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Interest rates linkages for G-6 countries

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Abstract: *This study examines the long-run, medium-run and short run interest rates linkages among G-6 countries from 1991 till 2009. We use several conventional and unconventional techniques such as cointegration, codependence and wavelet comovement. Our results show that 19 out of 45 pairs are cointegrated and 11 of them have cointegration relation with a structural break. Existence of cointegration relation implies that only 19 pairs have common stochastic trend. On the other hand, using codependence, we find that 15 out of 19 pairs both have common stochastic trend and common cycles and 23 pairs have only common cycles. In total 38 out of 45 pairs have common cycles. In terms of the Rua (2010) wavelet comovement methodology, our results are in line with the argument that the comovement was dependent on the US at every frequency.*

Key-words: *Interest rates, G-6 countries, codependence, wavelet comovement*

1. Introduction and motivation

Relations between interest rates among countries are an important aspect of understanding international financial linkages and constructing financial and economic models. The idea of existence of interest rate linkages across countries usually arise from the interest rate parity condition which builds a connection between two countries' interest rates via integration of the foreign exchange market. Hence, a high degree of international capital mobility between two countries leads to financial assets of these countries being substitutes for each other and arbitrage opportunities should equalize one country's interest rate with other one plus the forward premium on the two currencies. As a consequence, if forward premium has stationary time series properties then the two interest rates may move together over time (Zhou, 2003). To the best of our knowledge this study is the first attempt that investigates short, medium and long term interest rates linkages among the developed countries of United States, United Kingdom, Germany, Italy, France and Canada. We exclude Japan because especially during 1990s Japan suffered from liquidity trap and we thought that it deserves a special interest. We hope to obtain

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some information about the relations of yield curve movements which would be crucial for monetary policy makers.

2. Literature Review

Several studies investigate relationships between the different types of interest rates. Pain and Thomas (1997) found linkages between long term real interest rates among the US, Japan and Germany especially in the post-1980 period (sample period is 1968Q3:1992Q4). Karfakis and Moschos (1990) found some short-run causal connections between European Monetary System (EMS) interest rates, but no long-run relation between German and other EMS interest rates. Katsimbris and Miller (1993) argued that "little direct evidence suggests the existence of cointegration between the German interest rate and other EMS rates", but "stronger evidence emerges of cointegration between the US interest rate and EMS rates". Hassapis et al. (1999) showed that there is no cointegrating relationship between interest rates in countries participating in the EMS and German rates. Bremnes et al. (2001) investigated short run and long run interest rate linkages among US, Germany and Norway during the period 1990M11-1997M4. They found that US long-term interest rates influence both German and Norwegian long-term rates. Linderberg and Westermann (2009) investigated money market rate and 10-year government bond yield linkages in G-7 countries over the period 1975Q1-2007Q1. They found limited evidence of cointegration relation (6 out of 21 possible pairs are cointegrated).

3. Data and methodology

Short-run interest rate is 3-month T-bill rate, medium-run interest rate is 5-year government bond yield and long-run interest rate is 10-year government bond yield. We use monthly data and sample period runs through 1991 April -2009 August. All data are collected from corresponding countries' Central Banks.

In traditional time series analysis, investigation of relation between variables is depending on the time series properties of variables. Cointegration represents co-movement between nonstationary variables which implies that two series exhibit common stochastic trend. On the other hand, co-movement between stationary variables termed as codependence and codependence between two stationary time series is defined as a serial correlation common feature. This implies that a linear combination of the stationary variables removes all past correlation (Engle and Kozicki, 1993; Engle and Vahid, 1993). Suppose x_t and y_t are two nonstationary variables, then;

$$x_t - \beta y_t = \varepsilon_t \tag{1}$$

where ε_t is a stationary series then x_t and y_t are said to be cointegrated and β is cointegration vector. This indicates that x_t and y_t move together in the long run. Suppose x_t and y_t are two I(1) series then Δx_t and Δy_t are two stationary variables. Δx_t and Δy_t said to be have a common cycle if;

$$\Delta x_t - \delta \Delta y_t = \upsilon_t \tag{2}$$

where δ is a parameter and υ_t is a white noise error term.

For cointegration analysis, we employ Johansen cointegration test and a cointegration test developed by Carrion-i-Sylvestre and Sans´o (2006) which takes into account the structural breaks. Since countries experienced monetary regime shifts during the corresponding period and three countries are member of EMS (which is established in January 1999) a possible structural break in the cointegration relation is likely. Gregory et al (1996) illustrated that the presence of a structural break in the cointegrating relation frequently lead to the rejection of cointegration. Carrion-i-Sylvestre and Sans´o cointegration test avoids the problem of disentangling a regime shift from a stable cointegration relationship which presents itself in the well-known Gregory and Hansen (1996a, 1996b) cointegration test with structural break (Beyer et al. 2009). Since interest rates do not include deterministic trend, we allow for structural change only in the constant term and cointegrating slope parameters, at an unknown point in time.

To test for common cycles, the method of codependence is used (Engle and Kozicki, 1993; Engle and Vahid, 1993). By following Morley and Pentecost (2000) to test serial correlation common feature, we estimate following form of equation;

$$\Delta x_t = \gamma_0 - \gamma_1 \Delta y_t - \lambda \hat{\nu}_{t-1} + \omega_t \tag{3}$$

where x_t and y_t are I(1) series, $\hat{\nu}_{t-1}$ error correction term from cointegration relationship between $\hat{\nu}_{t-1}$, and ω_t is random error term. We employ two-stage least squares method for estimation. Instruments are lagged values of both variables and constant. We start by using 12 lags due to monthly data and control over identifying restriction by using J-statistics. If twelve lag is not legitimate then we reduce the lags till it turns out to be the significant one.

We investigate the comovement of the data through the wavelet comovement methodology developed by Rua (2010). This will give the chance to measure in what extend whether US and the G-5 moved together or not over time and frequency

dimensions. Not only we quantify the comovement at the frequency level but also we will show the strength of the comovement through the correlation coefficients. The measurement of comovement among selected economies is the key to identify the conditions existing in the markets just before the Great Recession and while the recession is in full swing. Wavelet analysis merges the approaches of time and frequency domains through a wave band so we can see the global effects to the economies coming from US before and just at the start of the crisis. Hence, the wavelet-based measure of comovement is significant in understanding the composition, magnitude and direction of the relationship between the US and the G-5, which are proposed to move together over time and across frequencies. Moreover, the wavelet comovement analysis reveals the distinction between the short and long-term fluctuations, low or high frequency movements.[3]

5. Results and discussions

5.1. Unit root, cointegration and codependence tests

Table 1 shows that none of our series is stationary and the differences display that all of our series are integrated of order 1.

Maturity →	**Long-run rates**		**Medium term rates**		**Short-run rates**	
COUNTRY	Level	Diff	Level	Diff	Level	Diff
Canada	-1,58	-13,86*	-1,64	-8,25*	-1,41	-3,83*
France	-0,58	-9,77*	-2,23	-11,79*	-2,46	-4,47*
Germany	-1,87	-7,46*	-1,94	-11,84*	-2,01	-5,41*
Italy	-2,01	-5,30*	-1,47	-12,68*	-1,32	-4,60*
UK	-2,18	-8,22*	-1,85	-5,44*	-2,33	-5,64*
US	-1,74	-7,47*	-1,71	-9,93*	-2,79	-3,33**

Notes: (*) indicates significance at % 1 and (**) indicates significance at % 5 levels, respectively. Maximum lag is 12 and lags are determined based on Akaike Information Criterion (AIC).

Table 1. ADF Unit Root Tests

Next, we perform the cointegration tests for interest rates pairs of countries. For the pairs that Johansen cointegration is rejected we employ Carrion-i-Sylvestre and Sans´o cointegration test. 1 indicates Johansen cointegration relation, and 1* indicates the cointegration relation with structural break.[4] According to Johansen cointegration tests, given in Table 2, only 8 out of 45 possible pairs are cointegrated.

[3] We do not explain the wavelet comovement in detail to save space. See Rua (2010) for details.
[4] Estimated break dates are given in the Appendix.

On the other hand taking into account a possible structural break in cointegration relation we have found that 11 possible pairs have cointegration relation. None of the EMS countries' short run interest rates are cointegrated, again displayed in Table 2.

Long–run interest rates					
COUNTRY	US	UK	Italy	Germany	France
Canada	1*	1*	0	1	0
France	0	0	1	1*	
Germany	0	1*	1*		
Italy	0	1			
UK	0				
Medium–term interest rates					
COUNTRY	US	UK	Italy	Germany	France
Canada	0	0	0	1	0
France	0	1*	1	1*	
Germany	0	0	0		
Italy	0	1			
UK	0				
Short–run interest rates					
COUNTRY	US	UK	Italy	Germany	France
Canada	1	1*	1*	1*	1*
France	0	0	0	0	
Germany	0	0	0		
Italy	0	0			
UK	1				

Notes: 1 indicates Johansen cointegration relation based on maximum eigenvalues statistics. Lag length is selected by AIC and maximum lag is 12. 1* indicates cointegration relation with structural break based on Carrion-i-Sylvestre and Sans´o cointegration test statistics for Model E (Carrion-i-Sylvestre and Sans´o, 1996).

Table 2. Cointegration Relations

These findings indicate that including a structural break in possible cointegration relation play a crucial role in cointegration analysis of interest rates and ruling it out possibly produces misleading results.

Codependence test for pairs which are not cointegrated indicates that for long-run interest rates 5 out of 7 pairs, for medium-run interest rates 8 out of 10 pairs and for short-run interest rates all of 9 pairs are codependent i.e. they have common

cycles.[5] In total 23 out of 26 pairs which do not include common stochastic trend have common cycles, given in Table 3.

Long–run interest rates					
COUNTRY	US	UK	Italy	Germany	France
Canada			0.25 (2.26)**		0.82 (3.77)*
France	0.24 (2.47)**	0.71 (7.76)*			
Germany	0.21 (2.30)**				
Italy	0.04 (0.23)				
UK	0.15 (1.16)				
Medium–term interest rates					
COUNTRY	US	UK	Italy	Germany	France
Canada	1.15 (5.61)*	0.59 (3.97)*	0.21 (1.63)		0.85 (3.64)*
France	0.37 (3.08)*				
Germany	0.44 (4.73)*	0.61 (7.04)*	0.20 (2.51)**		
Italy	0.06 (0.26)				
UK	0.38 (1.70)***				
Short–run interest rates					
COUNTRY	US	UK	Italy	Germany	France
Canada					
France	0.44 (2.07)**	0.41 (2.42)**	1.14 (1.81)***	1.37 (4.89)*	
Germany	0.25 (2.41)**	0.45 (2.07)**	0.52 (4.45)*		
Italy	0.63 (2.47)**	0.46 (2.07)**			
UK					

Notes: $\Delta x_t = \gamma_0 - \gamma_1 \Delta y_t + \omega_t$ is estimated. t-statistics are in parenthesis for coefficients. (*), (**), (***) indicate significance at % 1, % 5 and % 10 levels, respectively.

Table 3. Codependence Tests for Pairs which are not Cointegrated

When we look at the codependence test results for pairs which have common stochastic trend, we have found that for long-run interest rates and medium-run interest rates all cointegrated pairs is also codependent but Germany-Italy long rates.

[5] According to J-statistics for some pairs using 12 lags is not legitimate. For having legitimate instruments, we use 10 lags for France-Germany, Italy-UK, Germany-Italy and Italy-US for long-run interest rates and Italy-UK for medium-run interest rates. We use 8 lags for France-Italy, Germany-Italy for long-run interest rates, Italy-UK and UK-US for short-run interest rates. We use 4 lags for UK-US medium-run interest rates. Last, we use 2 lags for France-Germany, France-Italy and France-UK short-run interest rates.

On the other hand, for short-run interest rates only 3 out of 6 cointegrated pairs are codependent, given in Table 4.

Long–run interest rates		
COUNTRY PAIR	γ_1	λ
Canada-US	0.39 (2.58)**	-0.02 (-0.42)
Canada-UK	0.60 (4.13)*	-0.02 (-0.56)
Canada Germany	1.08 (4.09)*	0.02 (0.20)
France-Germany	0.71 (8.13)*	-0.12 (-1.14)
France-Italy	0.31 (3.46)*	0.07 (1.44)
Germany-UK	1.16 (6.63)*	-0.19 (-2.64)*
Germany-Italy	0.50 (1.17)	-0.05 (-0.99)
Italy UK	0.61 (2.96)*	0.05 (0.81)
Medium–term interest rates		
COUNTRY PAIR	γ_1	λ
Canada Germany	0.97 (3.68)*	0.04 (0.43)
France-Germany	0.89 (11.20)*	-0.11 (-2.06)**
France-Italy	0.32 (2.70)*	0.11 (1.86)***
France-UK	1.15 (6.81)*	-0.13 (-2.38)**
Italy-UK	0.53 (2.25)**	0.04 (0.56)
Short–run interest rates		
COUNTRY PAIR	γ_1	λ
Canada US	0.01 (4.73)*	-0.27 (-2.55)**
Canada-UK	0.12 (1.48)	0.02 (0.77)
Canada-Italy	0.19 (1.60)	0.00 (0.14)
Canada-Germany	0.13 (2.05)**	-0.03 (-0.95)
Canada-France	0.14 (1.17)	-0.08 (1.85)***
UK-US	0.52 (3.49)*	0.59 (6.17)*

Notes: $\Delta x_t = \gamma_0 - \gamma_1 \Delta y_t - \lambda \hat{v}_{t-1} + \omega_t$ is estimated. t-statistics are in parenthesis for coefficients. (*), (**), (***) indicate significance at % 1, % 5 and % 10 levels, respectively.

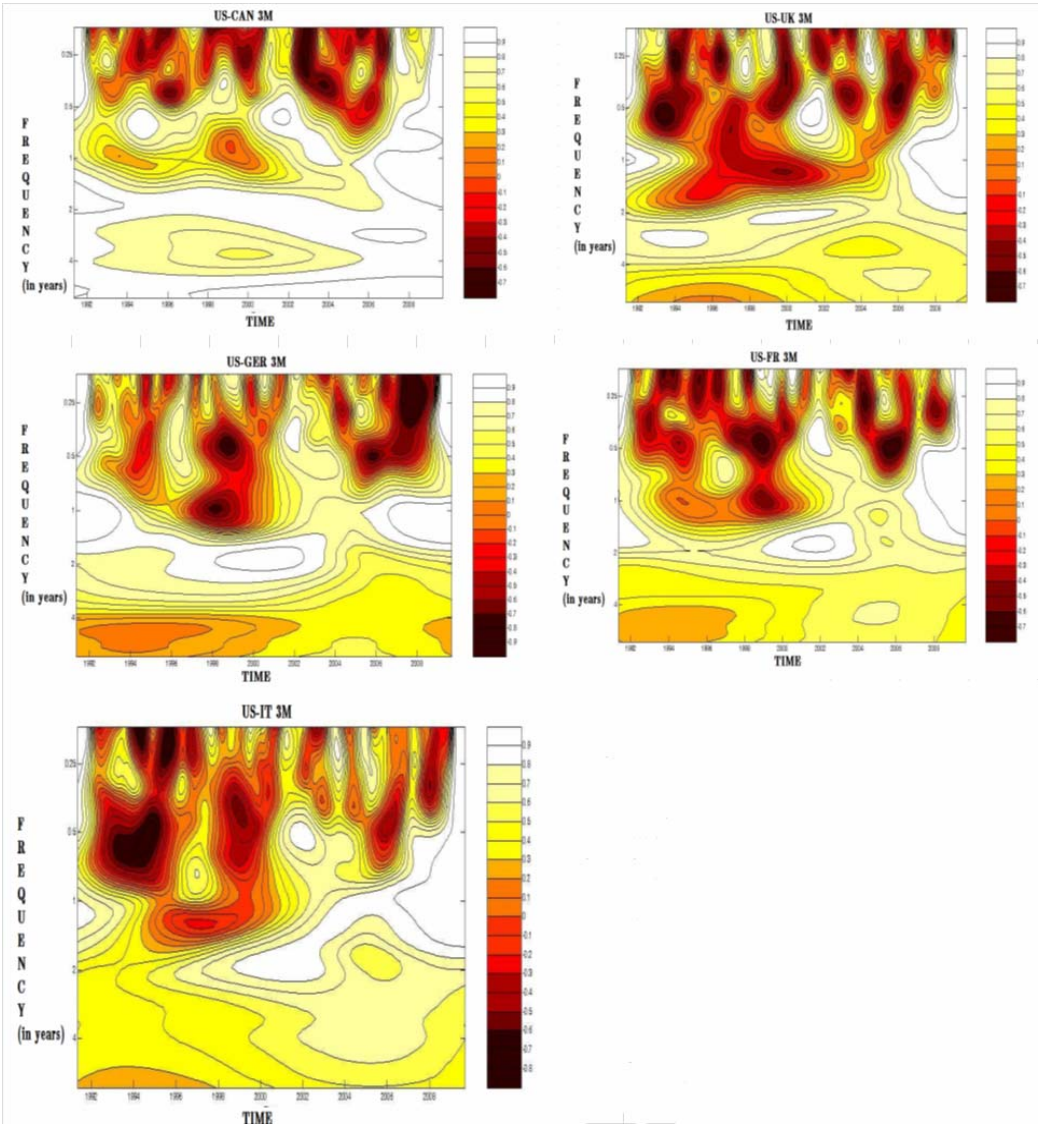
Table 4. Codepedence Tests for Cointegrated Pairs

5.2. Wavelet comovement analysis

The findings of the wavelet comovement analysis could be classified depending on the term of the interest rate.

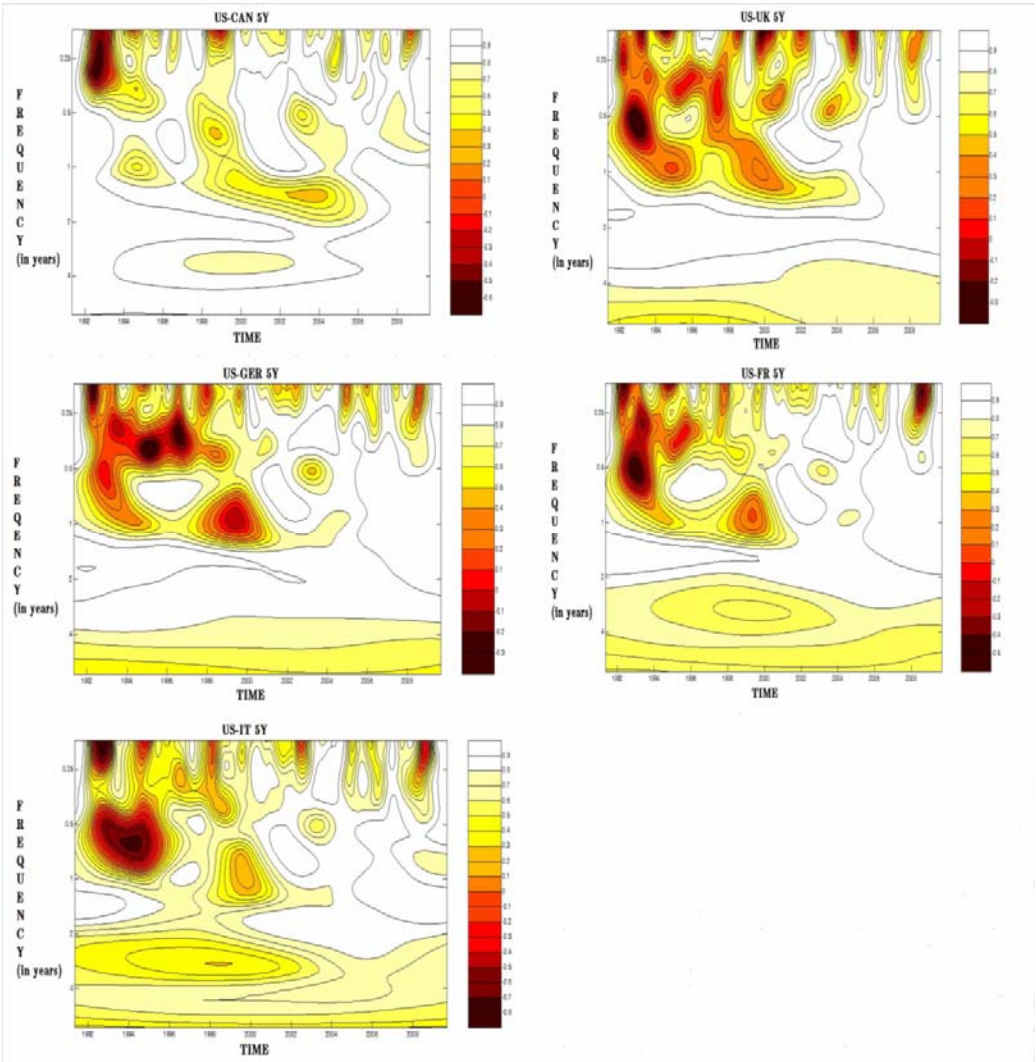
For the short term analysis, we find that the interest rates for US and Canada have negative significant correlation at 6 months whereas this is around a year for

US and Germany, France and Italy. Rather strikingly, this period is around two years between US and UK. Hence, it is possible that investors switch between these two countries securities causing a shift in the interest rate in the opposite direction. This is especially the observed outcome during 1994-2002 as Graph 1 shows.



Graph 1. Wavelet Comovement Analysis for Short-run Interest Rates

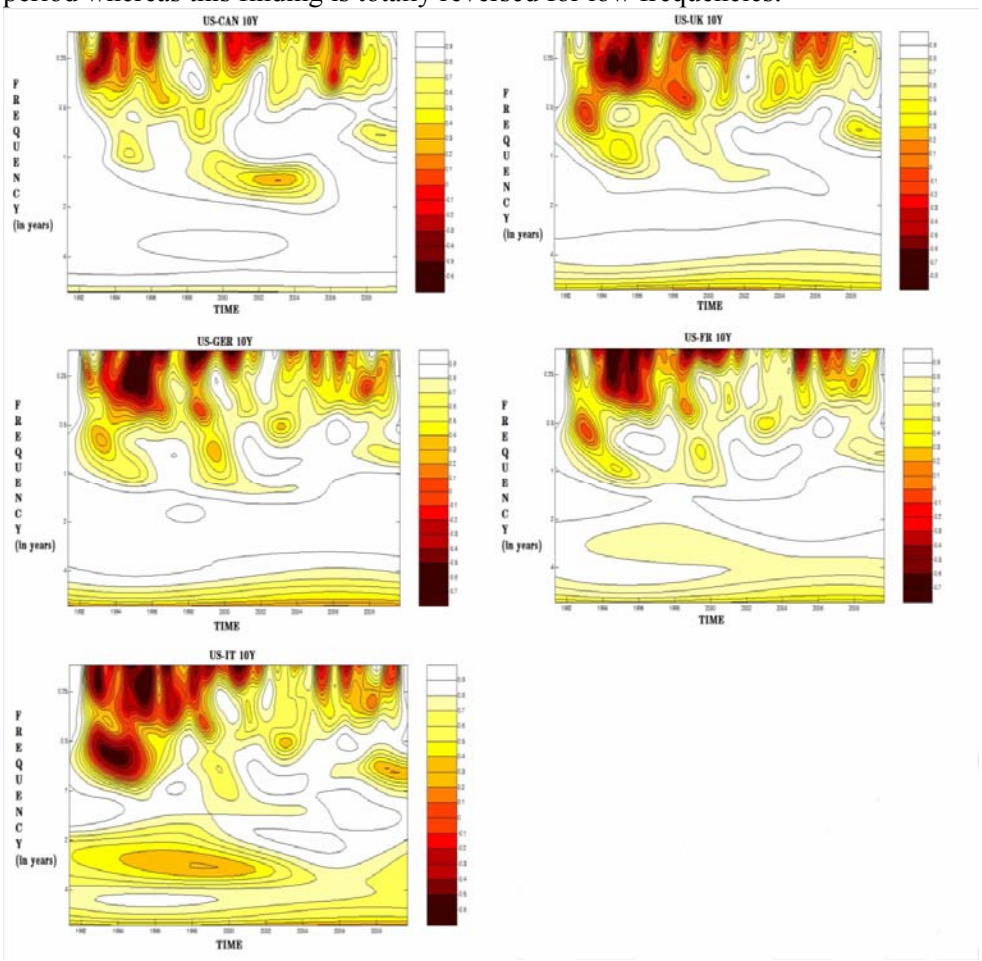
For the medium term analysis in which we consider the 5 year interest rates, the empirical results are significantly different than the short term as displayed in Graph 2. We find that the interest rates for US and Canada have positive and statistically significant correlations at almost all frequencies (except a few instances) which could mean that Canada might be the follower. For the European countries, the pattern changes drastically after 2001. There are significant negative correlations at high frequencies before September 11th and this is completely reversed afterwards.



Graph 2. Wavelet comovement analysis for the medium term interest rates

Most of the period after 2001, US and Germany, France and Italy have statistically significant correlation for 5 year interest rates. Nonetheless, there are a few bursts of negative significant correlations especially after 2007 when the recession starts in the US. A similar scenario is valid for US and UK with slight differences. Before 2001, the frequencies for the negative significant correlations are longer and after 2001 there are still negative significant correlations at shorter frequencies. Hence, this finding is in line with the short term results making the two markets substitutes rather than complements.

For the long term analysis of 10 year interest rates, the empirical results seem to be different than both the short term and the medium term in Graph 3. We find that the interest rates for US and Canada have negative and statistically significant correlations at high frequencies (between 3 and 6 months) during almost the entire period whereas this finding is totally reversed for low frequencies.



Graph 3. Wavelet Comovement Analysis for the Long-run Interest Rates

For the European countries, there are significant negative correlations at the horizons of one year and rather negative relationship is the dominant theme throughout the whole period. On the other hand, the US and UK analysis resembles the US and Canada findings. In the high frequencies, longer term interest rates have statistically significant negative correlations whereas this is reversed especially after 6 to 9 months period. Thus, it is possible to argue that US and UK are substitutes in the short term but rather complements in the long term.

6. Conclusions

In this study, we investigate the interest rates linkages among G-6 countries. We use three types of interest rates; 10 year government bond yield as long-run interest rates, 5 year government bond yield as medium run interest rates and 3 month T-bill rate as short-run interest rates. We employ different cointegration techniques and consider possible structural breaks for long-run relationships between interest rates pairs. We have found that 19 out of 45 pairs are cointegrated and 11 of them have cointegration relation with a structural break. Existence of these cointegration relation means that only 19 pairs have common stochastic trend. On the other hand, using codependence 15 out of 19 pairs both have common stochastic trend and common cycles and 23 pairs have only common cycles. In total 38 out of 45 pairs have common cycles. Last, we examine the wavelet comovement analysis taking US as the anchor economy. US and the G-5 are substitutes for each other as investors switch from one market to the other in a non-distinct pattern. In the longer term, US-UK and US-Canada markets seem to be complementary and a rather smooth relationship exists. However, this is not the outcome for pairing of US and the European countries of Germany, France and Italy. There is hardly any distinct pattern observed either in the medium term or in the longer term for those markets. Hence, it is possible to argue that US, UK and Canada markets follow similar comovements unlike US and Europe.

These findings indicate that interest rates among G-6 countries are linked, but that this connection is mainly through a common cyclical pattern rather than a common trend. Our findings may probably be showing why the US, UK and Canada economies have rebounded strongly from the Great Recession although they have been in a zero lower bound constraint whereas the European economies are still experiencing difficulties in obtaining positive rates of growth and still suffer from the catastrophic effects of the Great Recession, with low levels of growth, high levels of unemployment, an overvalued currency, shaky financial markets and the zero lower bound constraint still in effect.

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COUNTRY	US	UK	Italy	Germany	France
Canada	**1994 M2-LR**	**1997 M12-LR** **1994 M7-SR**	**1998 M2-SR**	**1996 M6-SR**	**1997 M6 – SR**
France		**2008M11-MT**		**1997 M8-LR** **2008 M9 -MT**	
Germany		**1999 M5-LR**	**1997 M5-LR**		

Appendix: Estimated Structural Break Dates
(LR: Long-run, MT: Medium Term and SR: Short-run)