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Abstract:

Some evidence for RIP among the G7 nations is evident over the time period 1970:1 to 2003:12. This is based on a smooth cointegration analysis of real interest rates on 3 month treasury bills. However, the strength of association weakens when the cointegration analysis is applied in 3 sub-periods 1970:1-1980:12, 1981:1-1990:12 and 1991:1-2003:12. There is evidence of 1 cointegrating vector in the first sub-period, 3 in the second and 2 in the third. We find from a graphical analysis of the trace statistic and eigenvalues from recursive estimation that breaks in the cointegrating vector occur simultaneously with the two oil price shocks in the 1970s, the 1990 recession, the Asian crisis in 1997 and the effects of the September 11 holocaust. This outcome is confirmed formally. The major finding is that the 5 shocks also cause structural instability in the cointegration of G7 rates. The implications are explained.

1. Introduction

The objective of the researchers in this study is to test for the presence of real interest parity (RIP) and therefore capital market integration among the G7 nations. The novelty of the argument in comparison with previous analyses of the G7 in this capital market context is twofold: first, the study is designed to explore the extent of capital market integration among the G7 both in a multivariate and bivariate context in contrast to earlier studies which are focused mainly on bivariate analysis. A second feature is that tests for breaks in the multivariate relationship between G7 states are conducted using a graphical analysis of the recursively estimated trace statistics and eigenvalues (see Hansen and Johansen 1999). This preference for a recursive analysis is described fully in the third section of this paper although the overriding consideration is that the researchers can examine the effects of more than one major shock to global markets. Alternative techniques are on occasions restricted to the analysis of a single break. Our concern here is to determine the impact of known events, such as the Asian crisis, on the extent to which the G7's capital markets are integrated. The time series chosen for this study (1970 to 2003) spans a period in global financial history which includes the effects of the liberalization of foreign exchange markets; the financial consequences of wars such as the Vietnam war; the impacts of two oil price shocks; the Asian financial crisis and the September 11th 2001 holocaust. The authors do not attempt to analyse all of these major events, but by applying the recursive analysis above we are able to keep all options open and consider the impact of several major disturbances on the financial integration of the G7 markets.

The G7 nations are chosen as the basis for this analysis because the financial behaviour of these seven nations individually and collectively is of critical importance to smaller nations such as Australia, New Zealand and the smaller nations in general which rely on the stability of the G7 for their own financial harmony. In this sense, the G7 is the engine room of the global financial system and the degree of its interdependence is significant for domestic economies outside the G7. If the G7 financial markets are closely integrated, then the prospects of a small nation running a monetary regime which increases its own national income and no one else's seems less likely to occur in this era of exchange rate flexibility given the dependence of the smaller nations on the G7 as a source of financial capital. Further, for international transactors and investors, the more integrated are the G7s capital markets, the less likely it is that these agents will be able to diversify away systemic risk by trading at different real rates in individual G7 markets. Therefore it seems that an analysis of financial market integration focused on the G7 group is of great interest to those nations outside this group of capital markets.

Real interest parity is chosen as an empirical basis for studies of capital market integration because it provides a direct test of the proposition that capital markets are integrated. Those studies inspired by Feldstein and Horioka (1980) which examine the relationship between the domestic savings and investment ratios provide a less direct basis for testing capital market integration. The indirectness of the Feldstein-Horioka based arguments is evident in the degree of interdependence between these ratios. Perfect capital market integration holds if the domestic savings and investment ratios are unrelated. Likewise, financial independence is implied if the domestic savings and investment ratios are equal however, a direct test, based on RIP is the preferred basis on this occasion.

Some recent tests for the presence of RIP condition between the G7 countries or individual G7 countries with others outside the G7 generally reject its presence. Included among these are studies by Cumby and Mishkin (1986), Felmingham, Zhang and Healy (2000) and

Fountas and Wu (1999). More recent studies of the G7 collectively include the studies conducted by Dreger and Schumaker (2003), Wu and Fountas (2000). Dreger and Schumaker, in particular, use monthly data over the sample period (1980:1 to 1998:12) applied to a cross section of G7 3 month term nominal interest rates. These authors base their tests for RIP on the differences between equivalent nominal rates in different countries. The US is treated as the foreign country in all of these bivariate studies. Dreger and Schumaker (2003) reject RIP between the US and each of the remaining G7 nations although there is some weak evidence of stationarity in the differences in equivalent rates between European members of the G7. Dreger and Schumaker base their analysis on weak form tests for stability and do not encompass the impact of shocks, generally and in particular those generated by the Asian crisis in 1997 or by September 11th 2001. Their data sets truncate prior to the occurrence of these events. Wu and Fountas (2000) overcome one limitation of the Dreger and Schumaker study by allowing for structural breaks. The Gregory and Hansen (1996) test is used to test for bivariate cointegration of G7 short term real interest rates subject to a structural break. The Wu and Fontas study is based on a time series covering the period 1974 to 1995 and produces strong evidence in favour of bilateral interest rate convergence between the US and several of the remaining G7 countries particularly at the short end of the capital market. However, Canadian and UK long run rates are not influenced by equivalent US rates so that these countries can expect monetary policy to act as a stabilisation tool.

Neither of these more recent studies consider shocks occurring beyond 1995 and 1998 respectively, and the effects of the Asian crisis, so we need some later data to determine the full impact on financial market integration. Both of these studies focus on bilateral relationships. This study updates the data set employed in studies to accommodate both the

Asian crisis and the impact of September 11th on capital markets. Further, both bivariate and multivariate analyses are conducted.

The remainder of this paper is organised in the following manner: Section 2 details the methodological basis and its theoretical underpinnings, Section 3 defines the properties of the data set, results are discussed in Section 4 and the analysis concludes with an interpretation of the major results of the study in Section 5. Implications are also considered.

2. Model and Methodology

The brief argument supporting the use of the RIP condition in the introduction warrants an extended comment. There is a theoretical dimension underpinning the preference for RIP based tests of capital market integration in addition to the policy issues referred to above and identified by Feldstein (1983). In a theoretical context RIP holds only if both uncovered and purchasing power parity both hold. The failure of either or both equilibria means that RIP cannot hold. The advantage of the RIP condition as a basis for assessing the degree of capital market integration is that it is closely linked to other international equilibria in the way described.

2.1 Real Interest Parity

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

$$r_t' = i_t - E_{t-1}\pi_t \qquad (1)$$

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,

$$r_t = i_t - \pi_t = r_t' - \left(\pi_t - E_{t-1}\pi_t\right) = r_t' - \varepsilon_t \tag{2}$$

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

π_t = the actual rate of inflation

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

A critical assumption underlying this model is rational expectations, which implies that the forecast error of inflation, ε_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 the following:

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

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 $t-1$.

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:

$$f_t - s_t = i_t - i_t^* \tag{5}$$

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

$$\mathrm{E}_{t-1}\left[(\pi_t - \pi_t^* - \left(s_t - s_{t-1}\right)\right] = 0 \tag{6}$$

and the speculative efficiency condition follows from the above

$$f_t = E_{t-1}s_t \quad (7)$$

Combining these three equations gives the UIP condition:

$$\mathrm{E}_{t-1}\left[\mathrm{i}_t - \mathrm{i}_t^* - (\mathrm{s}_t - \mathrm{s}_{t-1})\right] = 0 \quad (8)$$

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

$$E_{t-1}\left(r_t - r_t^*\right) = 0 = r_t' - r_t'^* \quad (9)$$

2.2 The Johansen Test

The Johansen (1988) VAR and Johansen and Juselius (1990) model is used to test for the presence of cointegration in both bivariate and multivariate cases. These cointegrative models are the basis of our tests for RIP among the G7. The following VAR model for RIP is applied to the data:

$$\Delta r_t = \mu + \sum_{i=1}^{p-1} \Gamma_i \, \Delta r_{t-1} + \gamma \, r_{t-p} + e_t \quad (10)$$

Where r_t is a *(n*1)* column vector of *p* real interest rates, μ is a *(n*1)* vector of constant terms, Γ is a coefficient matrix, 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 maximum eigenvalue statistic defined in the following:

$$\lambda_{max} = - T \ln (1 - \lambda r{+}1) \quad (11)$$

where $\lambda\, r+1, \ldots \lambda n$ are the *n-r* smallest squared canonical correlations among the G7 rates of interest and *T*= the number of observations. The second test is based on the trace statistic under which the null hypothesis of *r* cointegrating vectors against the alternative of *r* or more cointegrating vectors. This statistic is given in expression (12).

$$\lambda_{trace} = -T \Sigma \ln (1 - \lambda i) \tag{12}$$

$\lambda_{trace} = -T \Sigma \ln (1 - \lambda i)$. The cointegrating vectors indicate the long term relationships present in the system. Perfect cointegration requires n-1 cointegrating vectors for n variables and a unit slope coefficient in the relationship between all pairs of real rates. In this study, perfect cointegration implies that six cointegrating vectors apply to the cointegration among G7 real rates.

2.3 Testing for Structural Breaks

An important characteristic associated with this paper is to analyse the impacts of some major shocks to international markets which may well have affected the strength of the long-term relationship between the individual G7 capital markets. There have been several shocks to the international financial system over the reference period 1970 to 2003. The events which are generally agreed to be as important as any others are the two oil price shocks. The first occurring in 1973 and 1974, and the second between 1978 and 1980. The Asian crisis spanning the period mid 1997 to the end of 1998 and the September 11th holocaust occurring in the US. Our examination of the recursive estimates of the cointegrating vector will involve tests for any breaking effect flowing from these major disturbances.

This study of tests for the presence of shock impacts is different from recent analyses of shocks because in this case the timing of such shocks is known or predetermined. In recent times, the research emphasis of many time series analyses has shifted to a study of the occurrence of break points which are not pre-determined. However, in this study we identify the major shocks to the financial system and seek to answer the question: do these disturbances break the cointegrating vector given by expression (10). Did the two oil price shocks, the Asian crisis and September 11th cause a significant break in the cointegrating relationships between equivalent G7 real interest rates?

These questions about structural breaks are addressed initially by applying the more modern procedures outlined by Hansen and Johansen (1999) based on a recursive approach to estimation. This procedure is discussed by Hansen and Juselius (2002) in the CATS for RATS software package. The procedure allows for a graphical evaluation from the eigenvalues of the recursive estimation of the model (10). Recursive estimation involves the successive estimation of parameters based on the observation $r_{-K+1,}......r_t$ for $t = T_0,.....T$. The estimates of the trace and eigenvalue statistics driven out by recursive estimation are then saved and plotted. The plots permit us to evaluate the recursively estimated trace statistics, and the 95% confidence bounds for the non-zero eigenvalues. Hansen and Johansen (1999) regard this as a misspecification test which identifies instability in the parameters when there is no previous knowledge of the break.

It is useful from the reader's perspective to indicate some general outcomes of the study upfront. The distributional and stationarity properties of the data set are examined first and following this analysis the cointegration results reveal perfect cointegration in the system. The eigenvalue statistics indicate that bivariate cointegration holds in all of the bivariate models while the trace statistics indicate bivariate cointegration in twenty of the twenty-one bivariate comparisons. There is evidence of six cointegrating vectors in the multivariate version of the study. The sample sub-period tests indicate that the number of cointegrating vectors changes across the sub-periods. So on balance, there is some evidence here of RIP holding. Further, the major historical episodic shocks do seem to disturb the long run relationship contributing to instability in selected sub-periods and finally, the two oil price shocks, the Asian crisis, the policy response to the 1990 recession and September 11 all break the cointegrating relationship with varying degrees of intensity.

3. Properties of the Data Set

The data used are three-month Treasury bill rates 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 2003.12. 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	6.03	3.01	4.92	8.14	7.61	7.22	9.96
Skewness	0.97	-0.20	0.73	0.33	-0.13	0.75	0.02
Kurtosis-3	1.49	-1.26	0.14	-0.89	10.59	0.40	-0.89
BJ Statistic	101.71	29.7	36.5	20.87	1907.7	40.97	13.79

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 the means 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 in each case. For France the kurtosis statistic is 10.59 suggesting excess kurtosis beyond that of a normal distribution. The last line reports the Bera-Jarque (BJ) test for normality. This is calculated as follows:

$BJ = n\left[\frac{s^2}{6}+\frac{(k-3)^2}{24}\right]$ 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 root tests. The results suggest that all interest rate series are non stationary except the UK series which appears to be I(0) under the Phillip-Perron (1987) test and I(0) at the 5% level under the ADF and KPSS test. Cointegration tests are carried out on all seven series. All data appear to be I(0) in first differences.

Table 2: Unit Root Tests

Variable	**ADF**	**PP**	**KPSS**	**ADF**	**PP**	**KPSS**
		Levels			First Differences	
Interest Rates:						
U.S.	-2.18	-1.78	0.793***	-19.37***	-8.09***	0.08
U.K.	-3.10**	-4.01***	0.711**	-23.58***	-22.29***	0.09
Canada	-1.86	-1.90	0.676**	-20.51***	-15.77***	0.08
Japan	-2.80*	-2.69*	1.82***	-26.82***	-23.47***	0.44*
France	-2.66*	-1.19	1.09***	-42.90***	-17.12***	0.12
Italy	-1.59	-1.71	0.865***	-22.10***	-9.93***	0.25
Germany	-2.30	-2.37	0.398*	-22.52***	-17.50***	0.07

Note:
Significance levels for the ADF and Phillip-Perron test without trend are: 10%, -2.58: 5%, -2.90 and 1%, -3.51
Significance levels for the KPSS test are: 10%, 0.347: 5% 0.463: 1%, 0.739 (null hypothesis: the series is stationary)
*, **, *** significant at the 10%, 5% and 1% levels respectively.

4. Results

4.1 Cointegration Tests for the Full Sample (1970:1 – 2003:12)

Cointegration tests are conducted by applying the standard trace and eigenvalue measures proposed by Johansen (1988) and Johansen and Juselius (1990). Panels A and B of Table 3 present cointegration tests for the bivariate and multivariate models respectively. The trace statistics presented in Table 3 (A) indicate 20 cointegrating vectors for the 21 bivariate models while the eigenvalue statistics indicate 21 cointegrating vectors for the 21 bivariate models. The multivariate tests in Panel B of Table 3 indicate six cointegrating vectors in the system of seven variables.

Table 3: Johansen Maximum Likelihood Cointegration Test

	Null	Alternative			95% critical value	
A.			**mλ**	**Trace**	**mλ**	**Trace**
			US-CANADA			
	r = 0	r = 1	24.81	28.35	15.87	20.18
	r< = 1	r = 2	3.54	3.54	9.16	9.16
			US- JAPAN			
	r = 0	r = 1	37. 13	41.60	15.87	20.18
	r< = 1	r = 2	4.47	4.47	9.16	9.16
			US-UK			
	r = 0	r = 1	27.68	31.35	15.87	20.18
	r< = 1	r = 2	3.67	3.67	9.16	9.16
			US-GERMANY			
	r = 0	r = 1	19.42	24.37	15.87	20.18
	r< = 1	r = 2	4.95	4.95	9.16	9.16
			US-FRANCE			
	r = 0	r = 1	162.30	167.04	15.87	20.18
	r< = 1	r = 2	4.73	4.73	9.16	9.16
			US-ITALY			
	r = 0	r = 1	17.11	19.58	15.87	20.18
	r< = 1	r = 2	2.46	2.46	9.16	9.16
			CANADA-JAPAN			
	r = 0	r = 1	38.91	42.48	15.87	20.18
	r< = 1	r = 2	3.57	3.56	9.16	9.16
			CANADA-UK			
	r = 0	r = 1	43.92	46.76	15.87	20.18
	r< = 1	r = 2	2.84	2.84	9.16	9.16

Null	Alternative	mλ	Trace	95% critical value mλ	Trace
		CANADA-GERMANY			
r = 0	r = 1	22.48	22.60	15.87	20.18
r< = 1	r = 2	4.12	4.12	9.16	9.16
		CANADA-FRANCE			
r = 0	r = 1	181.44	185.46	15.87	20.18
r< = 1	r = 2	4.01	4.01	9.16	9.16
		CANADA-ITALY			
r = 0	r = 1	22.76	25.14	15.87	20.18
r< = 1	r = 2	2.38	2.38	9.16	9.16
		JAPAN-UK			
r = 0	r = 1	35.69	45.16	15.87	20.18
r< = 1	r = 2	9.47	9.47	9.16	9.16
		JAPAN-GERMANY			
r = 0	r = 1	39.18	44.67	15.87	20.18
r< = 1	r = 2	5.48	5.48	9.16	9.16
		JAPAN- FRANCE			
r = 0	r = 1	174.55	197.14	15.87	20.18
r< = 1	r = 2	22.58	22.58	9.16	9.16
		JAPAN-ITALY			
r = 0	r = 1	46.59	49.24	15.87	20.18
r< = 1	r = 2	2.64	2.64	9.16	9.16
		UK-GERMANY			
r = 0	r = 1	23.87	29.18	15.87	20.18
r< = 1	r = 2	5.31	5.31	9.16	9.16
		UK-FRANCE			
r = 0	r = 1	159.94	168.92	15.87	20.18
r< = 1	r = 2	8.98	8.98	9.16	9.16
		UK-ITALY			
r = 0	r = 1	25.07	27.56	15.87	20.18
r< = 1	r = 2	2.48	2.48	9.16	9.16
		GERMANY-FRANCE			
r = 0	r = 1	187.26	192.59	15.87	20.18
r< = 1	r = 2	5.33	5.33	9.16	9.16
		GERMANY -ITALY			
r = 0	r = 1	15.87	18.76	15.87	20.18
r< = 1	r = 2	2.89	2.89	9.16	9.16
		FRANCE-ITALY			
r = 0	r = 1	228.68	231.33	15.87	20.18
r< = 1	r = 2	2.65	2.65	9.16	9.16

	Null	Alternative			95% critical value	
			mλ	Trace	mλ	Trace
B.			*ALL*			
	r = 0	r = 1	324.36	499.02	46.47	132.45
	r< = 1	r = 2	55.64	174.65	40.53	102.56
	r< = 2	r = 3	46.56	119.00	34.40	75.98
	r< = 3	r = 4	28.85	72.44	28.27	53.48
	r< = 4	r = 5	23.09	43.59	22.04	34.87
	r< = 5	r = 6	18.21	20.49	15.87	20.18
	r< = 6	r = 7	2.28	2.28	9.16	9.16

These results from the full sample estimation of the cointegrating relationship (10) are suggestive providing a case for the existence of real interest rate parity. Now this is a strong and potentially controversial finding which may be criticised on the grounds that global financial markets have changed in character over the 34 year time period and that an examination confined to the full sample will leave out changes in these characteristics and in particular the extent of cointegration which according to many preceding analyses has increased through time. An increase in the degree of cointegration will not be evident if this study is confined to the full sample period. Sub period estimation is more appropriate for this purpose. To this end, we break the full sample down into sub samples: sub period (SP) I: 1970:1 –1980:12, SP 2: 1980:1 – 1990:12, SP 3: 1990:1 – 2003:12. Here we do not repeat the bivariate analyses in each sub-period. In our opinion there is sufficient evidence from the multivariate case on which to base our economic interpretation.

A further advantage is that the effects of well known shocks on the strength of cointegration are more likely to be properly identified in sub-period estimation because particular international events occur in these sub-periods. The two oil price shocks (1973 –75 and 1978 – 80) occur in SP(I), the boom and crash into recession is the prominent feature of SP(2) while the Asian crisis (1997-98) and September 11, 2001 are the most important events occurring in SP(3).

Cointegration Results for Sub-samples

The results of tests for multivariate cointegration in each of the three nominated sub-periods are recorded on Table 4[1].

Table 4: Johansen Maximum Likelihood Cointegration Test: sub samples

Null	Alternative	mλ	Trace	95% critical value mλ	95% critical value Trace
I 1970:1-1980:12					
r = 0	r = 1	55.26	152.23	46.47	132.45
r< = 1	r = 2	34.82	96.97	40.53	102.56
r< = 2	r = 3	27.83	62.14	34.40	75.98
r< = 3	r = 4	19.70	34.32	28.27	53.48
r< = 4	r = 5	9.03	14.62	22.04	34.87
r< = 5	r = 6	5.51	5.59	15.87	20.18
r< = 6	r = 7	0.08	0.08	9.16	9.16
II 1981:1-1990:12					
r = 0	r = 1	170.58	314.62	46.47	132.45
r< = 1	r = 2	54.44	144.04	40.53	102.56
r< = 2	r = 3	40.92	89.60	34.40	75.98
r< = 3	r = 4	23.78	48.68	28.27	53.48
r< = 4	r = 5	16.36	24.90	22.04	34.87
r< = 5	r = 6	6.10	8.54	15.87	20.18
r< = 6	r = 7	2.44	2.44	9.16	9.16
III 1991:12-2003:12					
r = 0	r = 1	75.69	198.81	46.47	132.45
r< = 1	r = 2	64.61	123.12	40.53	102.56
r< = 2	r = 3	25.05	58.51	34.40	75.98
r< = 3	r = 4	15.48	33.45	28.27	53.48
r< = 4	r = 5	9.92	17.98	22.04	34.87
r< = 5	r = 6	7.22	8.06	15.87	20.18
r< = 6	r = 7	0.83	0.83	9.16	9.16

The results for the sub-periods differ from those of the full system. The results for the 1970:1-1980:12 sample indicates one cointegrating vector, the 1981:1-1990:12 sample three cointegrating vectors and the 1991:1-2003:12 sample two cointegrating vectors. Two observations are made about sub-period estimation in comparison with the full sample results. First, the extent of cointegration in each of the sub-periods is less in comparison with full sample estimation where 6 cointegrating vectors are identified the number of

[1] Bivariate cointegration is discarded for SP estimation because bivariate analyses for each sub-period add little if any further information but involves a substantial amount of extra analysis. There are 63 individual bivariate analyses involved.

cointegrating vectors evident in SP(1), SP(2) and SP(3) are 1, 3 and 2 respectively. This may be due to the smaller sample size applying to sub-periods in comparison with the full sample. Alternatively, the impact of well known shocks such as the two oil price crises, volatile phases of international business cycles and the monetary response to these, the Asian crisis and September 11 may weaken the interdependence of the G7 capital markets. To test this proposition, we are drawn to study the impacts of these shocks on G7 interest rate cointegration. Do these shocks cause breaks in the G7 interest rate cointegrating vectors?

4.2 Breaks in the Cointegrating Relationship

Breaks may be observed in the cointegrating vector by first examining the time path of the trace statistic from the recursive estimation of the cointegrating relationship described in Section 3. The procedure for conducting this graphical analysis are detailed in the CATS in RATS program cited above. Alternatively, shifts in the parameters of the cointegrating relationship between G7 real rates of interest may be detected by analysing the time path of the normalized eigenvalues from the recursive estimation of the cointegrating relationships within their 95% confidence limits. Finally, a formal test of the parameter constancy is provided to confirm the graphical analysis.

4.2.1 Change in the Rank Statistic Over Time

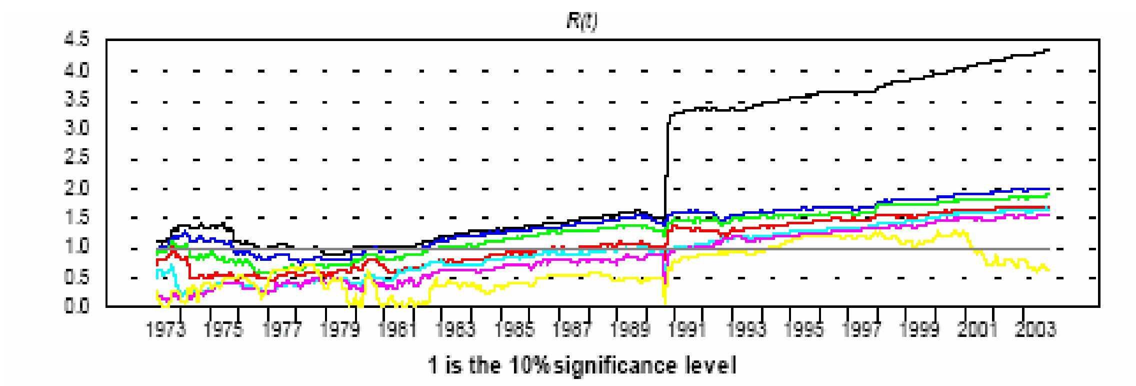
Recursive estimation, as discussed above enables the researcher to graph monthly values of the Trace test statistic for the full sample (1970:1 – 2003:12) and for each of the three sub-samples: 1970:1-1980:12; 1981:1 – 1990:12; 1991 – 2003:12. The trace statistic defined in expression (12) should display an upward slope for $j \leq r$ and is constant for $j > r$. If a significant downswing is apparent then the indication is that some change in the cointegrating relationship has occurred.

Figures 1 shows the time path of the Trace, while Figures 2-4 contain graphs of the Trace for the sub-periods.

I Trace Statistic Time path full sample: 1970:1 –2003:12

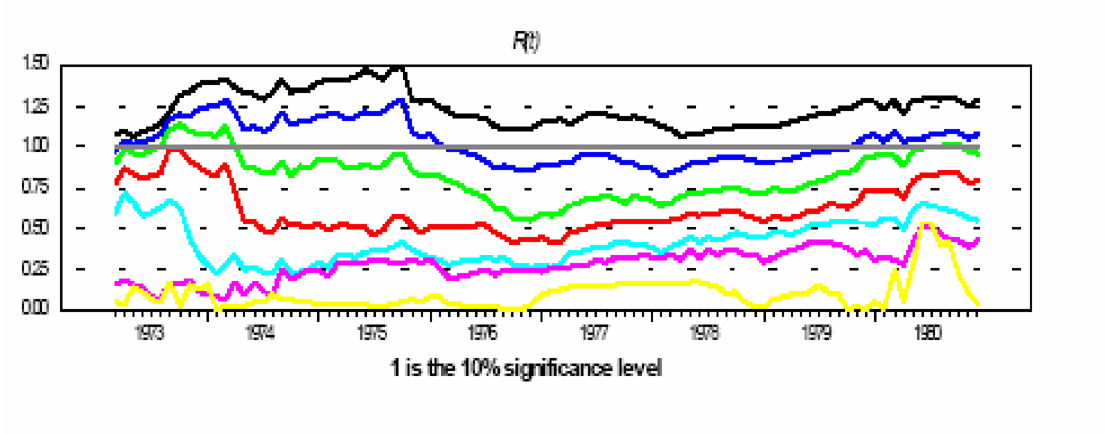
The 10 percent significance level for the Trace statistic is always positioned at 1.00 on the vertical axis of Figures 1 to 4. The number of cointegrating vectors in each case is indicated by the number of lines above 1 as we reject the null of no cointegration above the line. There are six cointegrating vectors evident on Figure 1. However, the focus at this point is on the presence of any structural breaks in the value of the Trace and therefore in the cointegrating vector. The outstanding feature of Figure 1 is the apparent break in the cointegrating vector in mid 1990. There is evidence also of a declining phase in the value of the Trace about the time of the first oil crisis in 1973. Figure 1 provides weaker evidence of potential breaks around September 11 and the Asian crisis. The evidence about the effects of these shocks may be clearer from sub-period estimation.

Figure 1: Trace Statistic Time Path 1970:1 – 2003:12



II Trace Statistic Time path 1970:1 –1980:12

Figure 2: Trace Statistic Time Path 1970:1 –1980:12

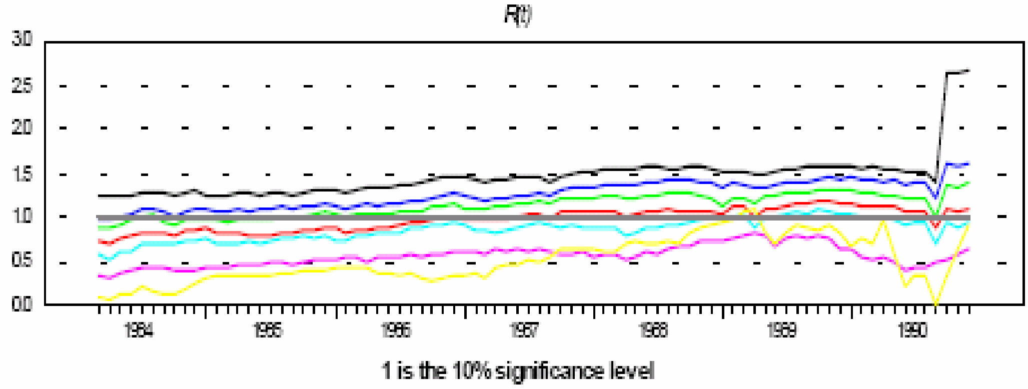


The first sub-period spans the 1970s decade in which there is only 1 cointegrating vector. However, the more important issue concerns potential breakpoints in this era based on substantial downswings in the time path of the Trace statistic. Applying this criteria to Figure 2 there is clearly a major disturbance in the period late 1973 and early 1974 about the time of the occurrence of the first oil price shock. There is also a disturbance apparent in late 1979 and 1978 and 1980 coinciding in time with the second oil price shock.

III Trace Statistic Time path 1981:1 – 1990:12

The time path of the Trace statistic from recursive estimation in this sub period confirms the findings of the multivariate cointegrating vectors tests in the sense that there are 3 cointegrating vectors above the 10 percent significance line on Figure 3. The major finding about the 1980s are apparently a comparatively smooth period from Figure 3. There are no evident sharp declines in the period 1981 to 1989 until 1990, when there is an evident downswing in the time path of the Trace. The 1990 recession was one in which the G7 countries were confronted with very high interest rates. The G7 monetary authorities reacted to the recession by easing liquidity, thereby reducing domestic interest rates and possibly dislocating established linkages between these series given that interest rate reductions occurred at non uniform rates in different G7 countries.

Figure 3: Trace Statistic Time Path 1980:1 – 1990:12

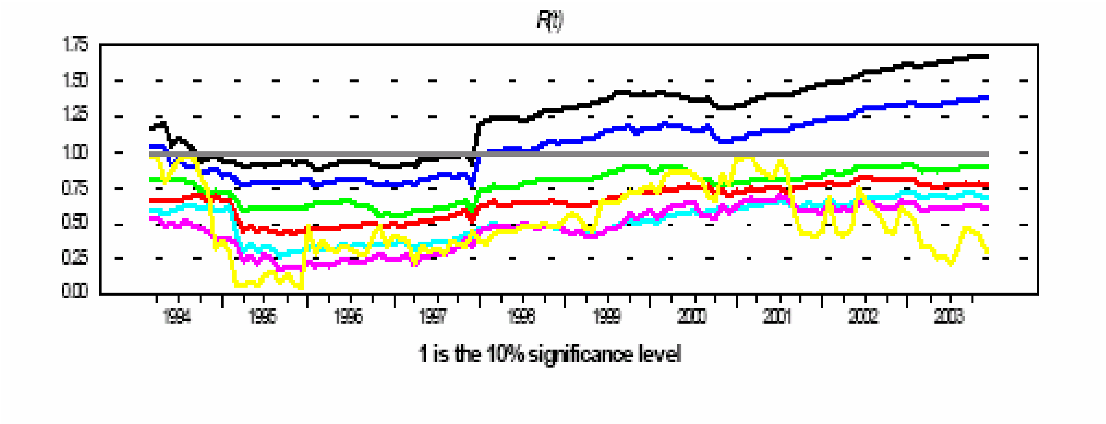


Finally Figure 4 shows the time paths of the rank statistic over 1991:1 – 2003:12. Again, the number of cointegrating vectors (those time paths above the 10 percent significance line on Figure 4) is two. This confirms the formal cointegration analysis in Table 4 for this period.

IV Trace Statistic Time path 1991:1 – 2003:12

The central issue here is the effects of shocks known to have occurred in the 1990s and 2000 on the integration of G7 capital markets. A substantial disturbance is evident from 1997 to 1998 coinciding with the occurrence of the Asian financial crisis which took toll of growth rates and financial stability among the G7. The Asian crisis is a prime suspect in explaining the instability evident in these years. There is some evidence of instability in the relationship between G7 financial markets around September 11 although the evidence is less conclusive in comparison with the Asian crisis.

Figure 4: Trace Statistic Time Path 1990:1 – 2003:12



4.3.2 Maximum Eigenvalues and Parameter Constancy

This analysis of parameter constancy based on the graphical evaluation of the time path of the trace statistic can be confirmed from a similar evaluation based on the time-path of the estimated eigenvalues from the cointegration equation (10). The use of these estimated eigenvalues for the purpose of evaluating parameter constancy or otherwise is based on the results derived by Hansen and Johansen (1999). These authors establish a direct relationship between the eigenvalues and the adjustment of the coefficients in cointegration vectors. Specifically, they prove that the time path of the estimated eigenvalues, λ_i represent changes in the i^{th} column of the constant and slope coefficient vectors. In this analysis we have uncovered the presence of 7 non-zero eigenvalues in each of the three sub-periods requiring: a total of 21 individual graphs of the time-path of the eigenvalues if we are to examine the constancy of individual parameters. This is impractical in the space available here. However, a joint test for parameter constancy can be carried out by looking at the sample time path of $\sum_{i=1}^{7} \ln\left(\frac{\hat{\lambda}_i}{1-\hat{\lambda}_i}\right)$ which is enough for the purpose of evaluating the extent of parameter instability. This aggregate test is based on the following Figures 5-8 inclusive.

The time paths of the summed eigenvalues are graphed on Figures 5-8 for the sub-periods 1970:1 – 1980:12, 1981:1 – 1990:12, 1991:1 – 2003:12.

Time path of the joint eigenvalues

The time path of the summed eigenvalues for the full sample is shown on Figure 5, where it is clear that substantial volatility of the summed eigenvalues over the period 1970 to 1980 we have substantial falls in the value of the eigenvalues. This era is one in which the two oil price shocks occur and most of the G7 countries deregulated their foreign exchange markets. The period 1981 to 1989 is comparatively stable until 1990 when the interest rate exposure of the monetary authorities to the prospect of severe recession causes a sharp adjustment of the combined eigenvalues. Beyond 1991, a relatively stable situation applies to the eigenvalues and therefore parameters although there is really no evidence of regime shifts around the time of the Asian crisis (1979-1998) or of impacts flowing from the September 11 holocaust. Again, we leave an analysis of impacts from these shocks to the following sub-period estimation and for the reasons argued above.

Figure 5: 1970:1 –2003:12 - Constancy of Joint Eigenvalues $\sum_{i=1}^{7}\xi_i$

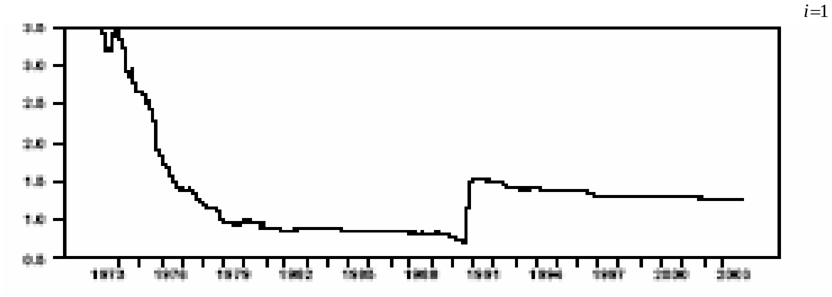


Figure 6: 1970:1 – 1980:12 - Constancy of Joint Eigenvalues $\sum_{i=1}^{7} \xi_i$

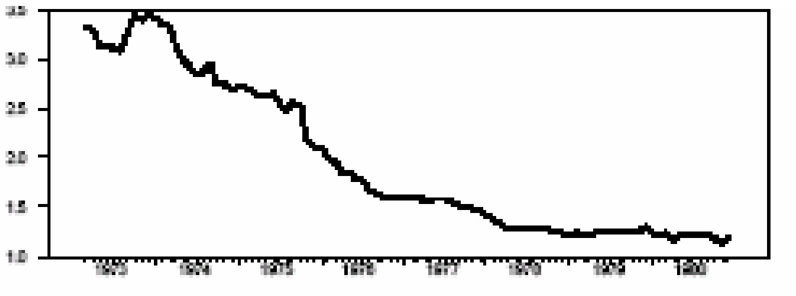


Figure 7: 1980:1-1990:12 - Constancy of Joint Eigenvalues $\sum_{i=1}^{7} \xi_i$

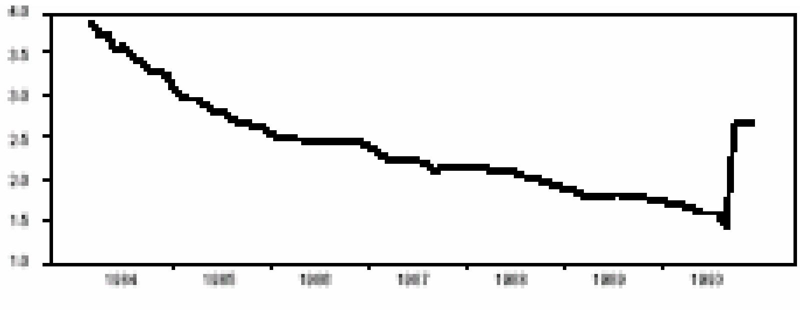
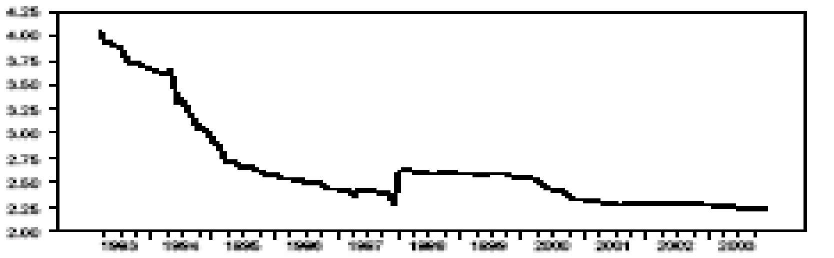


Figure 8: 1991:1 – 2003:12 - Constancy of Joint Eigenvalues $\sum_{i=1}^{7} \xi_i$



We see evidence on Figure 6 of turbulence in the parameters of the cointegrating vector of G7 rates around 1973 to 1975 at the time of the first oil price shock. Figure 7 is a relatively smooth period and we could accept an argument for the stability of the parameters of the cointegration vector of the G7 nations for the period 1983 to 1990, but there is evidence of a substantial shift in the cointegrating vectors of G7 rates in 1990, the years in which many nations including the G7 experienced the cold winds of severe recession. Finally, an outstanding feature of Figure 8 is an apparently unstable episode for the interdependence of

G7 interest rates in mid 1997 coinciding with the sudden occurrence of the Asian financial crisis. The change in behaviour of the moderate parameters before and after crisis is quite pronounced. This effect was not evident when we analysed the full sample.

This analysis of eigenvalues estimated from the G7 interest rate cointegrating vectors runs parallel in its arguments to our preceding study of the stability of the trace statistics which revealed turbulence also at the time of the two oil price shocks, the Asian crisis and the 1990 recession. If there is a difference between the trace and eigenvalue analyses of potential breaks in the cointegrating or of parameter constancy it concerns the impacts of the September 11th. There is no discernible shift in the summed eigenvalues on September 11, 2001 (Figure 8) although there is some limited evidence of turbulence of the trace statistic at this time (Figure 4). An explanation of the different effects of the Asian crisis and of September 11 on the interdependence of the G7 capital markets is provided in the concluding section.

4.3.3 Formal Tests of Parameter Constancy

To test formally for parameter constancy we use Hansen's (1992a,b) heteroskedasticity-robust version of the Nyblom (1989) test. This is an LM test for parameter constancy adjusted for hetroscedasticity. The null hypothesis of constant parameters is tested against the alternative of that the parameters are non-constant.

Hansen’s stability test is in essence the average of the squared cumulative sums of the first order conditions for a maximum of the likelihood function of the cointegrating equation (10). The null hypothesis in this test is that the parameters taken collectively are constant and the first order conditions of the likelihood function are mean zero and the cumulative sum of parameters will oscillate around zero. If, however, the parameters collectively are unstable then the cumulative sums have non zero means at points in the sample and consequently the test statistic (L_c) assumes large values leading to the rejection of the null hypothesis (parameter stability). The asymptotic critical values for Hansen's stability test is non standard in the way described by him while the critical values are contained in Hansen (1992 Table I, p.524). The asymptotic distribution theory required to support Hansen's calculations are attributed to Nyblom (1989) and Hansen (1990a,b).

Table 5:Tests of Parameter Constancy*

Period	Test Statistic	Calculated	P Value
1970:0-2003:12	L_c	12.18	0.00
1970:1-1980:12	L_c	3.74	0.00
1981:1-1990:12	L_c	4.57	0.00
1991:1-2003:12	L_c	10.06	0.00

***** Critical values are given in Hansen (1991, Table I) where for 1 degree of freedom at the 5% level, the critical value is 0.470 in each sub-period. The calculated test statistic exceeds its critical value of 0.407.

4.3.4 Chow Break point Test

The inferences drawn from Table 5 clearly indicate parameter instability in the full sample and in each of the three sub-samples. However, we have not discovered if the instability apparent in particular time periods coincide with the occurrence of the two oil price shocks in the seventies (sub-period I); the impact of impending recession in 1990 (sub-period 2); the Asian crisis of 1997 and the effects of September 11, 2001 (sub-period 3). The two stand out episodes in our full sample estimation were the first oil price shock in 1973-74 and strong turbulence around 1989-90. In our first sub-sample (1970:1 – 1980:12), the two prominent unstable episodes are the two oil price shocks (1973-74) and (1978-80), while in our second sub-period (1981:1-1990:12) the effects of boom and bust in 1989-90 on the integration of short term (3 month treasury bill rates) G7 capital markets is another period of great instability. Finally, the turbulence of parameters as indicated by eigenvalue and trace plots in the third sub-period (1991:1 – 2003:12) is greatest around the time of the Asian crisis with some less emphatic evidence about the impact of September 11. The fact that the parameters of (10) are unstable in both full and sub-period estimation is established from Table 5. However, we cannot be sure that such breaks occur at the time of the two oil price shocks, the 1989-90 recession, the Asian crisis or September 11.

To fill this gap, we are able to call into service an established technique – the Chow (1960) test to determine if our cointegrating vectors break at these points. A simple Chow break point test is available on this occasion because the date of each break point is known in advance from inspection of the trace and eigenvalue graphs. We relate the structure of the Chow test to the graphical analysis in the way outlined on Table 6.

Table 6: Chow Tests for Structural Breaks

Data Source	Potential Break Point	Estimation Periods in Chow Test	Calculated F-Statistic	P Value
1970:0 – 2003:12 Full Sample	1973, 1990	1970:1 – 1973:1 1973:2 – 1990:6 1990:7 – 2003:12	26.08	0.00
1970:1 – 1980:12 SP 1	1973 – 1974 1978 – 1980	1970:1-1973:12 1974:1 – 1978:12 1979:1 – 1980:12	3,87	0.00
1981:1 – 1990:12 SP 2	1989 – 1990	1981:1 – 1998:12 1989:1 – 1990:12	4.68	0.00
1991:1 – 2003:12 SP 3	1997, 2001	1991:1 – 1997:6 1997:7 – 1999:12 2001:1 – 2003:12	41.79	0.00

The Chow test from the reduced samples shown in column 3 of Table 6. For example the cointegrating equation is estimated for the sub-periods 1970:1 – 1973:1 and again in 1973:2 – 1990:6 to determine if the first oil price shock is associated with a break in the cointegrating equation in early 1973 (shown as 1973 I the first row of the second column of table 7) A test for a chow type break for the Asian crisis in 1997 is indicated by SP 3 where the cointegrating equation (10) is estimated for the periods 1991:1 to 1997:6 and from 1997:7 to

1999:12 accommodating a potential break in the cointegrating equation in July 1997. The F-statistic shown in column 4 of Table 6 is a joint test of the hypothesis that breaks do now occur at the times indicated. It is clear that all five breaks, namely the two oil price shocks, the recession of 1989-90, the Asian financial crisis and the September 11 holocaust have broken the cointegrating vectors linking G7 and real treasury bill rates.

5. Conclusions

When we test real interest parity among the G7 Treasury bill rates over the long run 1970:1 to 2003:12 we find up to six cointegrating vectors linking them. Likewise when we conduct bivariate tests for cointegration we find that in 20 of the 21 bivariate comparisons bivariate cointegration holds. This is evidence supporting the argument that the G7 treasury bill markets are perfectly cointegrated and that there is some evidence here of perfect capital market integration.

This conclusion is challenged when we conduct sub-period estimation splitting the full sample into 3 sub-samples: 1970:1-1980:12; 1981:1-1990:12; 1991:1-2003:12. Then this ideal picture changes: we can find evidence of only 1 cointegrating vector in the first sub-period, 3 in the second and two in the third. Although the extent of cointegration of the G7 capital markets increases between the 1970s and 1980s it appears to reduce once more in the 1990s and the early years of the new millennium.

This explanation for these divergent results maybe found in the occurrence of known shocks which from our analysis appear to have broken the cointegrating vector of G7 treasury bill real rates at these times. A graphical analysis of the trace statistics and eigenvalues of the cointegration suggest that the first oil crisis and the 1989/90 recession are periods of greatest instability in full sample estimation. In sub-period I it is the two oil price shocks which are evident on our trace and eigenvalue graphs as periods of prominent disturbance in the cointegrating vectors of G7 real treasury bill rates, while in sub-period 2 it is the 1989-90 period in which most stability is evident. Finally, in sub-period 3, instability can be observed at the time of the Asian crisis and again on September 11, 2001, although the evidence for a break occurring at this time is much less convincing.

These less formal graphical analyses of parameter inconstancy are supported by Hansen's stability test which suggests that the parameters of the cointegration are not consistent in the full sample or in any of the sub-periods. Finally, a simple Chow test was applied to determine if the major shocks to the global financial system caused the cointegrating relationships governing the link between G7 three month Treasury bill rates to break. The Chow test indicates that breaks are evident at the time of the two oil price shocks, the recession of 1989-90, the Asian crisis and September 11, 2001.

The central finding of this analysis is that five well known shocks appear to produce parameter inconsistency and therefore parameter instability among G7 Treasury bill rates of interest. A differing monetary policy response to impending recession in 1990 may explain why there is such a pronounced break in the trace statistic and eigenvalue relating to the cointegrating vector for G7 real rates at this time. The policy response to impending recession may have differed among the G7 countries authorities to the point where individual country interest rate reductions took place at differing rates: home rates were adjusted more slowly than others potentially untying links between the individual G7 treasury bill rates. The lesson to be learnt from this experience is that sudden changes in the intervention of the monetary authorities in individual countries impacts directly on the domestic rate structure thereby affecting the degree of international interdependence of these domestic rates.

It is not surprising for breaks to occur at the time of the Asian crisis 1997-98. There were direct effects on domestic rate structures among the G7 and these might have impaired any linkage around countries. The two oil price shocks created a current account imbalance for some of the G7 counties ultimately causing their authorities to make adjustments to domestic rates which may again disturb the relationship between them. The September 11 holocaust has a significant impact although this is not as strong as the other direct effects on interest rates. An interesting reflection upon the smaller effect of September 11 holocaust and purely monetary phenomenon such as the Asian crisis is that the source of shocks may be of importance in determining their relative impact. Shocks occurring in the financial markets may impact more strongly than shocks such as September 11 which are not internal to the markets. This is an issue warranting further research.

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