Original scientific paper
UDC 330.552: 65.012.4

Flexible Fourier Stationary Test in GDP per capita for Central Eastern European Countries*

Hsu-Ling Chang[1], *Chi-Wei Su*[2], *Meng-Nan Zhu*[3]

Abstract

The main goal of the paper is to investigate whether real GDP follows a trend stationary or a different stationary process. Our hypothesis is that real output is characterized by a non-linear mean reverting process. It is flexible Fourier stationary unit root test proposed by Enders and Lee (2004, 2009) to assess the non-stationary properties of the real GDP per capita that has been applied for nine Central Eastern-European Countries from 1969 to 2009. The results of our research have proved that Fourier stationary unit root test has higher power than linear method if the true data generating process of per capita real GDP is in fact a stationary non-liner process of an unknown form with structural change using the low frequency components. The investigation of the stationary of per capita real GDP from the non-linear point of view provides strong evidence clearly indicating that real output is well characterized by a non-linear mean reverting process, namely in Bulgaria, Latvia and Romania. The evidence is that these three countries are non-linear stationary, implying that per capita real GDP follows a steady rate of growth, and policy innovations rather then have temporary effects. These results have important policy implications for macroeconomic policy, modeling, testing and forecasting for Central Eastern-European Countries.

***Key words**: Fourier Stationary Test, structural change, trend breaks, Real GDP per capita*

***JEL classification**: C22, O1, O4*

* Received: 07-12-2010; accepted: 06-06-2011

[1] *Associate Professor, Department of Finance, Xiamen University, China and Department of Accounting and Information, Ling Tung University, Taiwan., 1, Ling Tung Rd., Taichung, Taiwan. Scientific affiliation: corporate governance, international finance, financial accounting. Phone: 886-4-23892088. E-mail: hsulingchang@yahoo.com.tw*

[2] *Assistant Professor, Department of International Business, Tamkang University, Taipei, Taiwan. and Department of Finance, Xiamen University, China, No.151, Yingzhuan Rd., Danshui Town, Taipei, County 25137, Taiwan (R.O.C.). Scientific affiliation: international finance, financial time series analysis, banking. .Phone: 886-4-22920677. Fax: 886-4-2292-0677. E-mail: cwsu@mail.tku.edu.tw (Corresponding author)*

[3] *Full Professor, Department of Finance, Xiamen University, 361005 Fujian Province, P.R. China. Scientific affiliation: international finance, international economics. E-mail: zmnan@xmu.edu.cn*

1. Introduction

The modeling of per capita real GDP as either a trend stationary or a difference stationary process has received much attention since Nelson and Plosser (1982). Researchers have been especially interested in the time-series properties of real output levels. The characteristics of real output have important implications for macroeconomic policy making, modeling, testing and forecasting. Studies on this issue are of concern not only to empirical researchers but also policymakers. The question of whether real GDP can be characterized by unit roots has been an issue of particular interest (Wasserfallen, 1986; Ben-David and Papell, 1995; Cheung and Chinn, 1996; Rapach, 2002; Cheung and Westermann, 2002). Nelson and Plosser note that a unit root in real output is inconsistent with the notion that business cycles are stationary fluctuations around a deterministic trend. Instead, it suggests that shocks to real output have permanent effects on the system.

The Central and Eastern European (CEE) countries underwent major changes in their economic and political system during their transition to market economies in the 1990s. The economic transformations in the CEE countries have shared various common features ranging from institutional changes promoting a market economy to practical issues like the exchange rate regime or the inflow of foreign direct investment to industries with comparative advantage. During the ongoing transformation, the CEE countries launched various privatization programs and adopted an extensive range of measures to implement monetary and fiscal policies that would suit the needs of overall transformation. Therefore, we neither know whether the extraordinarily high growth rates in some countries (e.g. Poland, Slovakia) reflect only a temporary recovery or will persist for longer time periods, nor is it clear whether the slow growth of output in other countries (e.g. Bulgaria, Romania) will accelerate when shortcomings in institution building and macroeconomic policies are overcome. The variance in the growth rates of GDP and physical investment among the CEE countries is extraordinarily high. Moreover, it remains unclear whether we can draw conclusions from present trends for the real output prospects in the CEE countries. Thus, uncertainty about economic development in the accession candidates from CEE is still high even ten years after the economic transition started. Therefore, we cannot derive a scenario for the long-run growth and convergence of per capita GDP from present growth trends in the CEE countries.

Determining whether per capita output can be characterized by a stochastic trend is complicated by the fact that infrequent breaks in trend can bias standard unit root tests towards non-rejection of the unit root hypothesis. The bulk of the existing literature has focused on the application of unit root tests allowing for structural breaks in the trend function under the trend stationary alternative but not under the unit root null. These tests, however, provide little information regarding the existence and number of trend breaks. Moreover, these tests suffer from serious power and size distortions due to the asymmetric treatment of breaks under the null and alternative hypotheses. It is not surprising that these factors have cast considerable doubt on many of the earlier findings that have been based on a unit root in real output levels. There is a growing consensus that conventional unit root tests such as the ADF and PP tests – fail to incorporate the structural breaks in the model – have low power in detecting the mean reversion of real GDP. 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. Meanwhile, structural changes present in the data generating process, but have been neglected, sway the analysis toward accepting the null hypothesis of a unit root. The general method to account for breaks is to approximate those using dummy variables. However, this approach has several undesirable consequences. First, recent developments in the econometrics literature highlight major drawbacks of commonly used unit root tests based on search procedures. When the break dates are unknown, it is useful to have information regarding the presence or absence of a change in order to investigate the potential presence a unit root. These are not usually known and therefore need to be estimated. This in turn introduces an undesirable pre-selection bias (see Maddala and Kim, 1998). Second, current available tests account only for one to two breaks. Nunes *et al.* (1997), Lee and Strazicich (2001, 2003) and Kim and Perron (2009), among others, demonstrate that such tests suffer from serious power and size distortions due to the asymmetric treatment of breaks under the null and alternative hypotheses. Third, the use of dummies suggests sharp and sudden changes in the trend or level. As a result, the test may reject the unit root null when the noise component is integrated but the trend is changing, leading to spurious evidence in favor of broken trend stationarity. However, for low frequency data it is more likely that structural changes take the form of large swings which cannot be captured well using only dummies. Breaks should therefore be approximated as smooth and gradual processes (see Leybourne *et al.*, 1998). These arguments motivate the use of a recently developed set of unit root and stationary tests that avoid this problem. 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.

Additionally, the existence of structure changes in real output levels might imply broken deterministic time trends and the result is a nonlinear pattern (Bierens, 1997). It should, therefore, not be unexpected that these shortcomings have seriously called into question many of the earlier findings based on a unit root in per capita GDP. As we cover a much shorter time period, we interpret the broken deterministic terms differently. In particular, we think of them as representing e.g. changes in the political and economic environment in the CEE countries due to structural reforms in the political and legal system, changes in the competition policy, and specific economic policy programs. In this sense the broken deterministic terms refer to exogenous events.

This empirical study contributes to this line of research by determining whether or not *root process* of the real GDP per capita of nine CEE countries using the unit root test with a Fourier function proposed by Enders and Lee (2004, 2009). The hypothesis is to test whether real GDP follows a stochastic or deterministic path. Testing whether a time series can be characterized by a broken trend is complicated by the fact that the nature of persistence in the errors is usually unknown. The lack of econometric studies may be explained by the difficulties involved modeling acceding country data: only relatively few time series observations are available and structural changes have occurred frequently. We analyze log-differences of real GDP per capita using Lagrange Multiplier (LM) unit root tests that allow for breaks in the trend and the level of a series at unknown time. With this, the current research hopes to fill the existing gap in the literature. To the best of our knowledge, this study is the first, to date, that utilizes the unit root test with a Fourier function in real GDP per capita for CEE countries. This empirical study contributes to the field of empirical research by determining whether or not the unit root process is characteristic of the in real output levels in the CEE countries.

The reminder of this empirical study is organized as follows. Section 2 describes the methodology of the Fourier unit root test. Section 3 presents the data used and discusses the empirical findings and policy implications. Section 4 reviews the conclusions we draw.

2. Enders and Lee's (2004, 2009) Fourier Unit Root Test

Enders and Lee (2004, 2009) implement a variant of the Flexible Fourier transform (Gallant, 1981) to control for the unknown nature of the breaks. One advantage of this Fourier function is that it is able to capture the essential characteristics of one or more structural breaks by using only a small number of low frequency components. This is true because a break tends to shift the spectral density function towards frequency zero. Especially, this test works best in the presence of breaks that are gradual and has good power to detect u-shaped and smooth breaks.

Enders and Lee (2004, 2009) develop their unit root test using the LM principle. As indicated by Pascalau (2010), the LM has increased power over the DF approach.

Following the Enders and Lee (2004, 2009), we consider the following data generating process (DGP):

$$y_t = \alpha_0 + \theta t + \gamma_1 \sin(2\pi kt / T) + \gamma_2 \cos(2\pi kt / T) + \varepsilon_t; \qquad (1)$$

$$\varepsilon_t = \beta \varepsilon_{t-1} + u_t, \qquad (2)$$

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. Where *k* represents the frequency selected for the approximation, and $\gamma = [\gamma_1, \gamma_2]'$ measures the amplitude and displacement of the frequency component. A desire feature of Equation (1) is that the standard linear specification emerges as a special case by setting $\gamma_1 = \gamma_2 = 0$. It also follows that at least one frequency component must be present if there is a structural break. Here, if it is possible to reject the null hypothesis $\gamma_1 = \gamma_2 = 0$, the series must have a nonlinear component. Enders and Lee (2004, 2009) use this property of Equation (1) to develop a test that can have more power to detect breaks of an unknown form than the standard Bai and Perron (1998) test. Under the null hypothesis of a unit root $\beta = 1$, where under the alternative hypothesis $\beta < 1$. Enders and Lee (20064, 2009) employ the LM methodology of Schmidt and Phillips (1992) and Amsler and Lee (1995) by imposing the null restriction and estimating the following regression in first differences:

$$\Delta y_t = \delta_0 + \delta_1 \Delta \sin(2\pi kt / T) + \delta_2 \Delta \cos(2\pi kt / T) + v_t \qquad (3)$$

The estimated coefficients $\tilde{\delta}_0$, $\tilde{\delta}_1$ and $\tilde{\delta}_2$ are then used to construct the following detrended series:

$$\tilde{S}_t = y_t - \tilde{\psi} - \tilde{\delta}_0 t - \tilde{\delta}_1 \sin(2\pi kt / T) - \tilde{\delta}_2 \cos(2\pi kt / T), t = 2....,T \qquad (4)$$

where $\tilde{\psi} = y_1 - \tilde{\delta}_0 t - \tilde{\delta}_1 \sin(2\pi kt / T) - \tilde{\delta}_2 \cos(2\pi kt / T)$ and y_1 is the first observation of y_t. The testing regression based on the detrended series has the following expression:

$$\Delta y_t = \theta \tilde{S}_{t-1} + d_0 + d_1 \Delta \sin(2\pi kt / T) + d_2 \Delta \cos(2\pi kt / T) + \varepsilon_t \qquad (5)$$

If y_t has a unit root then $\theta = 0$ and the LM test statistic (denoted τ_{LM}) is the *t*-test for the null hypothesis of $\theta = 0$. The innovation process ε_t is assumed to satisfy Phillips and Perron (1998)'s serial correlation and heterogeneity conditions. Equation (5) can be augmented with lag values of $\Delta\widetilde{S}_{t-j}$, $j = 1,2,...p$, to get rid of the remaining serial correlation (Ng and Perron, 2001). Enders and Lee (2004, 2009) derive the properties of the asymptotic distribution of the τ_{IM} statistic and demonstrate that it depends only on the frequency k and is invariant to all other parameters in the DGP. Enders and Lee (2004, 2009) suggest that the frequencies in Equation (5) should be obtained via the minimization of the sum of squared residuals. However, their Monte Carlo experiments suggest that no more than one or two frequencies should be used because of the loss of power associated with a larger number of frequencies. .

3. Data and empirical findings.

This empirical study based on yearly real GDP per capita data for nine Eastern-European countries, namely Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania and Slovakia for the period 1969 to 2009. All the data was converted into natural logarithmic form before the empirical analysis. The source of the data is World Bank World Development Indicators, International Financial Statistics of the IMF, Global Insight, and Oxford Economic Forecasting, as well as estimated and projected values developed by the Economic Research Service all converted to a 2005 base year. The summary statistics are provided in Table 1. Czech Republic and Bulgaria have the highest and lowest average per capita incomes of US$14029.20 and US$2313.964, respectively. The Jarque-Bera test results meanwhile indicate that the per capita real GDP datasets of the 9 CEE countries are all normal.

Table 1: Summary statistics of Real GDP per capita data sets

Country	Mean	Std	Maximum	Minimum	Skewness	Kurtosis	J-B
Bulgaria	2313.964	1386.430	5185.409	525.828	0.814	2.474	1.952
Czech Republic	8337.881	4199.604	16833.45	3551.5	0.864	2.379	2.250
Estonia	6451.003	4649.220	16369.88	1141.952	0.918	2.621	2.345
Hungary	7060.041	3401.536	13109.06	3723.682	0.659	1.767	2.171
Latvia	4648.528	3331.542	12206.99	813.212	1.044	3.001	2.907
Lithuania	4655.089	3153.913	10873.6	734.998	0.710	2.272	1.699
Poland	5572.846	2420.625	10291.94	2346.241	0.698	2.320	1.610
Romania	3031.130	2293.697	8583.6	1148.14	1.369	3.555	3.208
Slovakia	6088.990	3656.655	14470.09	2518.662	1.165	3.075	3.626

Note: Std denotes standard deviation and J-B denotes the Jarque-Bera Test Normality.

Source: Authors' calculation

For comparison, first, we apply conventional ADF statistic to examine the null of a unit root in the real GDP per capita of each country. The results in Table 2 clearly indicate that ADF and PP tests fail to reject the null of non-stationary per capita real GDP for all nine countries.

Table 2: Univariate unit root tests (with trend)

Country	Levels			First Differences		
	ADF	PP	KPSS	ADF	PP	KPSS
Bulgaria	-2.524(1)	-1.619[3]	0.198[5]**	-3.992(2)**	-3.811[5]**	0.103[3]
Czech Republic	-2.388(1)	-1.908[1]	0.122[4]*	-4.204(0)**	-4.161[3]**	0.107[0]
Estonia	-2.222(1)	-1.764[1]	0.195[5]**	-4.006(0)**	-3.357[2]*	0.089[3]
Hungary	-3.066(2)	-1.999[3]	0.202[5]**	-3.304(0)*	-3.353[2]*	0.119[3]
Latvia	-2.764(1)	-1.959[3]	0.353[5]***	-3.741(0)**	-3.846[2]**	0.097[3]
Lithuania	-2.477(1)	-1.857[3]	0.191[5]*	-4.016(1)**	-3.312[3]*	0.086[3]
Poland	-2.184(1)	-1.574[1]	0.168[4]**	-4.307(0)***	-4.315[2]***	0.068[0]
Romania	-2.521(1)	-1.721[3]	0.218[5]***	-3.688(0)**	-3.669[4]**	0.045[3]
Slovakia	-3.134(1)	-1.532[3]	0.201[5]**	-3.549(0)**	-3.416[5]*	0.105[3]

Note: ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively. The number in parenthesis indicates the lag order selected based on the recursive t-statistic, as suggested by Perron (1989). The number in the brackets indicates the truncation for the Bartlett Kernel, as suggested by the Newey-West test (1987).

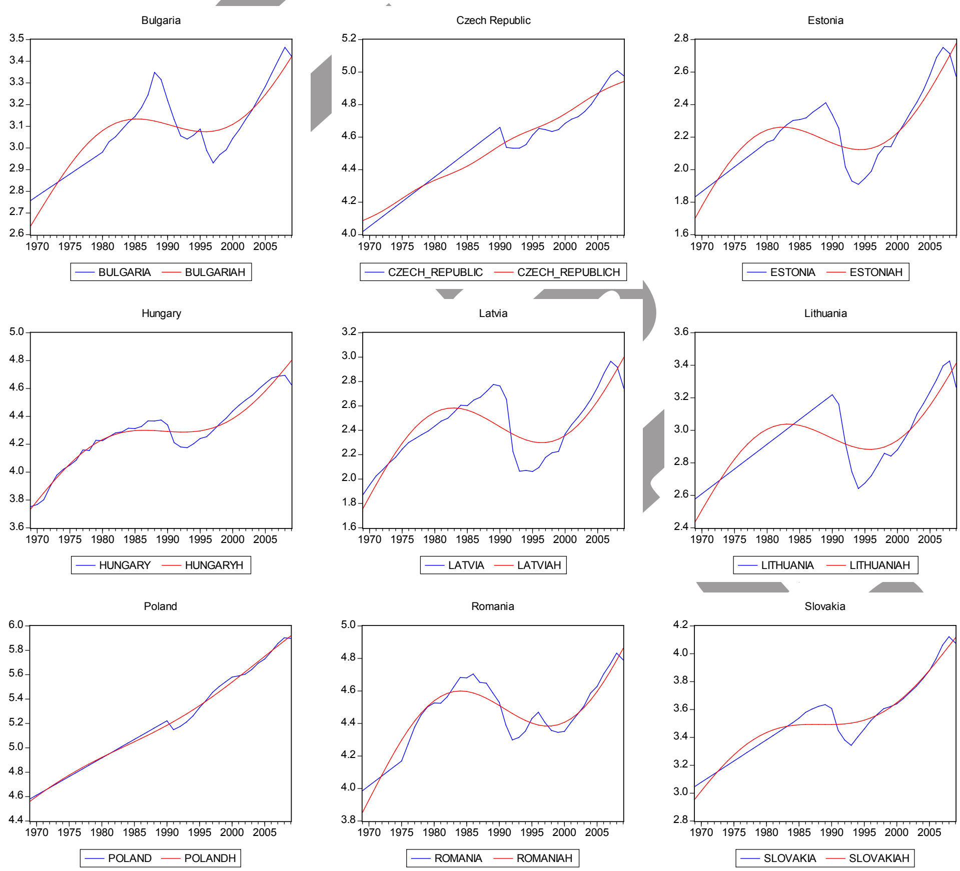
Source: Authors' calculation

The KPSS test also yields the same results. This finding is consistent with the real GDP unit root literature and is due to the low power of the ADF and PP tests when the real GDP are highly persistent and fail to incorporate the structural breaks in the model. 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. Meanwhile, structural changes present in the data generating process, but have been neglected, sway the analysis toward accepting the null hypothesis of a unit root. Therefore, we proceed to test the real GDP by using the unit root test with a Fourier function, proposed by Enders and Lee (2004, 2009).

First, a grid-search is performed to find the best frequency, as there is no a prior knowledge concerning the shape of the breaks in the data. We estimate Equation (5) for each integer $k = 1, \dots , 5$, following the recommendations of Enders and Lee (2004, 2009) that a single frequency can capture a wide variety of breaks. The second column in Table 3 displays the residual sum of squares (RSSs) and indicates that a single frequency works best for most of the series with the exception of Czech Republic we find frequency 3. The significant $F(\hat{k})$ statistic showed in the fourth column of Table 3 also indicate that both sine and cosine terms should be included in the estimated model except Czech Republic and Poland.

We follow Burke (1994) and use a 10% significance level and select the lag order of the test on the basis of the recursive *t*-statistic, as suggested by Perron (1989). The fifth column in Table 3 shows the number of lags of ΔS_t needed to remove serial correlation in residuals. The last column in Table 3 reports the results of unit root test with a nonlinear Fourier function based on the estimated frequencies. We are not able to reject the unit root null hypothesis for CEE countries at the 5% significance level, with the exception of Bulgaria, Latvia and Romania. Our evidence points that three of nine CEE countries are non-linear stationary, implying that real GDP per capita follows a steady rate of growth, and policy innovations then have temporary effects. As far as major policies are concerned, this study implies that a fiscal and/or monetary stabilization policy would possibly permanently affect the real output levels of most CEE countries under study. Figure 1 displays the time paths of the real GDP per capita for each country.

Figure 1: Plots of Real GDP per capita for CEE countries and fitted nonlinearities



Source: Authors' calculation

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 of the time-varying intercepts are also shown in the Figures 1.

Table 3: Unit Root Test with a Nonlinear Fourier Function

Country	Residual Sum of Squares (RSSs)	$\hat{k}$	$F(\hat{k})$	The number of Lags of ΔS_t	$\tau_{LM}(\hat{k})$
Bulgaria	0.002	1	85.598^{***}	2	-6.021^{***}
Czech Republic	0.007	3	1.041	0	-0.249
Estonia	0.004	1	42.098^{***}	2	0.461
Hungary	0.018	1	8.842^{**}	4	0.137
Latvia	0.014	1	49.945^{***}	2	-7.125^{***}
Lithuania	0.003	1	77.530^{***}	2	0.215
Poland	0.018	1	2.198	4	-3.291
Romania	0.001	1	1027.559^{***}	0	-8.654^{***}
Slovakia	0.003	1	48.186^{***}	1	0.031

Note: *** and ** indicate significance at the 0.01 and 0.05 levels, respectively. Critical values for the $\tau_{LM}(\hat{k})$ statistic are taken from Enders and Lee (2009)

Source: Authors' calculation

For most countries in the sample, with the exception of Bulgaria and Romania output started to grow sustainably in 1994 or 1995. Inflation rates also soared up, with some countries experiencing hyper-inflations. Again, with the exception of Bulgaria and Romania, by the end of the 1990s inflation had been brought down to one-digit or low two-digit numbers. Thus, among these countries, stabilization policy has been successful and growth is widely experienced.

4. Conclusion

The aim of this paper was to examine whether real GDP per capita was a non-stationary or stationary process for 9 CEE countries. We confirm our hypothesis that real output is characterized by a non-linear mean reverting process. Standard linear ADF, PP and KPSS statistics show that the data are basically non-stationary for these countries. In contrast, when we adopt a Fourier unit root test which has higher power than a standard univariate and non-linear unit root statistic to reject a false null hypothesis of unit root behavior, the empirical evidence suggests that real GDP per capita is well characterized in Bulgaria, Latvia and Romania by a non-linear mean reverting process which exhibits periods of exploding behavior. It shows whether real GDP follows a stochastic or deterministic path has far-reaching implications for modeling, forecasting and for judging the importance and role of macroeconomic stabilization programs. Thus, real GDP per capita follows a steady rate of growth, and policy innovations then have temporary effects for Bulgaria, Latvia and Romania. This might offer an alternative explanation for the difficulty researchers have encountered in rejecting the unit root hypothesis for real GDP per capita.

The mention results should be taken with a restriction considering that CEE countries that per capita real GDP time series since the radical change of Eastern Europe and the breakup of the USSR are evaluated from 1989 to now. Furthermore, we fail to consider information of adjusting for codependence between countries.

Further research could be extend the period of "the Financial Tsunami" to test the effect of mean reverting process of real output. Furthermore, the model will include other controllable variables as important determinants of real output.

Evidence from the *Fourier unit root tests proves* that CEE countries' real GDP per capita following a stochastic or deterministic path has far-reaching implications for modeling, forecasting and for judging the importance and role of macroeconomic stabilization programs. Finding macroeconomic fluctuations transitory around a deterministic path supports the role for temporary monetary and fiscal shocks. The effects of monetary and fiscal policy shocks are judged for duration above or below the trend, and long-run uncertainty is also limited by the expected duration of the business cycle around the trend. Thus, real GDP per capita follows a steady rate of growth, and policy innovations having temporary effects.

References

Amsler, C., and J. Lee. (1995) "An LM Test for a Unit-Root in the Presence of a Structural Change." *Econometric Theory* 11, 359-368.

Bai, J., and P. Perron. (1998) "Estimating and testing linear models with multiple structural changes." *Econometrica* 66, 47–78.

Becker, R., W. Enders, and J. Lee. (2004) "A general test for time dependence in parameters." *Journal of Applied Econometrics* 19, 899-906.

Becker, R., W. Enders, and J. Lee. (2006) "A stationairy test in the presence of an unknown number of smooth breaks." *Journal of Time Series Analysis* 27, no. 3, 381-409.

Ben-David, D., and D. H. Papell. (1995) "The great wars, the great crash and steady growth: some new evidence about old stylized fact." *Journal of Monetary Economics* 36, 453-475.

Bierens, H. J. (1997) "Testing the unit root with drift hypothesis against nonlinear trend stationarity, with an application to the U.S. price level and interest rate." *Journal of Econometrics* 81, 29-64.

Burke, S. (1994) "Confirmatory data analysis: The joint application of stationarity and unitroot tests." University of Reading 20.

Cheung, Y. W., and D. Chinn. (1996) "Deterministic, stochastic and segmented trends in aggregate output: a cross-country analysis." *Oxford Economic Papers 48*, 134-162.

Cheung, Y. W., and F. Westermann. (2002) "Output dynamics of the G7 countries-stochastic trends and cyclical movements." *Applied Economics* 34, 2239-2247.

Enders, W., and J. Lee. (2004) "Testing for a unit root with a nonlinear Fourier function." working paper, Department of Economics, Finance & Legal Studies, University of Alabama, Tuscaloosa, AL, USA.

Enders, W., and J. Lee. (2009) "The flexible Fourier form and testing for unit roots: An example of the term structure of interest rates." Working paper, Department of Economics, Finance & Legal Studies, University of Alabama, Tuscaloosa, AL, USA.

Gallant, R. (1981) "On the basis in flexible functional form and an essentially unbiased form: The flexible Fourier form." *Journal of Econometrics* 15: 211-353.

Kim, D., and P. Perron. (2009) "Unit Root Tests Allowing for a Break in the Trend Function at an Unknown Time under Both the Null and Alternative Hypotheses." *Journal of Econometrics* 148, 1-13.

Lee, J., and M. C. Strazicich. (2001) "Break Point Estimation and Spurious Rejections with Endogenous Unit Roots." *Oxford Bulletin of Economics and Statistics* 63, 535-558.

Lee, J., and M. C. Strazicich. (2003) "Minimum Lagrange Multiplier Unit Root Test with Two Structural Breaks." *The Review of Economics and Statistics* 85, 1082-1089.

Leybourne, S., P. Newbold, and D. Vougas. (1998) "Unit roots and smooth transitions." *Journal of Time Series Analysis* 19, 83-97.

Maddala, G., and I. M. Kim. (1998) "Unit roots, cointegration and structural change." *Cambridge University Press*, UK.

Nelson, C., and C. Plosser. (1982) "Trends and random walks in macroeconomic time Series." *Journal of Monetary Economics* 10*,* 139-162.

Ng, S., and P. Perron. (2001) "Lag length selection and the construction of unit root tests with good size and power." *Econometrica* 69, no. 6, 1519-1554.

Nunes, L. C., P. Newbold, and C.-M. Kuan. (1997) "Testing for Unit Roots with Breaks: Evidence on the Great Crash and the Unit Root Hypothesis Reconsidered." *Oxford Bulletin of Economics and Statistics* 59, 435-448.

Pascalau, R. "Unit root tests with smooth breaks: an application to the Nelson-Plosser data set." *Applied Economics Letters* 17, (2010): 565-570.

Perron, P. (1989) "The great crash, the oil price shock and the unit root hypothesis." *Econometrica* 57, no. 6, 1361-1401.

Phillips, P. C. B., and P. Perron. (1988) "Testing for a Unit Root in Time Series Regression." *Biometrika* 75, 335-346.

Rapach, D. E. (2002) "Are real GDP levels nonstationary? Evidence from panel data tests." *Southern Economic Journal* 68, 473-495.

Schmidt, P., and P. C. B. Phillips. (1992) "LM Test for a Unit Root inthe Presence of Deterministic Trends." *Oxford Bulletin of Economics and Statistics* 54, 257-287.

Wasserfallen, W. (1986) "Non-stationarities in marco-economic-time series-further evidence and implications." *Canadian Journal of Economics* 19, 498-510.

Fleksibilni Fourierov stacionarni test BDP-a po stanovniku za Srednjoistočne europske zemlje

Hsu-Ling Chang[1], *Chi-Wei Su*[2], *Meng-Nan Zhu*[3]

Sažetak

Glavni cilj ovog rada je istražiti slijedi li realni BDP stacionarni trend ili različiti stacionarni proces. Naša hipoteza je da realni učinak ima svojstvo nelinearnog povratnog procesa. Primijenjen je fleksibilni Fourierov stacionarni test jediničnog korijena kojeg su predložili Enders i Lee (2004, 2009) za procjenu ne-stacionarnih svojstava realnog BDP-a po stanovniku za devet Srednjoistočnih europskih zemalja od 1969. do 2009. godine. Utvrđeno je da Fourierov stacionarni test jediničnih korijena ima veću jačinu nego linearna metoda ako su podaci koji generiraju proces realnog BDP-a po stanovniku zapravo stacionarni nelinijski proces nepoznatog oblika sa strukturalnom promjenom pomoću nisko-frekvencijskih komponenata. Istraživanje stacionarnosti realnog BDP-a po stanovniku s nelinearnog aspekta rezultiralo je snažnim dokazima koji jasno ukazuju da realni učinak ima svojstvo nelinearnog povratnog procesa, kao što je slučaj u Bugarskoj, Latviji i Rumunjskoj. Naši dokazi pokazuju da su ove tri zemlje nelinearno stacionarne, što podrazumijeva da realni BDP po stanovniku prati stalnu stopu rasta, a političke inovacije imaju privremene učinke. Ovi rezultati imaju važne implikacije na makroekonomsku politiku, modeliranje, testiranje i prognoziranje za Srednjoistočne europske zemlje.

Ključne riječi*: Fourierov stacionarni test, strukturalne promjene, pauze trenda, realni BDP po stanovniku*

JEL klasifikacija*: C22, O1, O4*

[1] *Izvanredni professor, Department of Finance, Xiamen University, China and Department of Accounting and Information, Ling Tung University, Taiwan., 1, Ling Tung Rd., Taichung, Taiwan. Znanstveni interes: korporacijsko upravljanje, međunarodne financije, financijsko računovodstvo. Tel.: 886-4-23892088. E-mail: hsulingchang@yahoo.com.tw*

[2] *Docent, Department of International Business, Tamkang University, Taipei, Taiwan. and Department of Finance, Xiamen University, China, No.151, Yingzhuan Rd., Danshui Town, Taipei, County 25137, Taiwan (R.O.C.). Znanstveni interes: međunarodne financije, analiza financijskog vremenskog slijeda, bankarstvo. Tel.: 886-4-22920677. Fax: 886-4-2292-0677. E-mail: cwsu@mail.tku.edu.tw (Kontakt osoba)*

[3] *Redoviti profesor, Department of Finance, Xiamen University, 361005 Fujian Province, P.R. China. Znanstveni interes: međunarodne financije, međunarodna ekonomija. E-mail: zmnan@xmu.edu.cn*