canonical correlations

T = the number of observations

The second test is based on the trace statistic which tests the null hypothesis of r cointegrating vectors against the alternative of r or more cointegrating vectors. This statistic is written,

$$\lambda_{trace} = -T \sum \ln(1 - \lambda i) \qquad (13)$$

In order to apply the Johansen procedure, a lag length must be selected for the VAR. A lag length of one is selected on the basis of the Akaike Information Criterion (AIC).

Table 4 presents cointegration tests for the bivariate and multivariate models. The cointegration tests presented in Table 4 indicate 20 cointegrating vectors for the 21 bivariate models. The multivariate tests indicate four cointegrating vectors implying the existence of only three independent common stochastic trends in the system of seven variables.

Table 4: Johansen-Juselius Maximum Likelihood Cointegration Test

Null	Alternative			95% critical value	
		mλ	**Trace**	**mλ**	**Trace**
		US-CANADA			
r = 0	r = 1	21.67	26.17	15.87	20.18
r < = 1	r = 2	4.49	4.49	9.16	9.16
		US- JAPAN			
r = 0	r = 1	36.45	42.20	15.87	20.18
r < = 1	r = 2	5.75	5.75	9.16	9.16
		US-UK			
r = 0	r = 1	23.99	28.83	15.87	20.18
r < = 1	r = 2	4.84	4.84	9.16	9.16
		US-GERMANY			
r = 0	r = 1	16.28	22.73	15.87	20.18
r < = 1	r = 2	6.45	6.45	9.16	9.16
		US-FRANCE			
r = 0	r = 1	170.14	175.96	15.87	20.18
r < = 1	r = 2	5.82	5.82	9.16	9.16
		US-ITALY			
r = 0	r = 1	18.54	23.30	15.87	20.18
r < = 1	r = 2	4.75	4.75	9.16	9.16
		CANADA-JAPAN			
r = 0	r = 1	35.33	39.36	15.87	20.18
r < = 1	r = 2	4.02	4.02	9.16	9.16
		CANADA-UK			
r = 0	r = 1	37.39	40.52	15.87	20.18
r < = 1	r = 2	3.12	3.12	9.16	9.16
		CANADA-GERMANY			
r = 0	r = 1	18.25	22.52	15.87	20.18
r < = 1	r = 2	4.26	4.26	9.16	9.16
		CANADA-FRANCE			
r = 0	r = 1	181.12	184.15	15.87	20.18
r < = 1	r = 2	4.03	4.03	9.16	9.16
		CANADA-ITALY			
r = 0	r = 1	25.22	28.59	15.87	20.18
r < = 1	r = 2	3.37	3.37	9.16	9.16
		JAPAN-UK			
r = 0	r = 1	32.50	43.15	15.87	20.18
r < = 1	r = 2	10.65	10.65	9.16	9.16
		JAPAN-GERMANY			
r = 0	r = 1	36.16	41.42	15.87	20.18
r < = 1	r = 2	5.25	5.25	9.16	9.16

Null	Alternative	mλ	Trace	95% critical value mλ	Trace
		JAPAN-	***FRANCE***		
r = 0	r = 1	147.58	176.20	15.87	20.18
r < = 1	r = 2	28.47	28.47	9.16	9.16
		JAPAN-ITALY			
r = 0	r = 1	35.17	42.16	15.87	20.18
r < = 1	r = 2	6.45	6.45	9.16	9.16
		UK-GERMANY			
r = 0	r = 1	20.35	26.14	15.87	20.18
r < = 1	r = 2	5.79	5.79	9.16	9.16
		UK-FRANCE			
r = 0	r = 1	156.78	167.21	15.87	20.18
r < = 1	r = 2	10.42	10.42	9.16	9.16
		UK-ITALY			
r = 0	r = 1	22.17	27.72	15.87	20.18
r < = 1	r = 2	5.56	5.56	9.16	9.16
		GERMANY-FRANCE			
r = 0	r = 1	187.84	192.82	15.87	20.18
r < = 1	r = 2	4.98	4.98	9.16	9.16
		GERMANY -ITALY			
r = 0	r = 1	14.19	19.55	15.87	20.18
r < = 1	r = 2	5.36	5.36	9.16	9.16
		FRANCE-ITALY			
r = 0	r = 1	197.30	202.95	15.87	20.18
r < = 1	r = 2	5.65	5.65	9.16	9.16
		ALL			
r = 0	r = 1	279.40	436.92	46.47	132.45
r < = 1	r = 2	48.10	157.51	40.53	102.56
r < = 2	r = 3	39.41	109.40	34.40	75.98
r < = 3	r = 4	31.70	69.98	28.27	53.48
r < = 4	r = 5	19.31	38.28	22.04	34.87
r < = 5	r = 6	14.80	18.97	15.87	20.18
r < = 6	r = 7	4.17	4.17	9.16	9.16

Given that there are four cointegrating vectors, the Likelihood Ratio (LR) statistics for the restriction that there is a 1:1 relationship between the real interest rates in the bivariate case are reported in Table 5. Restrictions have been imposed only on one cointegrating vector for Japan-UK, Japan-France and UK-France where there were 2 cointegrating vectors. The

LR statistics are all above the 95% critical value of 3.84 rejecting the hypothesis that there is a 1:1 relationship between the pair-wise real interest rates in the G7.

Table 5

	LR
US-Canada	17.07
US-Japan	26.20
US-UK	18.44
US-Germany	9.57
US-France	128.6
US-Italy	13.77
Canada-Japan	27.78
Canada-UK	33.67
Canada-Germany	13.87
Canada-France	149.38
Canada-Italy	21.79
Japan—UK	16.08
Japan-Germany	22.07
Japan-France	84.34
Japan-Italy	24.48
UK-Germany	12.22
UK-France	116.05
UK-Italy	16.18
Germany-France	137.25
France-Italy	167.19

Table 6 reports the error correction relations for the variables in the VAR. A significant error correction term suggests that past equilibrium errors are important in determining current outcomes. Note that most elements of the matrix are significant suggesting a short term relationship between the real interest rates in the G7 and note also that the significant error correction parameter estimates are less than one in value suggesting partial adjustment back towards a long run equilibrium.

Table 6: The Error Correction Relations for the Variables in the VAR

	EC_1	EC_2	EC_3	EC_4
US	-.005(-.29)	-.01(-.23)	.01(.55)	.006(.29)
Canada	.05(2.64)	-.09(-3.09)	.01(.42)	.08(3.72)
Japan	.04(1.80)	.005(.12)	-.22(-6.28)	-.02(-.75)
UK	-.07(-3.18)	.18(4.94)	-.03(-.87)	-.13(-4.98)
Germany	.004(.40)	.04(2.52)	.00(.01)	-.00(-.07)
France	.38(6.98)	-.06(-.59)	.29(3.43)	.02(.28)
Italy	.01(.32)	.08(2.26)	.01(.45)	.002(.09)

3.2 *Impulse Response and Forecast Error Variance Decomposition Analysis*

This section examines the generalized impulse responses of Canada, Germany, UK, France, Italy and Japan to an interest rate shock in the US. The US is chosen as the source of an interest rate shock because it is still viewed as the leading nation in the G7 capital markets and we want to determine the sensitivity of other country rates to US inspired shocks. Following Pesaran and Shin (1998), this can be represented by the following. If X_t has a VAR representation of the following form:

$$\Delta X_t = \mu + \sum_{i}^{p} \phi_i X_{t-i} + e_t$$

where μ is a vector of constant terms and is a vector of Gaussian error terms with $E(e_t) = 0$ and $E(e_t e_t') = \sum = (\sigma_{ij})$. The generalized impulse response of X_{t+n} relating to a unit shock in the jth variable at time t is:

$$Z_n \sum \varepsilon_j / \sigma_{ij} \qquad n=0, 1, 2\ldots$$

Where $Z_n = \phi_1 Z_{n-1} + \phi_2 Z_{n-2} + \ldots + \phi_p Z_{n-p}$

n $=1, 2, 3,\ldots$

$Z_n = 0$ for $n < 0$

The forecast variance of *i, n* periods hence takes place due to the innovations in the *j*th variable. This can be calculated as:

$$\sigma_{ij}^{-1}\sum_{k=0}^{n}\left(\varepsilon_i' Z_k \sum \varepsilon_j\right)^2 \Big/ \varepsilon_i' Z_k \sum Z_k' \varepsilon_j \qquad i, j = 1,\ldots$$

The above equations will hold in a system of cointegrated variables.

Figures 1 - 6 show the generalized impulse response functions for each country with respect to a standard deviation interest rate shock in the US. Figure 1 shows the generalized impulse response function of the US real rate with response to an interest rate shock of the US interest rate and the generalized impulse response of the Canadian interest rate to a standard deviation shock of the US interest rate. The lighter lines in Figures 2 - 6 show the impulse response of Japan, UK, Germany, France and Italy respectively to a standard deviation shock of the US interest rate. For Canada, Germany, Italy and Japan, a shock to the US interest rate appears to increase steadily over time and then remain constant. For the UK, a shock arising in the US seems to have hardly any impact on the UK real rate at all.

Figure 1

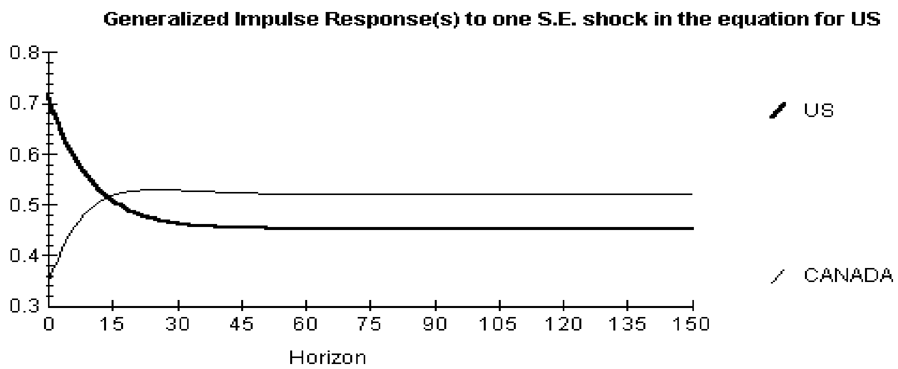


Figure 2

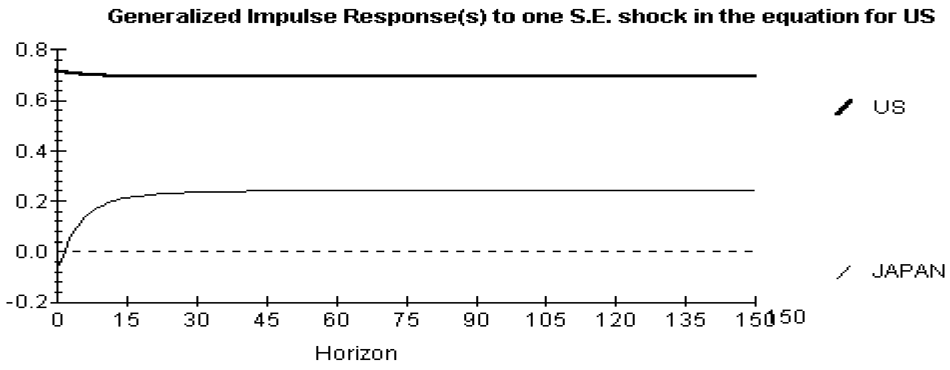


Figure 3

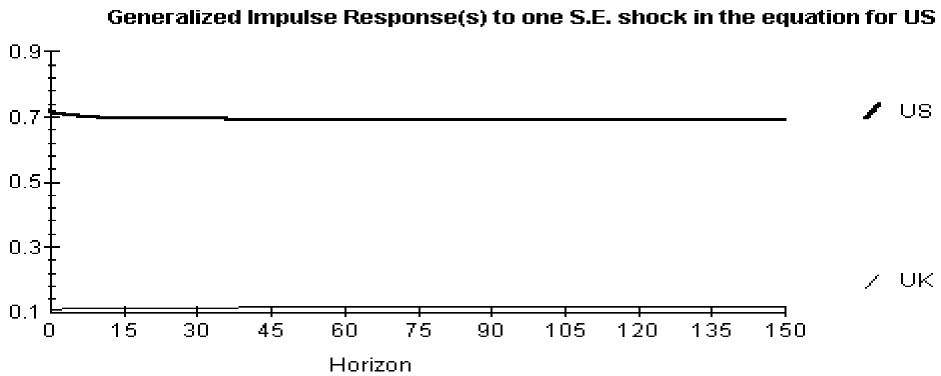


Figure 4

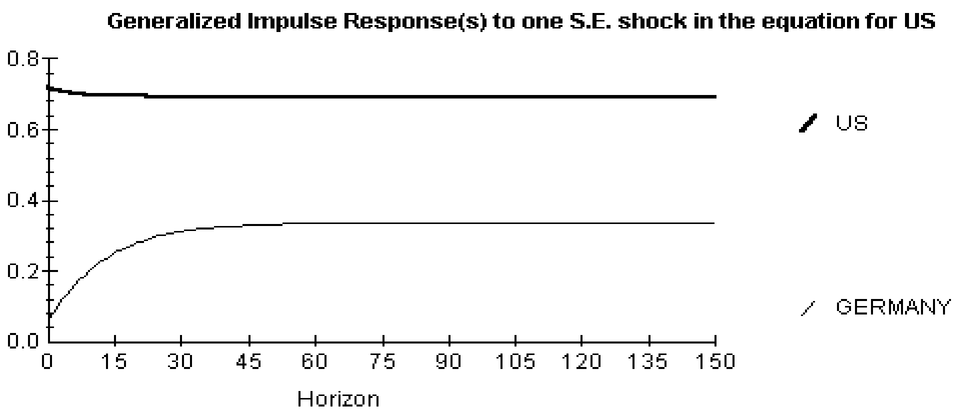


Figure 5

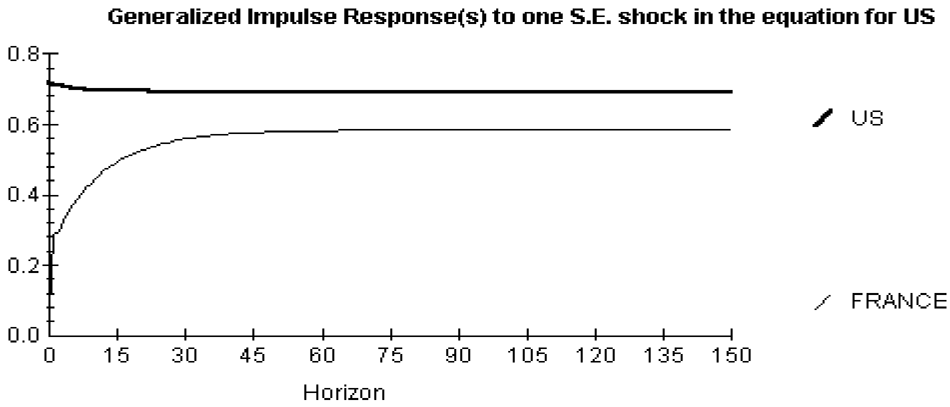
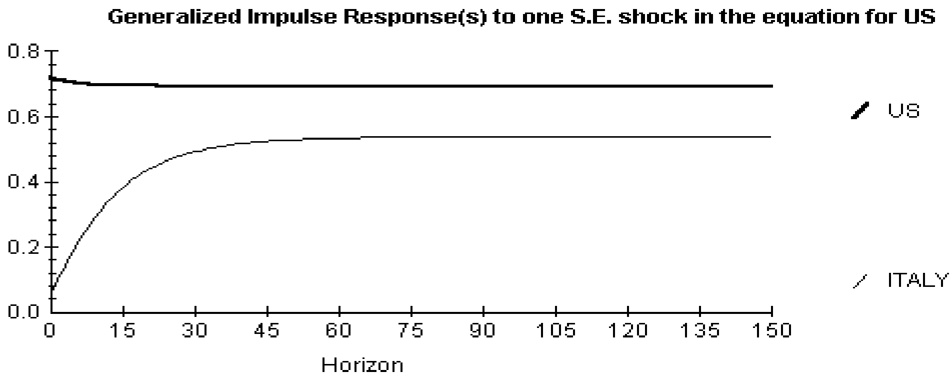


Figure 6



3.3 *A Non Parametric Test*

The analysis to this stage has proceeded on the assumption that the standard tests for cointegration are robust to the kind of non-normality revealed by the Bera-Jarque statistic on Table 1. However, we take out insurance about the risk that the non-normality of the time series applied to this study may distort the results of the analysis. In this respect, the Persaran-Timmermann test provides a non-parametric test of real interest parity and it is of interest to see if it provides the same conclusions as the parametric tests.

The Pesaran-Timmermann (PT) Test

The test statistic as proposed by Persaren and Timmermann (1992, 1994) is presented below.

Let $x_t = \hat{E}(y_t / \phi_{t-1})$ be the predictor of y_t based on the information set, ϕ_{t-1}.

The Pesaren – Timmermann test is based on the proportion of times the direction of change in y_t is accurately predicted by x_t. This test statistic is computed as follows:

$$Sn = \frac{\hat{P} - \hat{P}^*}{\hat{Z}(\hat{P}) - \hat{Z}(\hat{P}^*)^{\frac{1}{2}}} \sim N(0,1)$$

where $\hat{P} = n^{-1}\sum_{t=1}^{n} \text{sign}(y_t, x_t)$

$$\hat{P}^* = \hat{P}_y \hat{P}_x + (1 - \hat{P}_y)(1 - \hat{P}_x)$$

$$\hat{Z}(\hat{P}) = n^{-1}\hat{P}^*(1 - \hat{P}^*)$$

$$\hat{Z}(\hat{P}^*) = n^{-1}(2\hat{P}_y - 1)^2 \hat{P}_x (1 - \hat{P}_x) + n^{-1}(2\hat{P}_x - 1)^2 \hat{P}_y (1 - \hat{P}_y) + 4n^{-2}\hat{P}_y \hat{P}_x (1 - \hat{P}_y)(1 - \hat{P}_x)$$

$$\hat{P}_y = n^{-1}\sum_{t=1}^{n} \text{sign}(y_t)$$

$$\hat{P}_x = n^{-1}\sum_{t=1}^{n} \text{sign}(x_t)$$

If $\hat{P}_x$ or $\hat{P}_y$ take on extreme values of zero or one, the test statistic is indeterminate.

The null hypothesis that x_t and y_t are distributed independently is set against the alternative that x_t and y_t are not statistically independent. If the PT statistic exceeds 1.96 the hypothesis that x_t and y_t are statistically independent is rejected.

Table 7: The Pesaran-Timmermann Test for the First Differences of the Series

	PT Statistic
US-Canada	2.72
US-Japan	1.91
US-UK	0.12
US-Germany	2.34
US-France	0.31
US-Italy	0.50
Canada-Japan	-1.25
Canada-UK	-0.08
Canada-Germany	-1.20
Canada-France	0.67
Canada-Italy	0.55
Japan-UK	3.44
Japan-Germany	0.93
Japan-France	-0.60
Japan-Italy	0.06
UK-Germany	2.21
UK-France	-0.06
UK-Italy	1.29
Germany-France	0.89
Germany-Italy	3.03
France-Italy	2.30

From Table 7, the null hypothesis that interest rates are normally distributed and statistically independent, is rejected on six occasions. In each instance, the PT test Statistic exceeds its 5% critical value and so the null hypothesis is rejected. There are six bivariate studies in which the null is rejected: the US-Canada, US-Germany, Japan-UK, UK-Germany, Germany-Italy, France-Italy, while the PT test statistic for the US and Japan (1.91) is in close proximity to the relevant critical value so we might think of the US-Japan case as one in which a high degree of capital market integration applies. Market conditions which involve the acceptance of the null include: US-UK, US-France, US-Italy, Canada-Japan, Canada-UK, Canada-Germany, Canada-France, Canada-Italy, Japan-Germany, Japan-France, Japan-Italy, UK-France and UK-Italy.

When the non-normality of the distributions describing the G7 real rate series is accommodated in the analysis, it appears as if the strong ties between the G7 real rate series loosens somewhat. Now there are only six of the twenty-one bivariate analysis which suggest that real interest rates are statistically dependent suggesting that a weak form of RIP holds. This compares with the twenty instances of bi-variate cointegration when the non-normality of the data series is not taken into account. Note also that these conclusions drawn from the comparison of tests for cointegration and non-parametric, non-normal tests for statistical independence are also consistent with key aspects of the preceding impulse response analysis. The Pesaran and Timmermann test statistics suggest the null of statistical independence be rejected in the case of the US-Canada, US-Japan, US-Germany. Note below that the Canadian, German and Japanese real rates exhibit a patterned response to real rate shocks emanating in the US, while US shocks have no apparent impact on the UK series consistent with the PT test for the US- UK series where we found no evidence of statistical dependence of these two series.

4. Interpretation and Conclusion

The G7 remains the powerhouse of the developed capital markets, so the issue of the degree of capital market integration among these is not a trivial issue. For individual G7 member countries, the presence of real interest parity in its strictest form limits or even eliminates the prospects of operating independent stabilization policies. Further the capital market integration of the G7 countries may create a stimulus for global integration given the influence of the individual G7 member countries will influence capital markets in the smaller nations within their sphere of influence. Japan among the Asian nations, the USA and Canada in the South, Central America and Australasia and the European G7 members in the rest of Europe.

Recent literature on capital market integration among the G7 is focused on pairwise, bivariate comparisons of the relationship between comparable G7 rates. These studies uncover evidence to support the weak interpretation of real interest parity based on standard (smooth) cointegration tests and non standard (breaks in the cointegrating vectors) in the case of the G7. However, the strict interpretation of real interest parity requiring the equality of pairs of comparable real rates does not appear to hold. This study extends from the recent literature about capital market integration among the G7 in the following ways: it redefines the weak and strong form tests of real interest parity for a multivariate, as opposed to the bivariate study and it recognizes the potential limitations of the non-normality of interest rate data for the G7 countries.

Comparable studies of G7 capital market integration for a similar time span reveal that there is evidence for the presence of weak form real interest parity, although no evidence supports the strong form of real interest parity. This study shows that the G7 satisfy the requirements for weak form real interest parity as bivariate cointegration is evident in 20 out of the 21 bivariate studies and in the multivariate case, there are fewer than six cointegrating vectors among the seven G7 rates. The non-parametric test applied leads to the rejection of the independence of real interest rate integration in some most important cases: US-Canada, US-Germany, Japan-UK, UK-Germany, Germany-Italy, France-Italy, while the PT test statistic for the US and Japan suggests strong links between the real rates of these two countries. The result for the US-Canada is not surprising given that the North American capital markets constitute a closely integrated single market. The links between the US and

Germany real rates is also pivotal in securing a connection between the operations of North American and European markets, while the Japanese markets major links with Europe is secured through Japan's real interest rate connections with the UK. Britain's capital market links with Europe are established through the connection between equivalent real rates prevailing in Germany and the UK. Otherwise, there are no links between the UK and Europe which may simply reflect Britains withdrawal from the European monetary system in the 1990s. For the rest of the world, it is of importance to note the strength of capital market integration among the major countries in particular, US-Japan, US-Germany, Japan-UK, UK-Germany.

This study indicates that over the period 1970-1997, the G7 was in general a closely integrated capital market. So the individual countries comprising the G7 would have fewer opportunities to conduct an independent monetary policy and international traders in the G7 capital markets would have fewer opportunities to diversify risk. However, when we allow for non-normality of the data set, certain caveats must be entered. The North American market appears to operate as a single entity while much of Europe is also closely integrated. Note here, the exception which is the UK whose only relationship with European capital markets is linked with Germany. It is important for the rest of the world to understand that some strategic capital market ties exist between the major countries, but that the capital market interdependence of the G7, examined from a real interest rate perspective is not so strong once non-normality of the time series involved is accommodated. An important signal emerging from this study is that the non-normality of the distribution of real interest rate time series can distort analyses of real interest parity and should be accommodated in the experimental design of such studies.

A further issue in conclusion is the suitability of cointegration tests for RIP. These are called into question by results from this study and the suggestion is that cointegration analysis must always be augmented by additional tests such as the Pesaran-Timmermann test applied here. As Bewley and Yang (1996) point out, size distortions and the power properties of likelihood based tests for cointegration are poor in many situations.

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