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International Linkages in Short- and Long-Term Interest Rates

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Abstract: This paper examines interest rate linkages in the G7 economies by testing for cointegration and employing the causality testing method for unstable systems recently introduced by Toda and Yamamoto (1995), which results in standard asymptotics. The results show that whilst domestic macroeconomic variables are important determinants of long-term interest rates, international linkages play a major role in the case of short-term rates. We also find that causation within the ERM runs from France to Germany, which suggests that, in order to function smoothly, a system such as the ERM requires its largest player to accommodate policy variation elsewhere, rather than impose its own monetary stance as in the 'German Leadership Hypothesis' (GLH). The main results are confirmed by the stability analysis.

Keywords: Causality Testing, Cointegrated VARs, Interest Rate Linkages, ERM, German Leadership Hypothesis (GLH)

JEL Classification: C32, C52, F3

Introduction

Understanding the linkages between interest rates across countries is essential to the proper interpretation of economic episodes and to the design of macroeconomic

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policy. Indeed, as the members of the European Union (EU) move toward the establishment of the euro as their common currency, the question of how interest rates behave is central to understanding and predicting the range of potential scenarios which might evolve.

It is often convenient to view interest rates as analogous to other assets prices and to consider interest rate movements as being determined by financial flows in fluid, profit-seeking capital markets. Within this type of framework one would expect *a priori* that interest rates would exhibit a high degree of comovement and have common stochastic trends which may allow prediction. Caporale and Pittis (1998) discuss the relationship between cointegration and predictability of asset prices, and show that in n-dimensional systems the two are not synonymous - in the presence of *r* cointegrating vectors, only *r* asset prices are predictable, and the exogeneity tests introduced by Johansen (1992) can be used to establish which ones can be predicted. However, despite the increasing integration of international financial markets, domestic factors can still be important in the determination of interest rates, especially in the case of long-term rates, for which there is some evidence that they are driven by fundamentals (see Caporale and Williams, 1998). Caporale and Pittis (1997) present a theoretical framework which allows for both domestic and external factors. They show that domestic monetary conditions affect even short-term rates if capital controls are imposed, or if the risk premium is a function of disequilibria in the money market. Their empirical results confirm that domestic macroeconomic developments affect interest rates even with a high degree of capital mobility.

Interest rate linkages have often been analysed in the context of the ERM, as a test of the German Leadership Hypothesis (GLH), according to which Germany is the 'dominant' player of the system, so that monetary authorities in other ERM countries cannot deviate from the course set by the Bundesbank, as in the 'strict' version of the GLH, or only temporarily, as in the 'weak' version'. In fact Giovannini (1998) argues that fixed exchange rate systems are inherently asymmetric, with a centre country setting a nominal anchor, such as the nominal interest rate. The empirical evidence is mixed. Some studies appear to be consistent with the 'strict' GLH (see, e.g., Giavazzi and Giovannini (1987), Karfakis and Moschos (1990)), or with its 'weak' version (see, e.g., Fratianni and von Hagen (1990)), whilst others conclude that the evidence does not support the GLH (see, e.g., Katsimbris and Miller (1993)). In many cases tests are implemented using interest differentials, which it is argued, should be stationary, as a result of the convergence which the system is intended to produce. In fact, as shown in Caporale and Pittis (1995) and Caporale et al (1996), standard parity conditions imply pairwise cointegration of interest rates only once convergence has been achieved, not during the transition process, when interest rate differentials should be expected to be non-stationary instead. Their empirical analysis indicates that in the short run there are some degrees of freedom for monetary authorities of ERM countries other than Germany.

This study revisits the issue of interest rate leadership by employing the method recently developed by Toda and Yamamoto (1995) to test for causality in unstable, possibly cointegrated systems. Caporale and Pittis (1999) discuss extensively the advantages of using such techniques, and apply them to examine linkages in short-term interest rates between Germany, the US and the Netherlands. We extend their analysis by considering linkages in both short- and long-term interest rates between the major EU countries and the rest of the G7 over the last two decades to see whether there is long-run comovement and causality. In addition, we consider two subsamples in order to identify any changes over time in the causality structure. Our results provide evidence that interest rate comovement is not always consistent with conventional priors. However, by reflecting on the nature of the policy regimes in which interest rates are determined and on the interpretation of the econometric methods used, we argue that the results we arrive at are both intuitive and appealing. In particular, the finding that causality runs from French to German rates can be interpreted as a consequence of the fact that France used interest rates as a policy instrument to target inflation, whilst Germany, being the centre country of the system and being responsible for its smooth functioning, had to accommodate policy developments elsewhere in order to achieve this objective.

Econometric Methodology

This section discusses briefly how to interpret cointegration tests between interest rates, and then describes the methodology followed below to test for casuality links.

Cointegration and Predictability

A common view is that, in a highly integrated world characterised by efficient financial markets and perfect capital mobility, interest rates are essentially determined by international parity conditions, (see, e.g., Gaab et al (1986)), although one should also allow for political or risk premia (see, e.g., Frankel and MacArthur (1987)), and that international linkages result in asset prices being cointegrated (see, e.g., Hakkio and Rush (1989)). However, as demonstrated by Caporale and Pittis (1998), if n asset markets are being considered, and r cointegrating relationships are found, this means that only r asset prices are predictable on the basis of their links with other prices. The exogeneity tests introduced by Johansen (1992) can be used to detect which particular prices are predictable. In the case of long-term interest rates, it is natural to think that economic fundamentals, as well as international financial flows, should play a role, which is confirmed by some empirical studies, for instance Caporale and Williams (1998). Domestic monetary disequilibria are also shown to affect interest behaviour by Caporale and Pittis (1997). As discussed above, a related issue, often raised in the context of the ERM, is whether a fixed exchange rate system such as the ERM, with a 'dominant' country, should imply pairwise cointegration of interest rates with the German ones - this in fact holds only during the transitional phase when convergence is still occurring (see Caporale and Pittis (1995), and Caporale et al (1996)).

Testing for Causality in VARs [1]

The issue of causality testing in possibly unstable VARs where cointegration maybe present was initially examined by Sims, Stock and Watson (1990) in the context of a trivariate VAR, and by Toda and Phillips (1993) for systems of higher dimension. These studies show that, in general, Wald test statistics for noncausality in an unrestricted VAR will have nonstandard limit distributions in which nuisance parameters will be present, although Wald test will have a limit _ ^{2} distribution under certain conditions which depend on the presence and location of unit roots in the VAR. Unfortunately this information is often difficult to obtain from the estimation of a VAR in levels.

Toda and Phillips (1993) and Toda and Yamamoto (1995) have suggested two alternative approaches to causality testing, both of which enable the researcher to use standard asymptotic theory and therefore to obtain valid statistical inference. The first method, though, is sequential, and requires determining the cointegration rank in the first step, which means that the validity of subsequent steps is conditional on avoiding biases in the estimation of this rank. Monte Carlo experiments by Toda (1995) have shown that the tests for cointegration ranks in Johansen-type ECMs are very sensitive to the values of the nuisance parameters, and hence causality inference may suffer from severe pretesting biases. The advantage of the procedure developed by Toda and Yamamoto (1995) is that it does not require pretesting for the cointegration properties of the system.

The basic idea is to artificially augment the correct order, k, of the VAR by the maximal order of integration, say d_{max}, exhibited by the process of interest. One can then estimate $(k+d_{max})$th-order VAR and ignore the coefficients of the last d_{max} lagged vectors, and test linear or nonlinear restrictions on the first k coefficient matrices by means of a Wald test, using standard asymptotic theory.

Consider the following VAR, which allows for a linear trend:

$$Z_t = \Phi + \Phi t + \Pi_1 Z_{t-1} + ... + \Pi_k Z_{t-k} + E_t, \quad t = 1,..T \tag{1}$$

where $E_t \sim N(0,\Omega)$.

Economic hypotheses can be expressed as restrictions on the coefficients of the model as follows:

$$H_0 : f(\pi) = 0 \tag{2}$$

where $\pi = vec(P)$ is a vector of parameters from model (1), $P = [\Pi_1, ..., \Pi_k]$ and f(.) is a twice continuously differentiable m-vector valued function with $F(\phi) = \partial f(\phi) / \partial \phi'$ and rank (F(.))=m.

Assume that the maximum order of integration which is expected to characterise the process of interest is at most two, i.e. $d_{max} = 2$. Then, in order to test the hypothesis (2), one estimates the following VAR by OLS:

$$Z_t = \hat{\Phi}_0 + \hat{\Phi}_1 t + \hat{\Pi}_1 Z_{t-1} + ... + \hat{\Pi}_k Z_{t-k} + \hat{\Pi}_{k+1} Z_{t-k-1} ... + \hat{\Pi}_p Z_{t-p} + \hat{E}_t \tag{3}$$

where $p \geq k + d_{\max} = k + 2$, i.e. at least two more lags than the true lag length k are included. The parameter restriction (2) does not involve the additional matrices $\Pi_{k+1}, ..., \Pi_p$, since these consist of zeros under the assumption that the true lag length is k.

Equation (8) can be written in more compact notation as follows:

$$Z_t = \hat{\Phi}\tau_t + \hat{P} x_t + \hat{\psi} y_t + \hat{E}_t \tag{4}$$

where:

$$\hat{\Phi} = \left[\hat{\Phi}_0, \hat{\Phi}_1\right]$$
$$\tau_t = [1, t]$$
$$x_t = \left[Z'_{t-1}, ..., Z'_{t-k}\right]'$$
$$y_t = \left[Z'_{t-k-1}, ..., Z'_{t-p}\right]'$$
$$\hat{P} = \left[\hat{\Pi}_1, ..., \Pi_k\right]$$
$$\hat{\Psi} = \left[\hat{\Pi}_{k+1}, ..., \hat{\Pi}_p\right]$$

or, in the usual matrix notation

$$Z' = \hat{\Phi} T + \hat{P} X' + \hat{\Psi} Y' + \hat{E}' \tag{4b}$$

where $X = [x_1, \ldots, x_T]'$ and so on.

One can then construct the following Wald statistic W_2 to test the hypothesis (2):

$$W_2 = f(\hat{\phi})' \left[F(\hat{\phi})' \left\{ \Sigma_E \otimes (X'QX)^{-1} \right\} F(\hat{\phi})' \right]^{-1} f(\hat{\phi})' \quad (5)$$

Where $\hat{\Sigma}_E = T^{-1} \hat{E}'\hat{E}, Q = Q_\tau Y(Y'Q_\tau Y)^{-1} Y'Q_\tau$ and $Q_\tau = I_T - T(T'T)^{-1} T$.

Toda and Yamamoto's (1995) theorem 1 (pp. 234-235) proves that the Wald statistic (5) converges in distribution to a χ^2 random variable with m degrees of freedom, regardless of whether the process Z_t is stationary, I(1), I(2), possibly around a linear trend, or whether it is cointegrated.

This method also requires some pretesting in order to determine the lag length of the process. Sims et. al. (1990) showed that lag selection procedures, commonly employed for stationary VARs, which are based on testing this significance of lagged vectors by means of Wald (or LM or LR) tests, are also valid for VARs with I(1) processes which might exhibit cointegration. Toda and Yamamoto (1995) extended their analysis and proved that the asymptotic distribution of a Wald of Likelihood Ratio test for the hypothesis that the lagged vector of order p is equal to zero is χ^2, unless the process is Markovian and I(2).

Empirical Results

For the empirical work we use those interest rates most likely to be used as policy instruments. Short-term rates are therefore the rate on three month Treasury bills and long-term rates are the yield on 10-year bonds. The data are from national sources and were obtained from Datastream. We chose the sample to cover the ERM period, 1980:1-1997:4.

We begin the empirical study by looking at the cointegration properties of the variables in our dataset. Tables 1 and 2 present the pre-tests for unit roots in the short- and long-term rates. We use standard Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests and the Pantula et al. (1994) weighted symmetric mean test (WSM). In each case the tests deliver the (now standard) result that each of the series are integrated of order one, so that they follow stochastic trends.

Cointegration and Long-run Causality

The results of Johansen's (1988, 1991) cointegration tests show that there is a marked difference between linkages in long-term rates (10-year bond yields) and linkages in short-term rates (3-month government bills). Whilst there is very little evidence that long-term rates have been linked to one another over the period 1980:1-1997:4, the evidence of comovement is more compelling for short-term rates.[3] These results are presented in Table 3, and suggest that domestic macroeconomic developments, especially policy variables, are likely to be more important in the case of long-term rates.

Exogeneity and Predictabilty

Table 4 presents the results of the exogeneity tests on the cointegrating system suggested by the results in Table 3. These show that all but two of the long-term rates considered, those of France and Italy, are determined exogenously, whereas only one of the short-term rates, that of France, is exogenous. These tests can also be interpreted as long-run causality tests, as in Mosconi and Giannini (1992) and Hall and Wickens (1993) so that, for example, the short-term rate in France appears not to be caused by developments in other G7 short-term rates.

Toda-Yamamoto Causality Tests

In order to investigate the *direction* of causality we apply the Toda and Yamamato (1995) procedure which, as discussed earlier, provides valid inference in the context of unstable, possibly cointegrated systems. The results of these tests are presented in Tables 5 and 6. They confirm that, over the full sample, most long-term rates are determined independently of those in other countries. We find that 10-year bond yields in the United States have a causal effect on those in France, and that German rates affect those in the United Kingdom, otherwise there is very little evidence of linkages between long-term rates elsewhere.

For short-term rates, we find evidence of a causal relationship in four out of the seven cases. In three of these cases the United States has a causal role, affecting short-term rates in Germany, Japan and also Canada, which in turn affects the United Kingdom. Japanese rates are also affected by each of the other countries, apart from Germany. This may be a symptom of the low yields on Japanese short-term debt which makes them sensitive to interest rate changes elsewhere. The United States, Italy and France are the exogenous rates, which may be due to the use of short-term rates as policy instruments in these countries. Where the monetary authority has a specific target, such as inflation or, in the case of France and Italy, an exchange rate parity, interest rates will be set to achieve the policy objective. This will provide a wedge between domestic interest rates and those in other countries since the influence of market participants, which would tend to cause interest rate comovement, will be offset by the actions of policy makers (see Caporale and Pittis (1997)). This explanation is supported by our finding of a causal link from France to Germany, which is consistent with German accommodation of French monetary policy within the exchange rate mechanism (ERM) and is not consistent with the standard 'German Leadership Hypothesis' (GLH).

Stability Analysis

We next look at the stability of the causal relationships we have established by splitting the sample in two to cover the 1980s and the 1990s. In particular, we are interested in establishing whether there has been a reduction in the influence of US rates, and an increase in that of German rates as a result of more integration of European financial markets, an idea discussed by, *inter alia*, Wyplosz (1993).[4] Our conclusions about the determination of long-term rates are unaltered. We find that there is very little evidence of international linkages between 10-year bond yields although the direction of causality does change. In particular, during the 1980s Canadian and US long yields are affected by developments in Europe, especially in Germany. However there is no evidence of a link between the European rates during this period. In the 1990s this conclusion changes and there is much more evidence for causation from international rates to European rates, especially those of Germany and France.

For short-term rates, the causality is much richer over each of the subsamples. The causality structure for Canada and Japan is stable in each period. US rates are determined largely by Japanese and Canadian rates over the 1980s but become more international during the 1990s. For the United Kingdom causality changes quite markedly. During the 1980s UK rates are determined principally by developments in Japan and the United States whereas during the 1990s they are determined only by developments in Germany. This is consistent with the closer involvement of the UK in the European Monetary System during the second period. Indeed we find evidence of a reduced impact of US rates during the 1990s across each of the other G7 countries.

As for the European rates, we find two consistent results. The first is the exogeneity of Italian short-term rates. This is consistent with the view that interest rates in Italy are mainly used to target the ERM parity or domestic inflation. Secondly, we find causation from France to Germany in each subperiod. This may be explained by the desire on behalf of the German authorities to accommodate changes in French short-term rates in order to provide stability within the ERM. As for French rates themselves, we find that during the 1980s, when the ERM provided currency stability and reduced the exchange rate risk, there is causality from German rates.

During the 1990s when the ERM is not effective, interest rates in France become exogenous, that is they target the exchange rate and/or domestic inflation rather than German rates.

Conclusions

Overall, our analysis of interest rates linkages suggests two main conclusions. First, long-term rates show very little evidence of international linkage and are better modelled by looking at macroeconomic variables as the underlying determinants. This finding is consistent with earlier empirical work on the importance of national (or local) influences on a country's long-term interest rates (see Caporale and Williams (1998)), although, as shown by Caporale and Pittis (1997), domestic monetary conditions can also affect the behaviour of short-term interest rates even in the presence of high capital mobility. Secondly, our findings are not supportive, either for short- or long-term rates, of German interest rate leadership, neither do they suggest a significant increase in German influence since the beginning of the eighties, in contrast to Wyplosz (1993). They confirm, instead, the results of Caporale and Pittis (1997), who conclude that German interest rates respond to policy developments in other ERM countries. Indeed it can be argued that within a system of strategic, mutually beneficial policy co-ordination such as the ERM, the largest player, rather than dominating the system, is likely to have to use its inherent stability to accommodate policy variation elsewhere. However, even within a system like the ERM, where exchange rate risk is reduced or absent, it is still possible for participating countries to adopt an exogenous interest rate policy.

NOTES

[1] The description of the methodology in this section follows very closely Caporale and Pittis (1999).

[2] The appropriate lag length for the VAR was selected in each case following the approach advocated by Caporale et al (1997).

[3] Detailed results are reported in the Appendix.

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Table 1: Long-Rates: Unit Root Tests.

Sample: 1980:1-1997:4							
Trend	BDLR	CNLR	FRLR	ITLR	JPLR	UKLR	USLR
WSM	-2.7652	-3.9947	-2.7255	-2.5308	-2.2404	-2.9125	-4.2973
	[0.1578]	[0.0047]	[0.1742]	[0.2741]	[0.4735]	[0.1077]	[0.0019]
ADF	-2.8894	-4.0199	-2.8970	-2.7243	-1.5193	-2.8991	-4.2401
	[0.1660]	[0.0082]	[0.1632]	[0.2261]	[0.8224]	[0.1625]	[0.0039]
PP	-7.8425	-17.2118	-12.0664	-9.4283	-8.0937	-13.4272	-17.6346
	[0.5963]	[0.1221]	[0.3126]	[0.4757]	[0.5764]	[0.2472]	[0.1125]
No-Trend	BDLR	CNLR	FRLR	ITLR	JPLR	UKLR	USLR
WSM	-1.9744	-1.0607	-0.8112	-1.3881	0.2038	-0.3670	-1.2079
	[0.2021]	[0.7954]	[0.8912]	[0.5936]	[0.9942]	[0.9687]	[0.7145]
ADF	-2.5143	-0.9400	-0.8553	-1.0893	-0.3909	-1.2220	-1.5125
	[0.1120]	[0.7745]	[0.8024]	[0.7193]	[0.9116]	[0.6641]	[0.5273]
PP	-4.2072	-2.1780	-1.1685	-1.3866	-1.3456	-3.8636	-3.3015
	[0.5151]	[0.7589]	[0.8704]	[0.8485]	[0.8527]	[0.5538]	[0.6206]
Sample: 1980:1-1990:3							
Trend	BDLR	CNLR	FRLR	ITLR	JPLR	UKLR	USLR
WSM	-1.6360	-1.5468	-1.6652	-1.9748	-0.3941	-2.0477	-3.5329
	[0.8456]	[0.8773]	[0.8338]	[0.6655]	[0.9956]	[0.6153]	[0.0185]
ADF	0.4960	-0.0559	-2.0825	-2.2117	0.7123	-1.2200	-3.4877
	[0.9968]	[0.9936]	[0.5559]	[0.4833]	[1.0000]	[0.9063]	[0.0407]
PP	-1.5265	-6.9192	-7.2159	-5.7178	0.6784	-4.8797	-10.4004
	[0.9805]	[0.6711]	[0.6469]	[0.7676]	[0.9988]	[0.8298]	[0.4098]
No-Trend	BDLR	CNLR	FRLR	ITLR	JPLR	UKLR	USLR
WSM	-2.4407	-1.9183	-1.4302	-1.7884	-1.3949	-0.9653	-1.8506
	[0.0591]	[0.2304]	[0.5629]	[0.3063]	[0.5887]	[0.8379]	[0.2683]
ADF	-1.7964	-1.9711	-1.2135	-1.2585	-1.8078	-1.5288	-1.8115
	[0.3823]	[0.2994]	[0.6678]	[0.6479]	[0.3766]	[0.5192]	[0.3748]
PP	-3.5802	-3.2344	-1.8343	-2.0303	-3.9643	-4.3283	-4.2672
	[0.5870]	[0.6287]	[0.7994]	[0.7766]	[0.5423]	[0.5020]	[0.5086]

Sample: 1990:4-1997:4							
Trend	BDLR	CNLR	FRLR	ITLR	JPLR	UKLR	USLR
WSM	-1.3384	-1.9464	-2.1217	-2.7961	-2.5871	-1.5969	-2.8511
	[0.9302]	[0.6840]	[0.5618]	[0.1459]	[0.2419]	[0.8602]	[0.1266]
ADF	-2.8428	-2.3116	-2.7825	1.1204	-2.5085	-3.3492	-3.3839
	[0.1817]	[0.4275]	[0.2034]	[1.0000]	[0.3237]	[0.0586]	[0.0536]
PP	-2.9186	-8.7512	-3.3441	-2.0745	-9.5685	-5.1262	-3.3876
	[0.9402]	[0.5255]	[0.9215]	[0.9683]	[0.4658]	[0.8122]	[0.9194]
No-Trend	BDLR	CNLR	FRLR	ITLR	JPLR	UKLR	USLR
WSM	-0.1541	0.3674	-0.1259	-0.8424	0.6817	0.5710	-1.2546
	[0.9832]	[0.9964]	[0.9845]	[0.8818]	[0.9986]	[0.9980]	[0.6852]
ADF	-1.5980	-0.9164	-1.5413	1.5780	-1.3529	-1.1554	-2.4573
	[0.4846]	[0.7825]	[0.5130]	[0.9978]	[0.6046]	[0.6925]	[0.1262]
PP	-1.9984	-2.9379	-3.3339	1.0087	-1.4029	-3.6212	-6.1636
	[0.7803]	[0.6653]	[0.6166]	[0.9898]	[0.8468]	[0.5821]	[0.3346]

Table 2: Short-Rates: Unit Root Tests

Sample: 1980:1-1997:4							
Trend	BDSR	CNSR	FRSR	ITSR	JPSR	UKSR	USSR
WSM	-2.8443	-2.2030	-2.5314	-2.7938	-2.4892	-2.3307	-2.0552
	[0.1288]	[0.5014]	[0.2737]	[0.1467]	[0.2994]	[0.4071]	[0.6100]
ADF	-3.3931	-3.4597	-2.4840	-2.9189	-2.4188	-2.9962	-1.9208
	[0.0523]	[0.0439]	[0.3360]	[0.1562]	[0.3697]	[0.1331]	[0.6438]
PP	-6.2939	-12.6825	-10.7004	-13.1441	-9.6547	-10.9488	-9.3553
	[0.7219]	[0.2815]	[0.3908]	[0.2598]	[0.4598]	[0.3756]	[0.4810]
No-Trend	BDSR	CNSR	FRSR	ITSR	JPSR	UKSR	USSR
WSM	-3.1782	-0.6535	-0.8673	-0.7760	-1.4529	-0.9784	-0.6508
	[0.0069]	[0.9292]	[0.8739]	[0.9010]	[0.5462]	[0.8325]	[0.9297]
ADF	-3.2397	-1.6518	-0.7514	-0.6217	-1.8794	-2.0341	-1.4236
	[0.0178]	[0.4561]	[0.8330]	[0.8660]	[0.3418]	[0.2718]	[0.5709]
PP	-4.7358	-4.4277	-2.4012	-1.3256	-3.3542	-6.0637	-4.7196
	[0.4596]	[0.4914]	[0.7317]	[0.8548]	[0.6141]	[0.3422]	[0.4612]
Sample: 1980:1-1990:3							
Trend	BDSR	CNSR	FRSR	ITSR	JPSR	UKSR	USSR
WSM	-1.8393	-2.3150	-1.5190	-1.4610	-1.9238	-1.1391	-1.1845

	[0.7489]	[0.4184]	[0.8859]	[0.9023]	[0.6985]	[0.9603]	[0.9548]
ADF	0.1439	-1.9943	-2.1105	-2.5445	-0.6423	-1.6951	-0.1702
	[0.9954]	[0.6045]	[0.5402]	[0.3061]	[0.9767]	[0.7530]	[0.9920]
PP	-1.5661	-5.8663	-6.5688	-7.1320	-4.8741	-5.3305	-6.4368
	[0.9798]	[0.7560]	[0.6997]	[0.6538]	[0.8303]	[0.7972]	[0.7104]
No-Trend	BDSR	CNSR	FRSR	ITSR	JPSR	UKSR	USSR
WSM	-1.6902	-2.0506	-1.4591	-1.0142	-1.7287	-1.0121	-0.8707
	[0.3719]	[0.1678]	[0.5416]	[0.8171]	[0.3454]	[0.8180]	[0.8727]
ADF	-1.5650	-2.9385	-1.2728	-0.5533	-2.3643	-2.1272	-1.2912
	[0.5012]	[0.0410]	[0.6415]	[0.8812]	[0.1521]	[0.2337]	[0.6332]
PP	-3.4036	-5.8465	-3.3650	-0.8508	-3.4888	-7.3212	-4.0023
	[0.6082]	[0.3593]	[0.6128]	[0.8993]	[0.5979]	[0.2572]	[0.5380]
Sample: 1990:4-1997:4							
Trend	BDSR	CNSR	FRSR	ITSR	JPSR	UKSR	USSR
WSM	0.0454	-1.5244	-3.0494	-3.3719	-2.6233	-0.6503	-1.5648
	[0.9988]	[0.8843]	[0.0742]	[0.0297]	[0.2226]	[0.9905]	[0.8714]
ADF	1.1651	-3.2906	-0.2932	-2.1783	-3.3538	-0.9852	-2.9898
	[1.0000]	[0.0678]	[0.9897]	[0.5021]	[0.0579]	[0.9461]	[0.1349]
PP	-6.4079	-6.3354	-3.2578	-2.6544	-4.8370	-2.3924	-5.7590
	[0.7127]	[0.7186]	[0.9255]	[0.9503]	[0.8328]	[0.9591]	[0.7644]
No-Trend	BDSR	CNSR	FRSR	ITSR	JPSR	UKSR	USSR
WSM	-1.4908	-0.0359	-0.9011	-1.2772	-0.2718	-0.1968	-1.8732
	[0.5180]	[0.9881]	[0.8623]	[0.6705]	[0.9762]	[0.9809]	[0.2552]
ADF	-2.6624	-1.2468	-1.4098	0.0488	-1.2413	-2.0483	-2.1682
	[0.0808]	[0.6532]	[0.5776]	[0.9624]	[0.6556]	[0.2658]	[0.2180]
PP	-0.7968	-5.7741	-0.6054	-0.8187	-1.1653	-4.5038	-8.6957
	[0.9038]	[0.3652]	[0.9190]	[0.9020]	[0.8707]	[0.4834]	[0.1850]

Table 3: Johansen Cointegration Tests

Long-rates: Sample 1980:1-1997:							
H0	λ_{max}	λ_{max-nm}	95% cv	H0	λ_{trace}	$\lambda_{trace-nm}$	95% cv
r=0	47.49*	29.02	45.3	r_0	150.3**	91.8	124.2
r=1	37.29	22.79	39.4	r_1	102.8*	62.8	94.2
r=2	29.58	18.08	33.5	r_2	65.48	40.01	68.5
r=3	22.48	13.74	27.1	r_3	35.90	21.94	47.5
r=4	10.87	6.45	21.0	r_4	13.41	8.19	29.7
r=5	1.83	1.12	14.1	r_5	2.54	1.55	15.4
r=6	0.709	0.433	3.8	r_6	0.709	0.433	3.8
a/corr:	1.1354 [0.2050]			VAR lags:	4		
normality:	24.047 [0.0452]			Dummies:	none		
Short-Rates: Sample 1980:1-1997:4							
H0	λ_{max}	λ_{max-nm}	95% cv	H0	λ_{trace}	$\lambda_{trace-nm}$	95% cv
r=0	154.6**	94.46**	45.3	r_0	456.5**	278.9**	124.2
r=1	104.1**	63.63**	39.4	r_1	301.9**	184.5**	94.2
r=2	76.14**	46.53**	33.5	r_2	197.8**	120.9**	68.5
r=3	67.75**	41.40**	27.1	r_3	121.6**	74.33**	47.5
r=4	39.08**	23.88*	21.0	r_4	53.88**	32.93*	29.7
r=5	11.58	7.079	14.1	r_5	14.80	9.043	15.4
r=6	3.254	1.964	3.8	r_6	3.214	1.964	3.8
a/corr:	1.5544 [0.0898]			VAR lags:	4		
normality:	17.082 [0.2518]			Dummies:	80:2, 80:4, 88:3, 90:2, 92:3		

The λ_{max-nm} and $\lambda_{trace-nm}$ statistics are adjusted for degrees of freedom as in Doornik and Hendry (1994). The normality test is a χ^2 test on the system residuals, the autocorrelation test is a F-test as in Doornik and Hendry (1994). Critical Values are from Osterwald-Lenum (1992). ** indicates rejection of the null at 5%, * indicates rejection of the null at 10%

Table 4: Long-run Causality Tests

Rank	BD	CN	FR	IT	JP	UK	US
Long Rates: Sample 1980:1-1997:4							
r=2	3.9764 [0.1369]	2.2924 [0.3179]	8.8282 [0.0121]*	6.8228 [0.0330]*	0.2542 [0.8806]	3.0489 [0.2177]	5.1651 [0.0756]
Short Rates: Sample 1980:1-1997:4							
r=5	40.824 [0.0000]**	51.089 [0.0000]**	8.3678 [0.1401]	56.904 [0.0000]**	117.39 [0.0000]**	36.869 [0.0000]**	59.767 [0.0000]**

Figures in brackets are the probability values.

Table 5: Long Rates: Toda-Yamamoto Causality Tests:

	BD	CN	FR	IT	JP	UK	US
Sample 1980:1-1997:4							
BD	-	4.5372 [0.3382]	8.3651 [0.0791]	4.5070 [0.3417]	0.5118 [0.9723]	1.8207 [0.7688]	5.1904 [0.2683]
CN	5.1192 [0.2753]	-	2.9160 [0.5720]	3.7240 [0.4446]	9.1154 [0.0583]	0.9917 [0.9110]	4.7925 [0.3093]
FR	3.6178 [0.4602]	7.9514 [0.0934]	-	9.0054 [0.0610]	4.3107 [0.3656]	3.1200 [0.5379]	10.941 [0.0272]*
IT	1.4696 [0.8320]	8.2723 [0.0821]	9.3864 [0.0521]	-	2.2630 [0.6875]	2.5667 [0.6327]	2.6946 [0.6102]
JP	1.8432 [0.7646]	4.3515 [0.3605]	7.5090 [0.1113]	2.4231 [0.6584]	-	4.0693 [0.3967]	1.4081 [0.8428]
UK	11.1410 [0.0250]*	6.1623 [0.1874]	4.9891 [0.2884]	4.5519 [0.3364]	5.8695 [0.2091]	-	4.7014 [0.3193]
US	2.9434 [0.5673]	6.1341 [0.1894]	0.6197 [0.9608]	1.5096 [0.8249]	5.8806 [0.2082]	1.3035 [0.8608]	-
a/corr: na normality: 20.822 [0.1063]				VAR lags: 5 Test: χ^2 (4)			

Sample 1980:1-1990:3							
BD	-	3.2250 [0.5209]	1.2723 [0.8661]	2.0097 [0.7340]	2.1698 [0.7046]	2.2737 [0.6856]	1.0317 [0.9047]
CN	24.736 [0.0001]**	-	3.7318 [0.4435]	9.8706 [0.0427]*	23.095 [0.0001]**	4.5120 [0.3411]	5.0708 [0.2801]
FR	7.1387 [0.1287]	4.1458 [0.3866]	-	3.9697 [0.4101]	3.8064 [0.4328]	3.4012 [0.4931]	4.3430 [0.3616]
IT	3.4531 [0.4850]	5.0925 [0.2779]	7.5378 [0.1101]	-	8.4663 [0.0759]	3.3765 [0.4969]	4.9176 [0.7554]
JP	1.8063 [0.7713]	2.0161 [0.7328]	3.1517 [0.5328]	0.6019 [0.9623]	-	2.9266 [0.5702]	1.8932 [0.7554]
UK	4.9732 [0.2901]	1.4807 [0.8301]	1.2296 [0.8732]	1.6467 [0.8004]	0.6726 [0.9847]	-	2.7258 [0.6047]
US	24.574 [0.0001]**	9.9137 [0.0419]*	6.4273 [0.1694]	15.932 [0.0031]**	16.883 [0.0020]**	6.5979 [0.1587]	-
a/corr: na normality: 21.029 [0.1009]				VAR lags: 5 Test: χ^2 (4)			
Sample 1990:4-1997:4							
BD	-	9.0730 [0.0107]*	8.1730 [0.0168]*	16.991 [0.0002]**	16.187 [0.0003]**	2.2287 [0.3281]	8.0216 [0.0181]*
CN	20.227 [0.0000]**	-	8.5727 [0.0138]*	0.5329 [0.7661]	9.2200 [0.0100]**	1.8946 [0.3878]	3.6156 [0.1640]
FR	3.5101 [0.1729]	0.7300 [0.6942]	-	26.553 [0.0000]**	11.273 [0.0036]**	7.2044 [0.0273]*	2.6881 [0.2608]
IT	0.9017 [0.6371]	0.2672 [0.8749]	3.3172 [0.1904]	-	0.1799 [0.9140]	2.1906 [0.3344]	0.0743 [0.9636]
JP	3.3190 [0.1902]	3.3446 [0.1878]	0.7540 [0.6859]	1.4088 [0.4944]	-	1.7624 [0.4143]	5.6007 [0.0608]
UK	3.5983 [0.1654]	3.5884 [0.1663]	5.0343 [0.0807]	1.7608 [0.4146]	0.0682 [0.9660]	-	1.5024 [0.4718]
US	5.2515 [0.0724]	5.4105 [0.0669]	0.5418 [0.7627]	2.4970 [0.2869]	5.5290 [0.0630]	3.6734 [0.1593]	-
a/corr: na normality: 17.407 [0.2351]				VAR lags: 3 Test: χ^2 (2)			

Figures in brackets are the probability values.

Table 6: Short-Rates: Toda-Yamamoto Causality Tests

	BD	CN	FR	IT	JP	UK	US
				Sample 1980:1-1997:4			
BD	-	3.1284 [0.5366]	12.795 [0.0123]*	3.1448 [0.5339]	6.6760 [0.1540]	5.2560 [0.2620]	20.657 [0.0004]**
CN	0.6239 [0.9604]	-	7.0964 [0.1309]	7.0783 [0.1318]	7.4622 [0.1134]	7.6161 [0.1067]	28.501 [0.0000]**
FR	6.1919 [0.1853]	4.2183 [0.3773]	-	1.4715 [0.8317]	1.3491 [0.8530]	1.4682 [0.8323]	5.7624 [0.2176]
IT	2.6147 [0.6242]	8.5077 [0.0747]	9.1746 [0.0569]	-	7.5520 [0.1094]	3.1747 [0.5290]	8.5326 [0.0736]
JP	5.0799 [0.2792]	36.013 [0.0000]**	33.794 [0.0000]**	12.469 [0.0412]*	-	13.382 [0.0096]**	30.289 [0.0000]**
UK	8.7262 [0.0683]	17.820 [0.0013]**	3.4362 [0.4876]	4.2226 [0.3767]	2.7643 [0.5980]	-	8.9424 [0.0626]
US	4.4232 [0.3517]	5.4868 [0.2049]	4.4264 [0.3514]	3.6084 [0.4615]	1.4580 [0.8341]	2.5913 [0.6284]	-
a/corr: na normality: 24.377 [0.0412]*				VAR lags: 5 Test: χ^2 (4)			
				Sample 1980:1-1990:3			
BD	-	2.7779 [0.2493]	9.2143 [0.0100]**	1.4699 [0.4795]	6.4798 [0.0392]*	1.8345 [0.3996]	13.8140 [0.0010]**
CN	1.0112 [0.6032]	-	2.1868 [0.3351]	1.5772 [0.4545]	4.6034 [0.1001]	0.4652 [0.7925]	7.3359 [0.0255]*
FR	11.3040 [0.0035]**	4.7330 [0.0938]	-	0.4298 [0.9787]	5.6966 [0.0579]	3.1135 [0.2108]	3.0581 [0.2167]
IT	0.0915 [0.9553]	2.1478 [0.6417]	1.5795 [0.4540]	-	2.5713 [0.2765]	0.3987 [0.8193]	3.3256 [0.1896]
JP	2.1933 [0.3340]	3.3268 [0.1895]	6.6799 [0.0354]*	5.4063 [0.0670]	-	3.5938 [0.1658]	8.8417 [0.0120]*
UK	1.0554 [0.5900]	5.8698 [0.0531]	1.9616 [0.3750]	0.1069 [0.9479]	7.4979 [0.0235]*	-	10.4840 [0.0053]**
US	5.2216 [0.0735]	7.8368 [0.0199]*	0.4296 [0.8067]	1.1526 [0.4694]	19.3070 [0.0001]**	0.6759 [0.7132]	-
a/corr: 0.7513 [0.7920] normality: 30.102 [0.0074]**				VAR lags: 3 Test: χ^2 (2)			

Sample: 1990:4-1997:4							
BD	-	7.9941 [0.0461]*	13.3590 [0.0039]**	2.0790 [0.5562]	3.1083 [0.3752]	3.4719 [0.3244]	3.8631 [0.2766]
CN	6.1852 [0.1029]	-	5.2068 [0.1573]	6.0021 [0.1115]	10.1220 [0.0176]*	7.2656 [0.0639]	10.5780 [0.0142]*
FR	1.3730 [0.7119]	4.0725 [0.2537]	-	3.5102 [0.3194]	2.5415 [0.4678]	7.1106 [0.0685]	0.8045 [0.8484]
IT	5.8544 [0.1189]	5.7720 [0.1403]	4.6990 [0.1952]	-	4.8248 [0.1851]	4.4050 [0.2209]	4.1207 [0.2487]
JP	5.1830 [0.1589]	34.2090 [0.0000]**	12.6210 [0.0055]**	19.0680 [0.0000}**	-	9.4730 [0.0236]	37.7210 [0.0000]
UK	12.5410 [0.0057]**	7.7118 [0.0524]	4.1670 [0.2440]	6.2311 [0.1009]	3.9363 [0.2684]	-	2.4552 [0.4834]
US	10.5440 [0.0145]*	13.3940 [0.0039]**	9.0503 [0.0286]*	8.9952 [0.0294]*	12.4730 [0.0059]**	13.1410 [0.0043]**	-
a/corr: na normality: 16.690 [0.2731]			VAR lags: 4 Test: χ^2 (3)				

Figures in brackets are the probability values.

APPENDIX

A.1 Short sample cointegration tests

The results in the main text provide stability analysis for the *direction* of causality by conducting the Toda-Yamamoto (1995) tests on two subsamples over the 1980s and 1990s. In this appendix we investigate the stability of the cointegrating relationships and the long-run causality structures by repeating the procedures discussed in Section 2 on the same sub-periods. Statistical inference from these tests is constrained by the short samples involved. Nevertheless, the results do provide some insights into the behaviour of the processes we are investigating.

A.2 Cointegration Analysis

Tables A1-A2 and A4-A5 present the Johansen tests for the number of long-run cointegrating relationships within the system. Basing inference on the $\lambda_{max\text{-}nm}$ and

$\lambda_{trace\text{-}nm}$ statistics, which are adjusted for degrees of freedom, we find no cointegration in the long-term rates over either sample and no cointgration for short-term rates during the 1990s. For the earlier part of the sample we find two cointegrating relationships amongst the short-term rates. On the basis of the λ_{max} and λ_{trace} statistics, which are more standard but which are affected by the short samples, we find more evidence of comovement. The results for the long-term rates are consistent with those in the main part of the study. In the case of the short-term rates, evidence of cointegration in the longer sample is not necessarily inconsistent with absence of such evidence in the shorter samples if, for example, the series exhibit the type of convergence process discussed in Caporale and Pittis (1995).

A.3 Long-run Causality Tests

Tables A3 and A6 present the results of the long-run causality tests based on the cointegrating rank delivered by the λ_{max} and λ_{trace} statistics. We find that for the earlier sample all of the long-term rates appear to be endogenous, whereas over the later period at least three are exogenous. For the short rates, we cannot reject exogeneity in four cases over the earlier sample and in two cases over the later sample. During the 1980s short-term rates in Germany, France and the United Kingdom appear to be determined independently of other short rates. During the 1990s short-term rates in Italy and Canada become exogenous. Both sets of results are consistent with the idea that in some cases the use of short rates as policy instruments disengages them from developments elsewhere. This in turn suggests that the determination of short-term rates is likely to depend intimately on the policy regime in place.

Table A1: Long-rates: Johansen Cointegration Tests: Sample 1980:1-1990:3

H_0	λ_{max}	$\lambda_{max\text{-}nm}$	95% cv	H_0	λ_{trace}	$\lambda_{trace\text{-}nm}$	95% cv
r=0	85.66**	29.02	45.3	r_0	275.5**	89.81	124.2
r=1	55.49**	22.79	39.4	r_1	171.8**	59.93	94.2
r=2	39.74**	18.08	33.5	r_2	116.3**	40.57	68.5
r=3	32.34**	13.74	27.1	r_3	76.57**	26.71	47.5
r=4	29.64**	6.45	21.0	r_4	44.23**	15.43	29.7
r=5	11.94	1.12	14.1	r_5	14.58	5.09	15.4
r=6	2.64	0.433	3.8	r_6	2.64	0.922	3.8
a/corr:	2.7162 [0.0552]			VAR lags:	4		
Normality:	17.924 [0.2102]			Dummies:	none		

See notes to table 3.

Table A2: Long-rates: Johansen Cointegration Tests: Sample 1990:4-1997:4

H_0	λ_{max}	λ_{max-nm}	95% cv	H_0	λ_{trace}	$\lambda_{trace-nm}$	95% cv
r=0	73.64**	38.09	45.3	r≤0	177.3**	91.70	124.2
r=1	39.45**	20.40	39.4	r≤1	103.6**	53.61	94.2
r=2	23.17	11.98	33.5	r≤2	64.20	33.21	68.5
r=3	19.50	10.09	27.1	r≤3	41.03	21.22	47.5
r=4	14.55	7.53	21.0	r≤4	21.53	11.14	29.7
r=5	6.62	3.42	14.1	r≤5	6.977	3.61	15.4
r=6	0.358	0.185	3.8	r≤6	0.358	0.185	3.8
a/corr:	0.6985 [0.7991]			VAR lags:	2		
normality:	15.380 [0.3527]			Dummies:	none		

See notes to table 3.

Table A3: Long-Rates: Long-run Causality Tests

Rank	BD	CN	FR	IT	JP	UK	US
Sample: 1980:1-1990:3							
r=5	20.6220 [0.0010]**	29.0130 [0.0000]**	33.1090 [0.0000]**	22.0510 [0.0005]**	18.8140 [0.0021]**	15.2490 [0.0093]**	38.2580 [0.0000]**
Sample: 1990:3-1997:4							
r=2	2.9155 [0.2328]	1.3674 [0.5047]	12.5620 [0.0019]**	7.6224 [0.0221]*	8.6321 [0.0134]*	1.3204 [0.5168]	10.3410 [0.0057]**

Figures in brackets are the probability values.

Table A4: Short-Rates: Johansen Cointegration Tests: Sample 1980:1-1989:4

H_0	λ_{max}	λ_{max-nm}	95% cv	H_0	λ_{trace}	$\lambda_{trace-nm}$	95% cv
r=0	105.8**	68.79**	45.3	r≤0	258.6**	168.1**	124.2
r=1	59.93**	38.96	39.4	r≤1	152.8**	99.3*	94.2
r=2	31.70	20.60	33.5	r≤2	92.84**	60.35	68.5
r=3	28.28*	18.38	27.1	r≤3	61.14**	39.74	47.5
r=4	15.55	10.11	21.0	r≤4	32.87**	21.36	29.7
r=5	14.67*	9.534	14.1	r≤5	17.32*	11.26	15.4
r=6	2.652	1.724	3.8	r≤6	2.652	1.724	3.8
a/corr:	na			VAR lags:	2		
normality:	21.674 [0.0856]			Dummies:	80:2, 88:2		

See notes to table 3.

Table A5: Short-Rates: Johansen Cointegration Tests: Sample 1989:1-1997:4

H_0	λ_{max}	λ_{max-nm}	95% cv	H_0	λ_{trace}	$\lambda_{trace-nm}$	95% cv
r=0	93.25**	38.86	45.3	r≤0	286.7**	119.5	124.2
r=1	60.88**	25.37	39.4	r≤1	193.5**	80.61	94.2
r=2	53.45**	22.27	33.5	r≤2	132.6**	55.24	68.5
r=3	39.15**	16.31	27.1	r≤3	79.14**	32.98	47.5
r=4	23.88**	9.949	21.0	r≤4	39.99**	16.66	29.7
r=5	12.02	5.01	14.1	r≤5	16.11**	6.713	15.4
r=6	4.088*	1.703	3.8	r≤6	4.088*	1.703	3.8
a/corr:	4.4855 [0.0103]*			VAR lags:	3		
normality:	10.879[0.6955]			Dummies:	none		

See notes to table 3.

Table A6: Short-Rates: Long-run Causality Tests

Rank	BD	CN	FR	IT	JP	UK	US
				Sample: 1980:1-1990:3			
r=5	5.1863 [0.0748]	13.1150 [0.0014]**	2.8864 [0.2362]	7.5812 [0.0226]*	47.031 [0.0000]**	0.6313 [0.7293]	35.4200 [0.0000]**
				Sample: 1989:1-1997:4			
r=5	25.9110 [0.0000]**	3.7107 [0.5918]	45.1490 [0.0000]**	6.6807 [0.2455]	55.7770 [0.0000]**	25.6490 [0.0001]*	15.9530 [0.0070]**

Figures in brackets are the probability values.