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THE EXPECTATİON HYPOTHESİS OF THE TERM STRUCTURE OF INTEREST RATES: EVİDENCE FROM SELECTED HİGH INCOME OECD COUNTRİES

Abstract. *This paper empirically investigates the expectation hypothesis of the term structure of interest rates for selected high income OECD countries over the period from 1990:01 through 2010:04 by means of fractional cointegration approach. The results show that long term and short term interest rates for all selected countries are not fractionally cointegrated, implying unvalidity of the expectation hypothesis of the term structure.*

Keywords: *Expectation Hypothesis, Term Structure of Interest Rates, Fractional Cointegration*.

JEL Classification C2, E43.

Introduction

The expectation hypothesis of the term structure suggests that a long term interest rate can be represented as a weighted average of the present and expected future short term interest rates. In other words, according to this hypothesis, long term interest rates should reflect future short term changes. Since this simple theory has an importance in assessing the impact of monetary policy of a country, predicting interest rates, exchange rates, economic activity and providing information about expectations of participants in financial markets, an enormous amount of attention has been given to investigate the expectation hypothesis of the term structure of interest rates in financial economics literature.

The expectation theory of the term structure is the joint hypothesis that agents hold national expectations and term premia are invariant. These time varying term premia or forecast errors which appear biased when viewed ex post, cause to reject the expectation hypothesis of term structure (Hezaji et. al., 2000). Different studies which use different econometric methods, test different implications of the

expectations theory and look at different interest rate maturities give contradictory results. The studies including Shiller(1979), Fama(1984), Mankiw(1986), Campbell and Shiller(1987, 1991), Boothe(1991), Campbell(1995), Siklos and Wohar(1996), Sarno et. al(2007) reject the expectation hypothesis of term structure while the studies including Hall et. al(1992), Engsted and Tanggaard(1994), Hardouvelis(1994), Hurn et. al(1995), Cuthbertson(1996) support the expectation hypothesis.

Generally, the cointegration methodology is used in order to test expectation hypothesis of term structure in the literature. Existence of a long run relationship between long term and short term interest rates is a necessary condition for corresponding hypothesis to hold(Campbell and Shiller, 1987). If the expectation hypothesis holds, the term spread is stationary, hence, short term and long term interest rates are cointegrated. Since the traditional cointegration methods are too restrictive because of they assume that all the variables are integrated of order one, $I(1)$ and restrict error correction term to be $I(0)$, it is possible to use other recently developed techniques for expectation hypothesis.

The aim of this paper is to investigate the expectation hypothesis of the term structure of interest rates for selected high income OECD countries over the period from 1990:01 to 2010:04 by using fractional cointegration concept which requires only a mean reverting relationship between the considered series. Lardic and Mignon(2004) test the expectation hypothesis by investigating the fractional cointegration relationship between short term and long term interest rates for G7 countries and find that the interest rates are fractionally cointegrated for the countries except Germany. The difference of our paper from the paper of Lardic and Mignon(2004) is that we use fractional cointegration approach introduced by Gil-Alana(2003) and Caporale and Gil-Alana(2004).

The outline of the paper is organized as follows: Section 2 briefly discusses the expectation hypothesis of the term structure of interest rates. Section 3 outlines the econometric methodology. Section 4 discusses the data and reports the empirical results. Finally, Section 5 concludes.

2. The Expectation Hypothesis of the Term Structure of Interest Rates

The expectation theory of the term structure of interest rates is a relationship between a longer term *n*-period interest rate $R_t^{(n)}$ and a shorter term *m*-period interest rate $R_t^{(m)}$. In details, with $n > m$, $R_t^{(n)}$ is the weighted average of the expected future *m* period interest rate $R_t^{(m)}$, and plus a term premium. The specification of this relationship can be seen in below:

$$R_t^{(n)} = \frac{1}{k}\sum_{i=0}^{k-1} E_t R_{t+i}^{(m)} + E_t\theta_t \quad , \quad k = n/m \tag{2.1}$$

where E_t is the expectation operator conditional on information at time *t* and θ_t gives the term premium which is a predictable excess return on the *n*-period bond over the *m*-period bond. This term premium may vary with *n* and *m* but it is assumed to be constant through time (Campbell and Shiller, 1991).

By re-arranging Equation (2.1), the yield spread between the *n*-period rate and the *m*-period rate can be obtained as follows:

$$S_t^{(n-m)} = R_t^{(n)} - R_t^{(m)} = \frac{1}{k}\sum_{i=1}^{k-1}\sum_{k=1}^{i} E_t \Delta R_{t+i}^{(m)} + E_t\theta_t \tag{2.2}$$

Here, if $R_t^{(n)}$ and $R_t^{(m)}$ have a unit root, interest rate spread ($R_t^{(n)} - R_t^{(m)}$) will be a stationary process. Thus, it can be said that $R_t^{(n)}$ and $R_t^{(m)}$ have a cointegrating relationship in the long run with a cointegrating vector (-1, 1)' and expectation hypothesis of term structure holds (Lardic and Mignon, 2004). On the other hand, there is a possibility that the error term in the cointegrating regression might be fractionally integrated, rather than stationary. In other words, if $R_t^{(n)} - R_t^{(m)}$ is a long memory process, then $R_t^{(n)}$ and $R_t^{(m)}$ are said to be fractionally cointegrated. In this context, deviations from the long run relationship shared by $R_t^{(n)}$ and $R_t^{(m)}$ take a long time to dissipate and return these two series to their equilibrium relationship (Bekdache and Baum 2000).

3. Methodology

In this paper, we investigate the expectation hypothesis of the term structure of interest rates by means of fractional cointegration approach, since traditional cointegration methods have low power when the residuals are mean reverting but not $I(0)$. This approach allows residuals to be fractionally integrated rather than stationary. For this purpose, we follow fractional cointegration concept of Gil-Alana(2003) and Caporale and Gil-Alana(2004) based on Robinson(1994a) test. In order to be able to understand the theoretical structure of their concept, it is better to give a brief description of Robinson test. Robinson(1994a) considers the following regression model,

$$y_t = \beta' z_t + x_t \quad , \quad t = 1, 2, ... \tag{3.1}$$

where y_t is the observed time series for $t = 1, 2, ...T$, $\beta = (\beta_1, ..., \beta_k)'$ is a $(k \times 1)$ vector of unknown parameters, z_t is a $(k \times 1)$ vector of deterministic regressors such as an intercept or a linear trend. And the regression errors x_t can be explained as follows:

$$(1-L)^d x_t = u_t \quad , \quad t = 1, 2, ... \tag{3.2}$$

where L is the lag operator and u_t is an $I(0)$ process. Here, d can take any real value. Robinson suggests a Lagrange Multiplier (LM) test statistic for testing unit roots and other forms of nonstationary hypotheses, embedded in fractional alternatives. The main advantage of the procedure is that it tests unit and fractional roots with a standard null limit distribution, which is unaffected by inclusion or not of deterministic trends. The notation of the LM test statistic under the null hypothesis $H_0 : d = d_0$ can be seen in below:

$$\hat{r} = \frac{T^{1/2}}{\hat{\sigma}^2} \hat{A}^{1/2} \hat{a} \tag{3.3}$$

where T is the sample size and

$$\hat{a} = \frac{-2\pi}{T} \sum_{j=1}^{T-1} \psi(\lambda_j) g(\lambda_j; \hat{\tau})^{-1} I(\lambda_j) \;\; ; \;\; \hat{\sigma}^2 = \sigma^2(\hat{\tau}) = \frac{2\pi}{T} \sum_{j=1}^{T-1} g(\lambda_j; \hat{\tau})^{-1} I(\lambda_j) ;$$

$$\hat{A} = \frac{2}{T} \left(\sum_{j=1}^{T-1} \psi(\lambda_j)^2 - \sum_{j=1}^{T-1} \psi(\lambda_j) \hat{\varepsilon}(\lambda_j)' \times \left(\sum_{j=1}^{T-1} \hat{\varepsilon}(\lambda_j) \hat{\varepsilon}(\lambda_j)' \right)^{-1} \times \sum_{j=1}^{T-1} \hat{\varepsilon}(\lambda_j) \psi(\lambda_j) \right)$$

$$\psi(\lambda_j) = \log \left| 2 \sin \frac{\lambda_j}{2} \right| ; \qquad \hat{\varepsilon}(\lambda_j) = \frac{\partial}{\partial \tau} \log g(\lambda_j; \hat{\tau}_j) ; \qquad \lambda_j = \frac{2\pi j}{T} ;$$

$$\hat{\tau} = \arg\min_{\tau \in T^*} \sigma^2(\tau) \; .$$

Here, $I(\lambda_j)$ is the periodogram of u_t and T^* is a compact subset or the Euclidean space. Robinson(1994a) showed that the test statistic under certain regularity conditions is as below:

$$\hat{r} \to_d N(0,1) \text{ as } T \to \infty. \tag{3.4}$$

Thus, a one sided $100\alpha\%$ level test of the null hypothesis $H_0 : d = d_0$ against the alternative $H_1 : d > d_0$ is given by the rule "Reject H_0 if $\hat{r} > z_\alpha$". Conversely, a

one sided $100\alpha\%$ level test of $H_0 : d = d_0$ against the alternative $H_1 : d < d_0$ is given by the rule "Reject H_0 if $\hat{r} < -z_\alpha$". Following these rules, Gil-Alana(2003) and Caporale and Gil-Alana(2004) suggest a fractional cointegration concept based on the following model:

$$(1-L)^{d+\theta} e_t = v_t \quad , \quad t = 1, 2, ... \tag{3.5}$$

where e_t is the OLS residuals from the cointegrating regression and v_t is $I(0)$. The null $H_0 : \theta = 0$ hypothesis is tested against the one sided alternative $H_1 : \theta < 0$. If H_0 hypothesis on the estimated residuals is rejected, there is an evidence of fractional cointegration of a certain degree since the residuals are integrated of a smaller order than the individual series. If we cannot reject the null hypothesis, it can be concluded that there is no evidence of fractional cointegration since the integration order of the residuals are same as the univariate series.

4. Data and Empirical Results

In order to examine the expectation hypothesis of the term structure of interest rates for selected high income OECD countries: Belgium, France, Italy, Spain, Canada, Switzerland and UK, we use quarterly series of short term and long term interest rates over the period from 1990:01 through 2010:04. We consider 3-month treasury bill rates (TR) for short term interest rates and 10-year government bond rates (GOV) for long term interest rates. The source of the data is IMF's International Financial Statistics (IFS) database. The first step of the empirical analysis is to investigate the integration order of the individual series. For this purpose, we perform Augmented Dickey Fuller (ADF), Philips and Perron (PP) and Kwiatkowski-Phillips-Schmidt and Shin (KPSS) unit root tests. These tests differ in the null hypothesis: The null hypothesis of the ADF and PP tests is that a time series contains a unit root, I(1) process, while the KPSS test has the null hypothesis of stationarity, I(0) process. The results of unit root tests under the different null hypothesis are characterised by four possible outcomes (Barkoulas et. al, 1997): i) When we reject the null hypothesis of the ADF and PP tests and we cannot reject the null hypothesis of the KPSS test, a time series is stationary. ii) Conversely, failure to reject a unit root by ADF and PP tests and rejection stationarity by KPSS test supports that a time series is nonstationary. iii) Failure to reject a unit root and stationary null hypotheses shows that the series are not sufficiently informative with respect to the low frequency properties. iv) rejection of null hypotheses indicates that series are not well represented as either I(0) and I(1), which indicates that the series appear to be a long memory process. The results of the ADF, PP and KPSS unit root tests are reported in Table 1.

Table 1: The results of ADF, PP and KPSS unit root tests

Countries	Variables	ADF	PP	KPSS
Belgium	GOV	-2.484	-2.222	0.245[a]
	ΔGOV	-6.297[a]	-6.243[a]	0.191
	TR	-1.967	-2.138	0.200[b]
	ΔTR	-7.471[a]	-7.478[a]	0.153
France	GOV	-3.051	-2.433	0.232[a]
	ΔGOV	-5.998[a]	-5.983[a]	0.122
	TR	-2.016	-2.293	0.210[b]
	ΔTR	-7.956[a]	-7.951[a]	0.103
Italy	GOV	-1.108	-1.688	0.263[a]
	ΔGOV	-6.263[a]	-5.357[a]	0.161
	TR	-2.419	-2.059	0.238[a]
	ΔTR	-6.011[a]	-5.986[a]	0.085
Spain	GOV	-2.353	-1.700	0.277[a]
	ΔGOV	-5.164[a]	-5.284[a]	0.030
	TR	-2.725	-1.768	0.257[a]
	ΔTR	-5.092[a]	-5.090[a]	0.160
Canada	GOV	-2.403	-2.400	0.199[b]
	ΔGOV	-8.135[a]	-8.130[a]	0.105
	TR	-5.052[a]	-3.190[b]	0.124[c]
	ΔTR	-	-	0.076
Switzerland	GOV	-3.315[c]	-2.763	0.201[b]
	ΔGOV	-	-6.493[a]	0.062
	TR	-2.126	-2.054	0.226[a]
	ΔTR	-6.311[a]	-6.358[a]	0.061
UK	GOV	-3.713[b]	-2.418	0.238[a]
	ΔGOV	-	-7.076[a]	0.166
	TR	-3.673[b]	-2.874	0.906[a]
	ΔTR	-	-5.270[a]	0.188

[a, b] and [c] denote that the unit root null hypothesis is rejected at the 1%, 5% and 10% significance levels.

As can be seen from the table, the results of ADF test indicate that long term interest rate series are nonstationary for the countries except Switzerland and UK while short term interest rates are nonstationary for the countries except Canada and UK. According to PP unit root test results, long term interest rates are nonstationary in level but stationary in the first difference for all selected countries while short term interest rate series are nonstationary for the countries except Canada. On the other hand, KPSS test results indicate that both long term and short term interest rates are nonstationary in level for all countries. These contradictory results may arise because the $I(d)$ concept where d is an integer, is too restrictive. Next, we also perfom Robinson(1994a) univariate unit root test on the individual series. The one sided $\hat{r}$ statistic values for $d = 1$ are reported in Table 2.

Table 2: The results of Robinson test for unit root

Countries	Variables	Test statistics
Belgium	GOV	0.084[b]
	TR	-0.095[b]
France	GOV	0.250[b]
	TR	-0.143[b]
Italy	GOV	0.513[b]
	TR	0.610[b]
Spain	GOV	0.686[b]
	TR	1.517[b]
Canada	GOV	0.159[b]
	TR	0.579b
Switzerland	GOV	0.413[b]
	TR	0.209[b]
UK	GOV	0.217[b]
	TR	0.464[b]

[b] indicates nonrejection values of the unit root null hypothesis ($d_0 = 1$) at the 95% significance level. **In bold**: the absolute value of the minimum of the Robinson test statistic. We consider only the test where u_t is assumed to be white noise, for the specification with an intercept.

The results show that there is evidence of a unit root at the 95% significance level for short term and long term interest rate series of all countries. Having found that all series exhibit a unit root behavior, following Gil-Alana(2003) and Caporale and Gil-Alana(2004), we investigate whether there is a fractional cointegration relationship between short term interest rates and long term interest rates. The long term interest rates are regressed against short term interest rates for each country, consistently with expectation hypothesis theory of term structure, and the residuals are obtained from these cointegrating regressions. The results of Robinson test applied on the residuals are tabulated in Table 3. Here, different values of d are considered, thus testing for a unit root ($d = 1$) but also other fractional possibilities.

Table 3: The results of Robinson test on the estimated residuals

d_0	Belgium	France	Italy	Spain	Canada	Switzerland	UK
0.00	9.843	8.852	9.400	10.323	12.191	8.325	12.885
0.05	9.420	8.386	9.052	10.015	11.684	7.718	12.440
0.10	8.989	7.912	8.683	9.681	11.155	7.111	11.960
0.15	8.549	7.428	8.290	9.317	10.604	6.504	11.444
0.20	8.101	6.937	7.876	8.924	10.033	5.898	10.893
0.25	7.645	6.440	7.442	8.502	9.446	5.296	10.309

0.30	7.182	5.939	6.991	8.050	8.846	4.701	9.694
0.35	6.714	5.437	6.526	7.572	8.237	4.118	9.053
0.40	6.241	4.935	6.051	7.069	7.623	3.549	8.392
0.45	5.766	4.437	5.572	6.547	7.009	2.998	7.718
0.50	5.290	3.945	5.092	6.009	6.398	2.468	7.036
0.55	4.817	3.462	4.616	5.461	5.794	1.961	6.356
0.60	4.347	2.990	4.149	4.908	5.201	1.479[b]	5.684
0.65	3.884	2.531	3.694	4.356	4.621	1.023[b]	5.027
0.70	3.430	2.087	3.255	3.811	4.057	0.593[b]	4.391
0.75	2.985	1.659	2.834	3.278	3.512	0.190[b]	3.782
0.80	2.553	1.249[b]	2.432	2.760	2.988	**-0.187[b]**	3.204
0.85	2.134	0.858[b]	2.052	2.262	2.486	-0.538[b]	2.658
0.90	1.729	0.485[b]	1.692	1.787	2.008	-0.864[b]	2.146
0.95	1.341[b]	0.332[b]	1.355[b]	1.336[b]	1.554[b]	-1.166[b]	1.669
1.00	**0.968[b]**	**-0.202[b]**	**1.037[b]**	**0.911[b]**	**1.124[b]**	-1.445[b]	**1.226[b]**

[b] indicates nonrejection values of the null hypothesis at the 95% significance level. **In bold**: the absolute value of the minimum of the Robinson test statistic. We consider only the test where u_t is assumed to be white noise, for the specification with an intercept.

The results show that nonrejection values occur at the values of $d = 0.95$ and 1 for Belgium, Italy, Spain and Canada; $d = 0.60, 0.65, 0.70, 0.75, 0.80, 0.85, 0.90, 0.95$ and 1 for Switzerland; $d = 0.80, 0.85, 0.90, 0.95$ and 1 for France and $d = 1$ for UK. It is clear that unit root null hypothesis ($d = 1$) cannot be rejected at all. On the other hand, for all countries except Switzerland, the minimum of the absolute values of the Robinson test statistics, which is indicated in bold, corresponds to the value of the d parameter equal to 1. For Switzerland, it can be seen that the unit root null hypothesis cannot be rejected although the minimum of the absolute values of the test statistics occurs at the value of $d = 0.80$. These results indicate that there is no evidence of fractional cointegration relationship between short term and long term interest rates, implying unvalidity of the expectation hypothesis of the term structure for considered countries.

Conclusions

In this paper, we examine the expectation hypothesis of the term structure of interest rates for selected high income OECD countries: Belgium, France, Italy, Spain, Canada, Switzerland and UK, over the period from 1990:01 through 2010:04 in the context of fractional cointegration. As a first step, the stationarity properties of the short term and long term interest rate series are investigated by using ADF, PP and KPSS unit root tests. Since these traditional unit root tests give contradictory results, we also apply Robinson(1994a) test on the individual series for a unit root case ($d = 1$). According to the obtained findings, the evidence of a

unit root for short term and long term interest rate series is found for all countries. In the next step, we investigate whether there is a fractional cointegration relationship between short term and long term interest rates following fractional cointegration procedure of Gil-Alana(2003) and Caporale and Gil-Alana(2004). The results indicate that there is no evidence of fractional cointegration relationship between short term interest rates and long term interest rates. Hence, it can be concluded that the expectation hypothesis of the term structure is not valid for considered coutries.

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