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BEHAVIOR OF TREASURY BOND RATES IN THE CE4 COUNTRIES: A COINTEGRATION ANALYSIS

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ABSTRACT

This article examines the behavior of Treasury bond rates in the CE4 countries. The Granger-causality tests were based on two testing approaches: the vector error correction modeling approach outlined in Toda and Philips. The other is the augmented level VAR modeling with integrated and cointegrated processes (of arbitrary orders) separately introduced by Toda and Yamamoto (1995) and Dolado and Lütkepohl (1996). Granger causality tests based on the VECM suggests only unidirectional causal linkages from changes in the Hungarian Treasury bond rates to changes in the Treasury bond rates in the Czech Republic, Poland and Slovakia. Test based on the augmented VAR procedure yields similar results from VECM in addition to a very strong unidirectional causality from the Hungarian Treasury to the Slovak bond rates. These empirical findings may be explained by factors such as relatively ineffective governance, the health of the government budget or inadequate institutional frameworks— both before and after the transformation to the market system— in those CE4 countries.

Keywords: Treasury bond rates; CE4 countries; Johansen cointegration test; TYDL augmented VAR procedure.

***JEL classification codes:** C22; F36; G14*

I. INTRODUCTION

With recent modern technological advances in telecommunications, transportations, the internet, computerization of production among others — which facilitate world trade and travelling, international flows of goods and services, financial assets and people among countries have accelerated rapidly since the collapse of the Soviet bloc in the 1980's. Moreover, the neoclassical export-led development strategy, advocated by the Bretton Woods system since World War II, and more memberships in the World Trade Organization since 1995 -with enforceable trade rules- have caused the volume of international trade to increase exponentially— including the flow of financial assets such as bonds and currencies.

This unprecedented mobility of capital due to new technologies and more international investment opportunities has been an impetus for nations around the world to embrace world trade and to improve economic efficiency— especially in the former planned economies of the

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four Central European countries— the Czech Republic, Hungary, Poland, and Slovakia. They are commonly known as the CE4 countries among the international financial institutions such as the International Monetary fund and the World Bank. Thus, newly free-market economies present an additional opportunity for investors to find the most attractive markets in the world to make financial investments— either in the forms of foreign direct investments or purchases for their portfolios.

However, yields on investable assets are not uniformed among diverse economies –even with seemingly similar economies of those CE4 members because of different socioeconomic factors in those countries. For instance, Adarove and Tchaidze (2011, p. 3) articulated that the CE4 members experienced similar transformation process from a centrally-planned to market-oriented economies from the 1980s. They also shared many common features in their institutional background and policy experiences with other emerging markets elsewhere— mostly in Asia and Latin America. Similarly, their financial intermediation is dominated by the banking sector, and their respective stock markets are relatively less relevant in terms of raising source of investable funds for economic development.

On the other hand, the CE4 countries already have developed and high-income market economies. As pointed out by Adarove and Tchaidze (2011, p. 3), according to the IMF classification both the Czech Republic and the Slovak Republic have been advanced economies since 2008. Additional, according to the 1980 annual report of the Economic Commission for Europe, Hungary was then the most technologically advanced country in the Council for Mutual Economic Assistance— popularly known as Comecon, a now defunct Soviet-led economic organization in the Eastern Bloc in reply to the Organization for European Economic Co-operation in western Europe— during the Cold War years.

However, Adarove and Tchaidze (2011, p. 3) observed that despite considerable efforts undertaken to facilitate financial development, it is frequently argued that financial systems in the CE4 countries are generally underdeveloped. More specifically, these authors further articulated that while public bond markets in the CE4 nations are as developed as found in other advanced economies. But, the private financial segments—the private credit market, the private bond market, and the stock market—are considerably to be less developed by western standards. Adarove and Tchaidze (2011) attributed this observed phenomenon to weak governance and other institutional impediments.

Most importantly, with almost identical levels of economic development, similar historical events, shared borders and linked government bond markets, the yields on public bonds of CE4 countries are expected to be cointegrated. However, it is also reasonable to conjecture that the weak governance and other institutional impediments in each particular member of CE4— articulated by Adarove and Tchaidze (2011) — may result in different risk profiles in holding bonds of these CE4 countries. These may, in turn, cause the yield on bonds to be differed and independent among those seemingly similar economies. Thus, it is worth to empirically investigate the behaviors of Treasury bond rates in those developed economies.

To achieve the above objective, this study follows Awokuse (2005-a) to investigate the dynamic linkages among the Treasury bond rates in the CE4 countries by applying the recent advances in time series statistical techniques: (i) the vector error correction modeling (VECM)

approach outlined in Toda and Phillips (1993); and (ii) the augmented VAR[k+d(*max*)] model with integrated and cointegrated processes (of arbitrary orders), separately introduced by Toda and Yamamoto (1995) and Dolado and Lütkepohl (1996)— henceforth, TYDL. In this model specification, *k* is the lag order of the original VAR(*k*) and *d(max)* is the order of cointegration of the time series under consideration. As pointed out by Awokuse (2005-a, p. 693), the latter methodological approach is useful because it bypasses the need for potentially biased pre-tests for unit roots and cointegration, common to other formulations.

II. THE DATA AND METHODOLOGY

1. Data

This empirical study uses available Treasury bond rates in CE4 countries. The data set covers the interval from 2001: 01 to 2011: 09. The Treasury bond rates for the Czech Republic, Hungary, Poland, and the Slovak Republic are denoted by CZECH, HURGY, POLND, and SLOVK, respectively. All time series data are collected from the International Financial Statistics— published by the International Monetary Fund.

Figure 1

BEHVIOR OF TREASURY BOND RATES OF THE CE4 COUNTRIES

January 2001 to September 2011

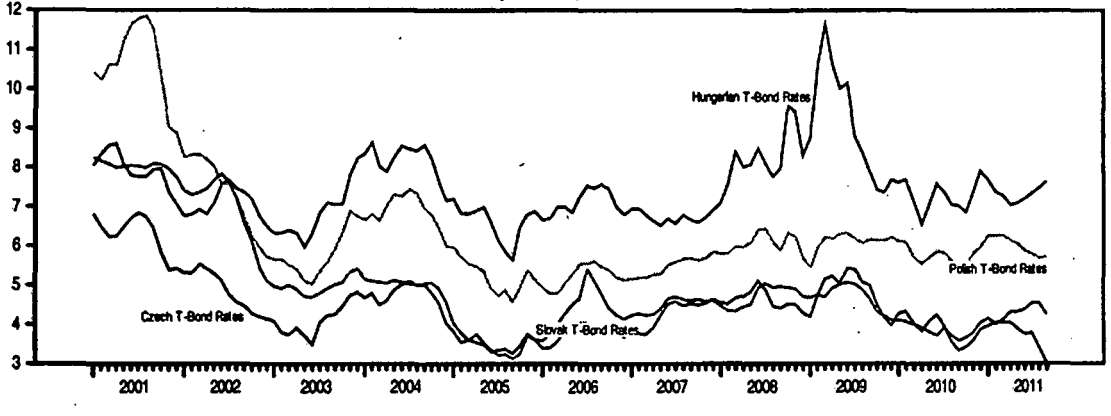

Figure 1 displays the behavior of the respective Treasury bond rate of CE4 countries over the sample period. A close examination of Figure 1 suggests seemingly simultaneous movements of these Treasury bond rates.

2. Methodological Method

In order to apply augmented VAR[k+d(*max*)] model, developed by TYDL, the lag order of the original VAR(*k*) and the order of cointegration, *d(max)*, must be determined. As to the maximum order of integration of the time series in question, *d(max)*, the two standard unit root tests were conducted. They are: the augmented Dickey–Fuller (1979) and Phillip–Perron (1988) tests. The null hypothesis for both tests is that a unit root exists in the autoregressive representation of the

series. The augmented Dickey-Fuller and Phillip-Person unit root test results are reported in Table 1. An analysis of the test results suggests the presence of unit roots in levels and all of the series are stationary after first differencing. These findings indicate that the time series under consideration are non-stationary and integrated of order I(1)

Table 1
ADF and PP Test Results, CE4 Countries, Monthly Data 2001: 01 to 2011: 09

	Augmented Dickey - Fuller		*Phillip - Person*	
Series	*Level*	*First Differencing*	*Level*	*First Differencing*
CZECH	-2.4528	-7.6880*	-2.5469	-7.4602*
HURGY	-2.8974	-10.3359*	-2.7914	-8.7163*
POLND	-2.5302	-6.9134*	-2.5242	-6.9134*
SLOVK	-2.3955	-6.3197*	-2.3793	-6.3522*

Note: * denotes rejection of the hypothesis at the 1 percent level.

The lag order of the original VAR model, k, can be determined by using several lag order selection criteria such as the sequential modified LR test statistic (LR), final prediction error (FPE), Akaike information criterion (AIC), Schwarz information criterion (SIC), and Hannan-Quinn information criterion (HQ). The results of the lag selection procedure are summarized in Table 2. The LR, FPE, AIC, and HQ suggest using a lag of two. Subsequent analysis therefore proceeds with the use of VAR with lag length $k = 2$.

Table 2
Maximum Lag length: CE4 Countries, Monthly Data 2001: 01 to 2011: 09

Lag	*LogL*	*LR*	*FPE*	*AIC*	*SIC*	*HQ*
0	-530.7395	NA	0.061074	8.555832	8.646338	8.592600
1	40.07127	1095.957	8.53e-06	-0.321140	0.131390	-0.137301
2	86.98305	87.06825*	5.20e-06*	-0.815729*	-0.001174*	-0.484818*
3	100.4231	24.08465	5.43e-06	-0.774770	0.401808	-0.296789
4	112.7115	21.23423	5.79e-06	-0.715384	0.823219	-0.090331

Notes: * indicates lag order selected by the criterion.
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SIC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Additionally, Engle and Granger (1987) articulated that if two series are integrated of order one, I(1), there is need to test for the possibility of a long-run cointegrating relationship among the variables. Since the cointegration and error correction methodology is well documented elsewhere (Engle and Granger 1987; Johansen and Juselius 1990; Banerjee *et al.* 1993,) only a brief overview is provided here. Johansen and Juselius' (1990) multivariate cointegration model is based on the error correction representation given by:

$$\Delta X_t = \mu + \sum_{i=1}^{p-1} \Gamma_i \Delta X_{t-1} + \Pi X_{t-1} + \varepsilon_t \qquad (1)$$

where X_t is an $(n \times 1)$ column vector of p variables, μ is an $(n \times 1)$ vector of constant terms, Γ and Π represent coefficient matrices, Δ is a difference operator, k denotes the lag length, and $\varepsilon_t \sim N(0, \Sigma)$. The coefficient matrix, Π, is known as the impact matrix, and contains information about the long-run relationships. Johansen and Juselius' (1990) methodology requires the estimation of the VAR equation (1), and the residuals are then used to compute two likelihood ratio (LR) test statistics that can be used in the determination of the unique cointegrating vectors of X_t. The number of cointegrating vectors can be tested for using two statistics: the trace test and the maximal eigenvalue test. The testing results are reported in Table 3.

Table 3
Johansen Cointegration Test Results, CE4 Countries, Monthly Data 2001: 01 to 2011: 09

	Trace Statistics		*Max-Eigen Statistics*	
Number of cointegrating vectors	*Statistics*	*C (5%)*	*Statistics*	*C (5%)*
r ≤ 0	57.82515*	54.07904	24.79570	28.58808
r ≤ 1	33.02946	35.19275	18.14356	22.29962
r ≤ 2	14.88589	20.26184	10.27031	15.89210
r ≤ 3	4.615586	9.164546	4.615586	9.164546

Note: * denotes rejection of the hypothesis at the 5 percent level.

As shown in Table 3, the calculated Max-Eigen statistics suggest the existence of, at most, one cointegrating vector. This implies the presence of four independent common stochastic trends in this system of five variables.

Moreover, the augmented VAR procedure, proposed by Toda and Yamamoto (1995) and Dolado and Lütkepohl (1996), complements the VECM technique because it allows for causal inference based on an augmented level VAR with integrated and cointegrated processes. The dynamic causal relationships among the Treasury bond rates in CE4 countries are examined, using the following VAR in level specification:

$$X_t = \mu + \sum_{i=1}^{p-1} \Gamma_i X_{t-k} + \varsigma_t \qquad (2)$$

where X_t is an $(n \times 1)$ column vector of p variables, μ is an $(n \times 1)$ vector of constant terms, Γ represents coefficient matrices, k denotes the lag length, and ς_t is *i.i.d.* and p-dimensional Gaussian error with mean zero and variance matrix Λ.

As pointed out by Awokuse (2005-a, p. 695), the TYDL procedure uses a modified Wald test for the restriction on the parameters of the VAR(k) model. This test has an asymptotic chi-squared distribution with k degrees of freedom in the limit when a VAR[k+$d(max)$] is estimated, where d(max) is the maximal order of integration for the series in the system. Awokuse (2005-b, p. 852) further articulates the attraction of the TYDL approach in that prior knowledge about cointegration and testing for unit root are not necessary once the extra lags, i.e., d(max) lags, are included, Given that VAR(k) is selected, and the order of integration d(max) is determined, a level VAR can then be estimated with a total of p = [k+d (max)] lags. Finally, the standard Wald

tests are applied to the first k VAR coefficient matrix (but not all lagged coefficients) to make Granger causal inference.

III. EMPIRICAL RESULTS

Based on the above determined appropriate lag length $k = 2$ and the $d(max) = 1$, the Granger causality test results using both the VECM and the augmented level VAR specifications are reported in Table 4. F-statistics and p-values (in parentheses) for Granger causality tests from the VECM specification are presented in Table 4(a).

Table 4
Granger Causality Test Results, CE4 Countries, Monthly Data 2001: 01 to 2011: 09

(a) Results based on error correction model (ECM)

Dep. Variables	*Short run lagged differences (F-statistics)* *ΔCZECH*	*ΔHUGRY*	*ΔPOLND*	*ΔSLOVK*
ΔCZECH	-	4.1210 (0.0162)	1.8120 (0.1633)	0.0228 (0.9770)
ΔHUGRY	0.4201 (0.6570)	-	0.1662 (0.8469)	1.8497 (0.1587)
ΔPOLND	2.0058 (0.1345)	4.3557 (0.0128)	-	0.5099 (0.6006)
ΔSLOVK	2.0156 (0.1332)	2.0508 (0.1286)	0.0100 (0.9901)	-

(b) Results based on an augmented VAR model (TYDL procedure)

Dep. Variables	*Modified Wald-statistics* *CZECH*	*HUGRY*	*POLND*	*SLOVK*
CZECH	-	5.6882 (0.0582)	3.1733 (0.2046)	0.9039 (0.6364)
HUGRY	1.3215 (0.5165)	-	0.2584 (0.8788)	4.7297 (0.0940)
POLND	3.5184 (0.1722)	6.0128 (0.0495)	-	1.4867 (0.4755)
SLOVK	6.9324 (0.0312)	6. 5214(0.0384)	0.2961 (0.8624)	-

Notes: The [k+d(max)]th order level VAR was estimated with d(max) = 1 for the order of integration equals 1.
Lag length selection of k=2 was based on all LR, FPE, AIC, SIC, and HQ.
Reported estimates are asymptotic Wald statistics. Values in parentheses are p-values.

An analysis of the empirical results of the VECM [see panel (a) of Table 4] indicates the only exogene which is changes in the Hungarian Treasury bond rate to changes in the Treasury bond rates in three other economies in the CE4 countries. Moreover, the dynamic causalities from changes in the Hungarian Treasury rate to changes in the Czech and the Polish Treasury bond yield are very strong as indicated by the p-values; while the linkage to changes in the Slovak bond rate is only marginal. There is no other Granger causality, unidirectional or otherwise, among changes in Treasury bond rates in the CE4 countries. Except for the very strong unidirectional causality from the Hungarian Treasury bond rate to the yield of Slovak bond—which is similar to conclusions from panel (a) of Table 4. The causality results from the TYDL testing approach [see panel (b) of Table 4] also indicate that the causal link between changes in the Hungarian Treasury to the Treasury bond rates of other CE4 countries exist.

These empirical findings suggest that only changes in the Hungarian Treasury bond rate Granger causes changes in the bond yields in the Czech Republic, Poland and Slovakia. As to the cointegration of the levels of the Treasury bond rates in the CE4 countries, the empirical findings indicate the same results. Moreover, there exists an additional unidirectional linkage

from the yield of Czech Treasury bond to the Slovak Treasury bond rate during the study period. In line with Adarove and Tchaidze's (2011) findings, these empirical findings may be caused by weak governance and other institutional impediments; especially, regional differences in development levels of their economies before those countries' transformation to market-oriented economies.

IV. CONCLUDING REMARKS

In short, this empirical analysis employs recently developed estimation techniques to examine the relationships among the Treasury bond rates in the CE4 countries. It also investigates whether they are cointegrated— given the geographical proximity, similar socio-political structures and almost identical levels of economic development— in terms of per-capita incomes and human development indices (HDIs) before and after the transition period. More specifically, VECM and the augmented level VAR model with integrated and cointegrated processes (of arbitrary orders) developed by Toda and Yamamoto (1995) and Dolado and Lütkepohl (1996) were used to test for Granger causality. Granger causality tests based on the VECM suggests only causal linkages from changes in the Hungarian Treasury bond rate to changes in the Treasury bond rates in the Czech Republic, Poland and Slovakia. These causalities are on unidirectional nature –originated from Hungary. More importantly, the Granger causality test based on the augmented VAR procedure yields similar results from VECM -in addition to a very strong unidirectional causality from the Hungarian Treasury to the Slovak Treasury bond rates. These empirical findings may be explained by factors such as relatively ineffective governance, the health of the government budget or inadequate institutional frameworks— both before and after the transformation to the market system— in those CE4 countries.

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