4. MEAN REVERSION OF REAL INTEREST RATES IN G-20: PANEL KSS TEST BY SPSM WITH A FOURIER FUNCTION

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Abstract

This study applies the Sequential Panel Selection Method (SPSM) to test the mean reversion properties in the real interest rates for the G-20 countries. SPSM classifies the whole panel into a group of stationary countries and a group of non-stationary countries. In doing so, we can clearly identify how many and which series in the panel are stationary processes. Empirical results from the SPSM using the Panel KSS test with a Fourier function indicate that the mean reversion holds true for all G-20 countries. Our results have important policy implications for the G-20 countries under study.

Keywords: Mean Reversion; Real Interest Rate; Sequential Panel Selection Method; G-10 Countries

JEL Classification: C22; C23

1. Introduction

Empirical evidence on the stationarity of real interest rates is abundant but inconclusive thus far. The results from such studies are not only valuable for empirical researchers and policy makers, but they have also unveiled extremely important implications in international finance. Details about previous studies see the work of Rose (1988), Rapach and Weber (2004), Phillips (2005), Lai (2008), Rapach and Wohar (2004) and Ji and Kim (2011). In this empirical study we apply the Panel KSS test, which are the Kapetanios et al. (2003, hereafter, KSS) tests based on the SPSM procedure by Chortareas and Kapetanios (2009), with a Fourier function, to test the validity of stationarity in the real interest rates for the G-20 countries. To the best of our knowledge, this study is the first to date to utilize the Panel KSS unit root test with a Fourier function under the SPSM procedure on the real interest rates for the G-20 countries.

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Rose (1988) finds that the nominal interest rate is I(1), while the inflation rate is I(0), indicating a nonstationary real interest rate for each country under consideration. Rapach and Wohar (2004) suggest a very high degree of persistence in international real interest rates for 13 industrialized countries. Rapach and Weber (2004) indicates that the nominal interest rate and inflation rate are both I(1), and there is little robust evidence of cointegration in real interest rates. Phillips (2005) indicates that the real interest rates in the US are nonstationary over 1934-1997 and over the more recent subperiods 1961-1985 and 1961-1997. Lai (2008) shows that, when unit-root tests permitting a mean shift are applied, strong evidence in favor of no unit root can be uncovered, rejecting unit-root dynamics for both industrial and developing countries. Kim and Ji (2011) suggest strong evidence that, in both major Western and East Asian capital markets, real interest rates are mean-reverting. We found that the unit root test with Fourier function under the Sequential Panel Selection Method rejects the unit root process on the interest rates for all of the G-20 countries.

Recently, it has been reported that conventional unit root tests - the Augmented Dickey and Fuller (1981, ADF), the Phillips and Perron (1988, PP), and the Kwiatkowski *et al*. (1992, KPSS) tests, not only fail to consider information across regions, thereby leading to less efficient estimations, but also have lower power when compared with near-unit-root but stationary alternatives. In this regards, first generation panel-based unit root tests - Levin-Lin-Chu (Levin *et al*., 2002), the Im-Pesaran-Shin (Im *et al*., 2003), and the MW (Maddala and Wu, 1999) tests are developed. A serious drawback of the first generation panel-based unit root tests is that they do not take (possible) cross-sectional dependencies into account in the panel-based unit root test procedure. Hence, four second generation panel-based unit root tests of Bai and Ng (2004), Choi (2002), Moon and Perron (2004), and Pesaran (2007) are proposed. However, they are not informative in terms of the number of series that are stationary processes when the null hypothesis is rejected. In contrast to those panel-based unit root tests that are joint tests of a unit root for all members of a panel and that are incapable of determining the mix of I(0) and I(1) series in a panel setting, the Sequential Panel Selection Method (hereafter, SPSM), proposed by Chortareas and Kapetanios (2009), classifies a whole panel into a group of stationary series and a group of non-stationary series. In doing so, they clearly identify how many and which series in the panel are stationary processes.

Perron (1989) argued that if there is a structural break, the power to reject a unit root decreases when the stationary alternative is true and the structural break is ignored. This argument motivates the use of nonlinearly trend function in data generating process for unit root and stationary tests that avoid this problem. Ucar and Omay (2009) proposed a nonlinear panel unit root test by combining the nonlinear framework in Kapetanios *et al*. (2003, KSS) with the panel unit root testing procedure of Im et al. (2003), which has been prove to be useful in testing the mean reversion of time series. Both Becker et al. (2004, 2006) and Enders and Lee (2009) develop tests which model any structural break of an unknown form as a smooth process via means of Flexible Fourier transforms. Several authors, including Gallant (1981), Becker *et al*. (2004) and Enders and Lee (2009), and Pascalau (2010), show that a Fourier approximation can often capture the behavior of an unknown function even if the function itself is not periodic. The authors argue that their testing framework requires only the specification of the proper frequency in the estimating equations. By reducing the number of estimated parameters, they ensure the tests have good size and power irrespective of the time or shape of the break. Hence, this empirical study applies Panel KSS test, which are the Kapetanios *et al*. (2003, hereafter, KSS) tests based on the SPSM procedure by Chortareas and Kapetanios (2009), with a Fourier function, to test the validity of stationarity in the real interest rates for the G-20 countries.

The remainder of this empirical study is organized as follows. Section 2 presents the data used, and Section 3 describes the methodology, the empirical findings and policy implications. Finally, Section 4 presents some concluding remarks.

2. Data

This empirical study employs the real interest rates for the G-20 countries (i.e., United States, United Kingdom, Germany, France, Japan, Canada, Italy, Turkey, Mexico, South Africa, Netherlands, Belgium, Ireland, Denmark, Greece, Portugal, Spain, Austria, Finland and Sweden) over the span of 1980M1– 2011M4, with 376 monthly observations for each country. All the data are taken from the database entitled International Financial Statistics Databank, provided by the International Monetary Fund (IMF). We use one-month Treasury bill rates as the nominal interest rates. All nominal interest rates are then deflated by the ex-post one-month inflation rates to produce the ex-post real interest rate series.

3. Methodology, Empirical Results, Economic and Policy Implications

3.1. Sequential Panel Selection Method and Panel KSS Unit Root Test with a Fourier Function

In line with Kapetanios *et al*. (2003), the KSS test is based on detecting the presence of non-stationarity against a nonlinear but globally stationary exponential smooth transition autoregressive (ESTAR) process. The model is given by

$$\Delta X_t = \gamma X_{t-1}\{1-\exp(-\theta X_{t-1}^2)\} + \nu_t \,, \tag{1}$$

where: X_t is the data series of interest, ν_t is an i.i.d. error with zero mean and constant variance, and $\theta \ge 0$ is the transition parameter of the ESTAR model and governs the speed of transition. Under the null hypothesis X_t follows a linear unit root process, but X_t follows a nonlinear stationary ESTAR process under the alternative. One shortcoming of this framework is that the parameter γ is not identified under the null hypothesis. Kapetanios *et al*. (2003) have used a first-order Taylor series approximation for $\{1-exp(-\theta X_{t-1}^2)\}$ under the null hypothesis $\theta = 0$ and have then approximated equation (1) by using the following auxiliary regression:

$$\Delta X_t = \xi + \delta X_{t-1}^3 + \sum_{i=1}^{k} \theta_i \Delta X_{t-i} + \nu_t \quad t = 1,2,....,T \tag{2}$$

In this framework the null hypothesis and alternative hypotheses are expressed as $\delta = 0$ (non-stationarity) against $\delta < 0$ (non-linear ESTAR stationarity). The system of the KSS equations with a Fourier function that we estimate here is:

$$\Delta X_{i,t} = \xi_i + \delta_i X^3_{i,t-1} + \sum_{j=1}^{k1} \theta_{i,j} \Delta X_{i,t-j} + a_{i,1} \sin(\frac{2\pi kt}{T}) + b_{i,1} \cos(\frac{2\pi kt}{T}) + \varepsilon_{i,t} \quad (3)$$

where: $t = 1,2,....,T$. The rational for selecting $[sin(2\pi kt / T), cos(2\pi kt / T)]$ is based on the fact that a Fourier expression is capable of approximating absolutely integrable functions to any desired degree of accuracy. Meanwhile *k* represents the frequency selected for the approximation, and $[a_{i,1}, b_{i,1}]'$ measures the amplitude and displacement of the frequency component. As there is no a priori knowledge concerning the shape of the breaks in the data, a grid-search is first performed to find the best frequency.

The SPSM proposed by Chortareas and Kapetanios (2009) is based on the following steps:

(1) The Panel KSS test with/without Fourier function is first conducted to all real interest rates in the panel. If the unit-root null cannot be rejected, the procedure is stopped, and all the series in the panel are nonstationary. If the null is rejected, go to Step 2.

(2) Remove the series with the minimum KSS statistic since it is identified as being stationary.

(3) Return to Step 1 for the remaining series, or stop the procedure if all the series are removed from the panel.

Final result is a separation of the whole panel into a set of mean-reverting series and a set of non-stationary series.

3.2. Empirical Results

Figure 1 displays the time paths of the real interest rates for each G-20 country. We can clearly observe structural shifts in the trend of the data. Accordingly, it appears sensible to allow for structural breaks in testing for a unit root (and/or stationarity). The estimated time paths are also shown in the Figure 1. A further examination of the figures indicates that the all Fourier approximations seem reasonable and support the notion of long swings in the real interest rates.

Tables 1 and 2 report the results for the first generation and second generation panel unit root tests. In Table 1, three first-generation panel-based unit root tests yield diverse results: Levin-Lin-Chu test cannot reject the unit root hypothesis whereas Im-Pesaran-Shin and Maddala-Wu tests indicate that real interest rates are non-stationary in G-20 countries. Table 2 shows that based on the second generation panel-based unit root tests, the stationarity does hold among these G-20 countries.

To identify how many and which series in the panel are stationary processes, we proceed to the SPSM procedure mixed with the Panel KSS test. As a benchmark, we firstly report the results of the Panel KSS test without a Fourier function. Table 3 shows that, the null hypothesis of unit root was rejected when the Panel KSS test was first applied to the whole panel, producing a value of -3.6289 with a very small *p*-value approximating to zero. After implementing the SPSM procedure, we found Ireland is stationary with the minimum KSS value of -10.5947 among the panel. Then, Ireland was removed from the panel and the Panel KSS test was implemented again to the remaining set of series. After that, we found that the Panel KSS test still rejected the unit root null with a value of -3.2623 (*p*-value of nearly zero), and Portugal was found to be stationary with the minimum KSS value of -3.2623 among the panel this time. Then, Portugal was removed from the panel and the Panel KSS test was implemented again to the remaining set of series. The procedure was continued until the Panel KSS test failed to reject the unit root null hypothesis at the 10% significance level. To check the robustness of our test, we continued the procedure until the last sequence. Apparently, the SPSM procedure using the Panel KSS test (without a Fourier function) provided stationary evidence in the real interest rates for 16 out of the G-20 countries, with exception of Belgium, France, Netherland and Austria.

We go for the Panel KSS test with a Fourier function. First, a grid-search is performed to find the best frequency, as there is no a priori knowledge concerning the shape of the breaks in the data. Table 4 reports the results of Panel KSS test with a Fourier function. Particularly, we estimate equation (3) for each Fourier frequency integer k = 1 to 5, following the recommendations of Enders and Lee (2004, 2009) that a small frequency k can capture a wide variety of breaks. From the fourth column at the Table 4, the residual sum of squares (RSSs) indicates the optimal frequency integer k. Similarly, the procedure was again continued until the Panel KSS test failed to reject the unit root null hypothesis at the 10% significance level, and finally we found that the unit root hypothesis are rejected for 18 out of the G-20 countries, with exception for Netherland and Austria. Our empirical findings suggest that allowing for nonlinearities and structural breaks results in more rejection of the unit root null hypothesis.

Notably, both the Panel KSS tests by SPSM with/without Fourier function come to the same conclusion for the nonstationarity of Netherlands and Austria. Belgium is classified as non-stationary without Fourier function but as stationary with Fourier function, implying that structural change in real interest rate dynamics, shown by Figure 1, can be responsible for the observed unit root behavior. In both cases of with and without Fourier function, the strong evidence of stationarity among some EU member countries such as Ireland, Sweden, Portugal, Demark, Italy and Greece, can be explained by the influence from the monopoly of European Central Bank. By virtue of this monopoly, it can set the conditions at which banks borrow from the Central Bank. Therefore it can also influence the conditions at which banks trade with each other in the money market. The non-stationary of Japan and United States can be represented by the monetary policies to stimulate economic growth by Central Bank.

The major policy implication that emerges from this study is that the real interest rates are regime-wise stationary along with structure change presented by Fourier function, for all G-20 countries. Furthermore, the mean reversion property can be used with confidence for the stochastic modelling of real interest rates. However, the economist should be mindful of the presence of structural breaks or changes caused by monetary and economic policies in the behaviour of the real interest rates over time.

4. Conclusions

This study applied the Sequential Panel Selection Method (SPSM) to test the mean reversion properties in the real interest rates for the G-20 countries. We proposed a Panel KSS test with a Fourier function for the SPSM procedure in our empirical study. When unit-root tests permitting a Fourier function are applied, strong evidence in favor of stationarity or mean-reversion can be uncovered, rejecting unit-root dynamics for both industrial and developing countries. Empirical results indicate that the mean reversion in real interest rates holds true for 18 out of the G-20 countries, with exception for Netherland and Austria. Our results have important policy implications for the G-20 countries under study.

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Table 1

First Generation Panel Unit Root Tests

Levin, Lin and Chu (2002)	t_{ρ}^{*}	$\hat{\rho}$	t_{ρ}^{*B}	t_{ρ}^{*C}	
	6.149 (1.000)	-0.026*** (0.000)	4.232 (1.000)	4.281 (1.000)	
Im, Pesaran and Shin (2003)	t_bar_{NT}	$W_{t,bar}$	$Z_{t,bar}$	$t\_bar_{NT}^{DF}$	$Z_{t,bar}^{DF}$
	-2.227	-3.803*** (0.000)	-3.682*** (0.000)	-2.909	-7.289*** (0.000)
Maddala and Wu (1999)	P_{MW}	Z_{MW}			
	71.793*** (0.001)	3.555*** (0.000)			

Notes: **, ** and *** indicate significance at the 10%, 5% and 1% level, respectively. The numbers in parentheses denote the p-value.*

Table 2

Second Generation Panel Unit Root Tests

Bai and Ng (2004)	$\hat{r}$	$Z_{\hat{e}}^{c}$	$P_{\hat{e}}^{c}$	MQ_c	MQ_f
	3	0.817 (0.207)	47.312 (0.199)	0	0
Moon and Perron (2004)	t_a^*	t_b^*	$\hat{\rho}_{pool}^{*}$	t_a^{*B}	t_b^{*B}
	-270.360*** (0.000)	-23.230*** (0.000)	0.657	-305.773*** (0.000)	-25.284*** (0.000)
Choi (2002)	P_m	Z	L^*		
	14.265*** (0.000)	-8.567*** (0.000)	-10.047*** (0.000)		
Pesaran (2007)	P^*	$CIPS$	$CIPS^*$		
	11	-2.254** (0.030)	-2.254** (0.030)		

*Notes: *, ** and *** indicate significance at the 10%, 5% and 1% level, respectively. The numbers in parentheses denote the p-value.*

Table 3

Panel KSS Unit Root Test

Sequence	OU statistic	Min. KSS statistic	Series
1	-3.6289(0.0000)***	-10.5947	Ireland
2	-3.2623(0.0000)***	-5.1828	Portugal
3	-3.1556(0.0000)***	-5.1483	Sweden
4	-3.0384(0.0000)***	-4.9379	Mexico
5	-2.9197(0.0000)***	-4.6389	Japan
6	-2.8051(0.0000)***	-3.9788	Greece
7	-2.7212(0.0000)***	-3.8905	United States
8	-2.6313(0.0000)***	-3.7183	Italy
9	-2.5407(0.0000)***	-3.4447	Denmark
10	-2.4585(0.0002)***	-3.3311	Turkey
11	-2.3712(0.0006)***	-3.2555	South Africa
12	-2.273(0.0074)***	-2.8008	Canada
13	-2.207(0.0048)***	-2.7593	Finland
14	-2.1281(0.0308)**	-2.6336	United Kingdom
15	-2.0439(0.0698)*	-2.5599	Spain
16	-1.9407(0.0754)*	-2.4517	Germany
17	-1.8129(0.2694)	-2.4293	Belgium
18	-1.6075(0.4756)	-2.188	France
19	-1.3172(0.3416)	-1.7325	Netherlands
0	-0.9019(0.752)	-0.9019	Austria

Note: **, ** and *** denote significance at the 10%, 5% and 1% levels, respectively. The significance level is 5%. The maximum lag is set to be 8. The bootstrap replications are 5000. The numbers in parentheses denote the p-value. OU statistic is the invariant average KSS statistic (Ucar and Omay, 2009).*

Table 4

Panel KSS Unit Root Test with Fourier Function

Sequence	OU statistic	Min. KSS	Fourier(k)	Series
1	-4.5871(0.0000)***	-10.626	1	Ireland
2	-4.2578(0.0000)***	-5.8562	3	United States
3	-4.115(0.0000)***	-5.7239	4	Japan
4	-4.0008(0.0000)***	-5.3785	1	Sweden
5	-3.9053(0.0000)***	-5.1243	1	Portugal
6	-3.8011(0.0000)***	-5.0029	1	Mexico
7	-3.7062(0.0000)***	-4.5705	4	Denmark
8	-3.6127(0.0000)***	-4.349	1	Italy
9	-3.4946(0.0000)***	-3.9222	1	Greece
10	-3.3306(0.0000)***	-3.6229	4	Canada
11	-3.2721(0.0000)***	-3.5253	4	Belgium
12	-3.141(0.0000)***	-3.5117	2	United Kingdom
13	-3.0891(0.0000)***	-3.2106	2	Turkey
14	-3.0509(0.0000)***	-3.1737	5	Germany
15	-2.9867(0.0000)***	-3.1067	1	South Africa
16	-2.9607(0.0002)***	-3.0566	1	Spain
17	-2.7749(0.0008)***	-3.0208	1	Finland
18	-2.5804(0.025)**	-2.7412	2	France
19	-2.1637(0.24880)	-1.9711	2	Netherlands
20	-1.4837(0.4016)	-1.1007	1	Austria

Note: *, ** and *** denote significance at the 10%, 5% and 1% levels, respectively. The numbers in parentheses denote the p-value. The bootstrap replications are 5000. OU statistic is the invariant average KSS statistic (Ucar and Omay, 2009).

Figure 1

Time Series Plots of Interest Rates for the G-20 Countries and Fitted Nonlinearities (1980M1-2011M4)