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ASSESSING INSTABILITY IN TRANSITION COUNTRIES USING PERRON'S MODIFIED AUGMENTED DICKEY-FULLER TEST

Natasha Trajkova- Najdovska
University St. Kliment Ohridski–Bitola, Faculty of Economics, Republic of Macedonia
natashatrajkova@yahoo.com

Abstract

GDP growth patterns of transition economies are characterised by many turns from positive to negative average growth rates caused by various changes they have experienced in the course of transition from planned to market economy. These sudden shifts break the single trend line, forming growth pattern that is episodic and intermittent, already observed in the case of developing economies and defined and described under the peculiar dimension of growth – instability. This paper is analysing the instability of growth in transition economies, theoretically and empirically, by use of the Perron's modified augmented Dickey-Fuller Test on the GDP series. Finally, based on the results it sets out the general conclusion that the economic development in these transition countries was often interrupted sufficiently severely to give rise to a detectable break in GDP series, which confirms the idea of a an interrupted instable growth pattern.

Keywords: Instability, economic growth, transition economies, Perron's modified ADF test, GDP

INTRODUCTION

GDP paths in most developing countries are very much different from the ones observed in developed countries because they do not follow a single time trend Pritchett (2000, p.1). In fact, Pritchett claimed that growth in developing countries is characterized by a peculiar characteristic – instability, much more emphasized from the one observed in developed countries, which causes countries' growth to be intermittent and episodic (Ben-David and Papell, 1997, Pritchett, 2000, Durlauf et al., 2004). Namely, growth in these countries is characterised by abrupt turns from positive to negative average growth rates (or vice versa) i.e. as "turnarounds" between the line trends (Ben-David and Papell, 1997, Pritchett, 2000).

This peculiarity of growth change the whole conception of the linear growth steady-state path, as established in neoclassical growth theory, and put forward the idea of growth interrupted by break points and turns that can be described as transitions between different growth regimes (Pritchett, 2000). Hence, in this paper the goal is to assess critically the newest breakthroughs in growth literature on shifts in growth regimes (instability) in order to then apply it in the context of group of transition countries. The assessment of the instability of growth is conducted by testing for the existence of shifts in growth rates within transition countries. Namely, use of univariate analysis for the presence or absence of unit roots in macroeconomic time series, conditional on the presence of a deterministic trend and trend breaks, should help to identify some features of underlying data-generating process of each series.

The paper is structured as follows. Firstly, the stylized facts of the economic growth patterns for transition economies (TEs) are presented, motivating the debate on instability. Subsequently, the review of the recent theory and empirical findings related to instability is presented, defining the instability and setting the rationale for the empirical analysis of the GDP growth rates time series. The testing procedure, its caveats and the estimation procedure and results are presented afterward. The final part sets out the conclusions, suggesting the further avenues for research.

Transition countries - stylized facts

The group of countries included within this research consist of the so called group of transition economies, consisting of the "successful" transition countries that managed to join the EU in a relatively short period of time, comprise countries of:

- Central Eastern European Countries (CEECs) such as Poland, Slovenia, the Czech Republic, Hungary, the Slovak Republic; and
- The Baltic Countries (BC) comprising Latvia, Lithuania and Estonia;

And, the second group of "lagging" transition countries consists of:

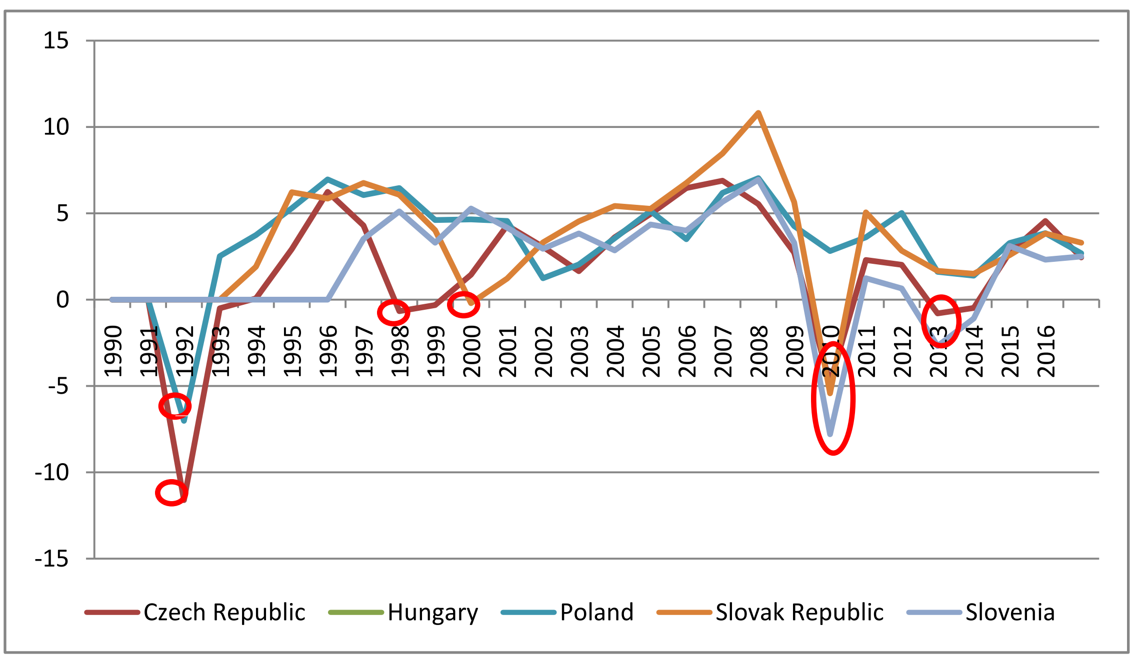
- South Eastern European Countries (SEECs) including Croatia, Macedonia, Albania, Serbia, Romania and Bulgaria; and,
- The Commonwealth of Independent States (CIS) group including Russia and the Ukraine as well as Armenia, Azerbaijan, Belarus, Georgia, Moldova, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan. Some of the countries, such as Bosnia and Hercegovina, Kosovo, Montenegro are not included in the analysis, as the data span is very short, due to missing data.

All these countries followed a particular path towards a modern market economy- named transition – a multidimensional process of political, economic, social and institutional changes. All these changes were supposed to be realized within a process of creative destruction, i.e. destruction of the inappropriate legacies of the old system and erection of new necessary system elements (European Bank for Restructuring and Development, 1997). However, the result was a slump in economic activity in the first stage of transition, followed by recovery of economic activity and reorganization of the whole society. Thus, transition often was referred also as a complex chain of policies to implement market mechanisms, to enhance structural changes and reallocations, to stimulate enterprise efficiency, new investments and hence, recovery and growth. However, this proved to be difficult, especially in the cases of some groups of transition countries, SEEC and CIS in particular. In these countries the destruction was rapid while creation went more slowly, resulting in deep recessions. Hence, Kornai (1994) named transition an institutional no-man's land and disruption.

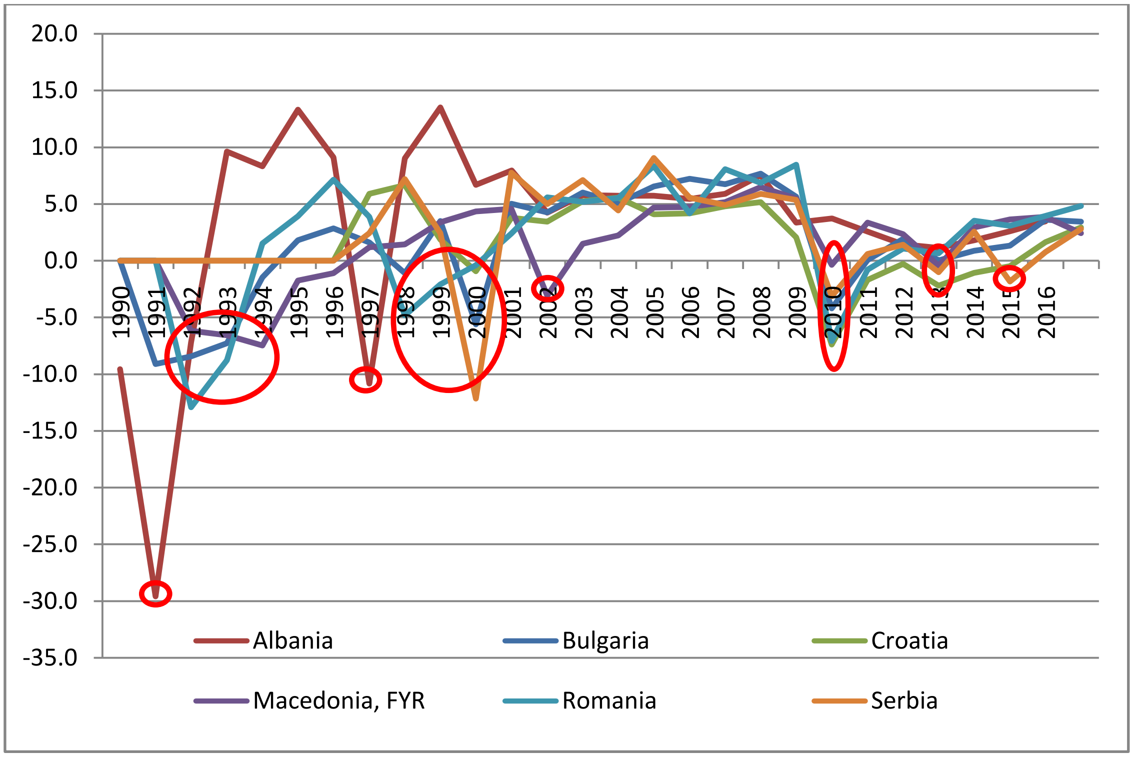
With respect to the growth patterns, the beginning of transition was marked by a sharp decrease in economic activity in all transition economies (Berg et al., 1999). Important fact is that big shifts in the data series are recorded even in a later transition caused by big shocks in the economies. Separate graphs in Figure 1 presents growth rates in the transition countries, measured by the annual per cent change of GDP per capita. On the graphs, the x- axis gives the time line, while y-axis represents the growth rates measured in percentages. Big shifts in data series from positive to negative growth rates (and vice versa) are marked in red circles.

Figure 1. GDP growth rates in Transition Economies' Groups

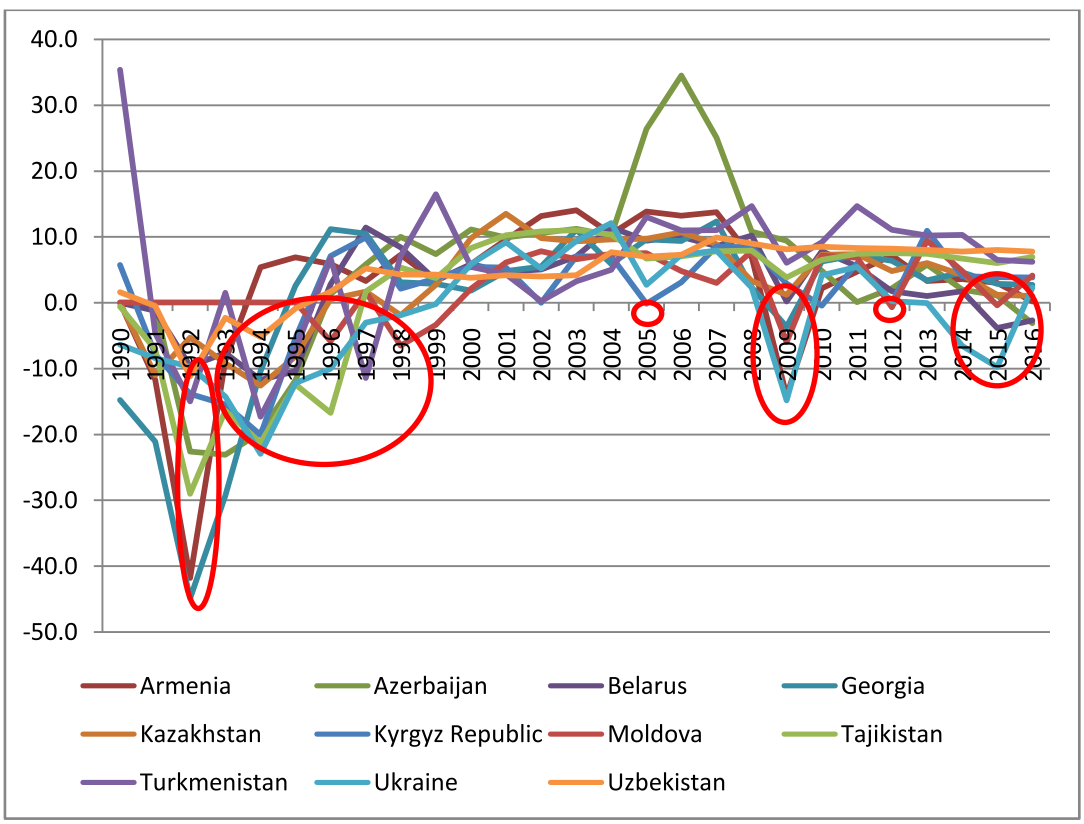
a) Central Eastern European Transition Countries (CEECs)



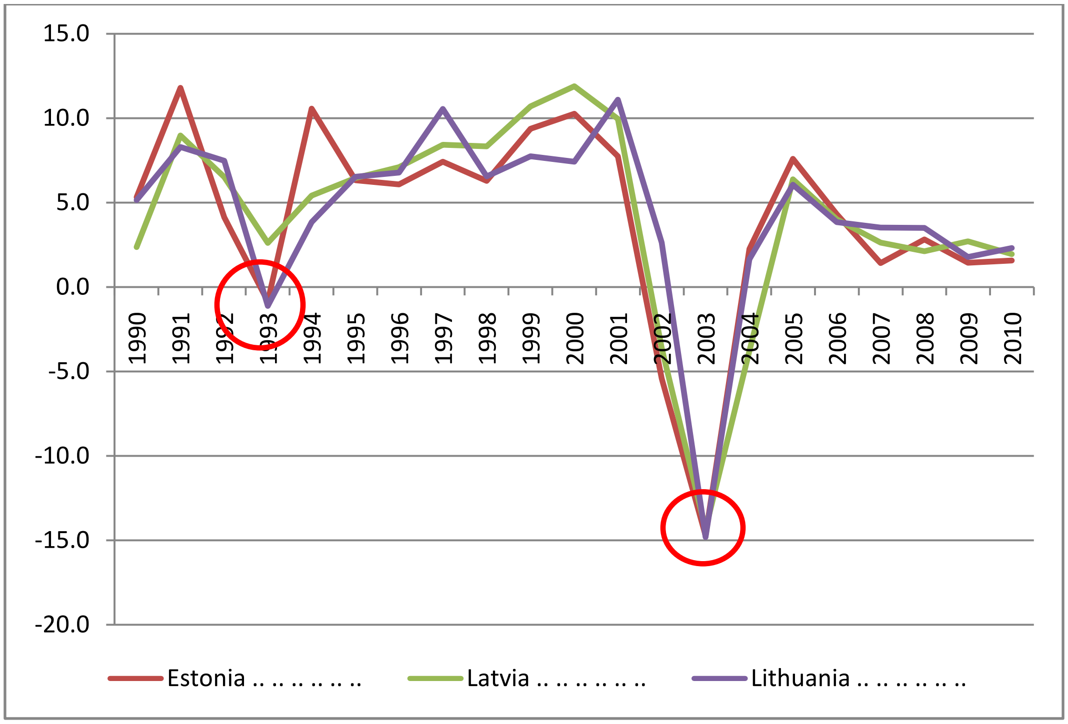
b) South Eastern European Transition Countries (SEECs)



c) Commonwealth of Independent States (CIS) group



d) Baltic Countries (BC)



Note: Graphs are not precisely comparable, as the y-axes are not marked in same scale span. However, the idea is not to compare the economic growth patterns amongst countries, but rather to observe the big switches from positive to negative (or vice versa) economic growth rates. All graphs include the linear trend line, given in black colour.

Source: World Development Indicators, World Bank, 2017.

The Figure reveals important fact related to sharp reversals in the growth rates in later transition. Most of the countries record negative growth rates in a middle transition and late transition (marked by circles in the graphs above). For some of the economies, the reversals repeated three or four times, contracting the economic activity severely. In addition, in some economies the reversals are related to the Financial Crisis, which hit the economies with different severity. In general, the figure accentuates the idea of growth pattern, interrupted by break points and turns that can be described as transitions between different growth regimes as explained by Pritchett (2000). Hence, the theoretical and empirical analysis of the breaking points in growth patterns has to determine whether their actuality was significant element.

DEFINING INSTABILITY: THEORETICAL BACKGROUND & EMPIRICAL FINDINGS

In the early nineties, Perron (1989) challenged the conventional understanding of the data generating processes (DGP) of macroeconomic data series, claiming that most macroeconomic series are not necessarily characterized by a unit root but, rather, by structural breaks due to large and infrequent shocks, which characterise a country's long-run development. Hence, Perron's (1989) proposal was to allow for huge structural breaks when analysing macroeconomic data series, which are directly related to the types of shocks that hit one economy. Namely, in some cases when the shocks hitting an economy are very big they can cause a switch of a country from one deterministic trend to another. Later this idea will be incorporated in the definition of instability of growth as a peculiar characteristic of the growth process.

Perron's ideas motivated the emergence of studies that investigate shocks that hit one economy and their impact on growth and real GDP data series. Easterly et al. (1993) found that the country specific shocks are hugely important for the medium-term growth of each country. Namely, Easterly et al. (1993) showed that correlation of growth across decades (1960-70 and 1970-80) within countries is very low – averaging from 0.1 to 0.3 in a worldwide sample of 115 countries. They explain the low persistence of growth rates by *the role of shocks* in the countries, such as the terms of trade, war related causalities, external transfers and debt crisis. More precisely, they argued that shocks are important over decade-long periods, especially for developing countries which are more prone to shocks, since they influence "policy" variables and thus estimates of the impact of policies. In similar manner, emphasizing the impact of the shocks in the economy, Ben-David and Papell (1997) identify a statistically significant single structural break in the growth series for 54 countries out of set of 74 countries from 1955 to 1990. Beginning with the scan of output (in levels), defined as the logarithm of real GDP per capita, they used Perron's (1989) testing procedure to identify structural breaks in the data series. The algorithm actually identified structural breaks on purely statistical grounds and the unit root null was rejected for 20 countries in their sample. Additionally, they applied the test in first differences for the series in which a unit root could not be rejected. Finally, they found 54 countries in total in which a structural break was statistically significant either in levels or rates analysis. In general, the reasons behind the big shocks were different: for the developed countries, the breaks were associated with the collapse of the Bretton-Woods system and the first oil embargo; while the meltdowns, i.e. the growth slowdowns in developing countries, commenced with the second oil shock and the start of debt crisis.

Motivated by the idea of variation of growth paths among countries, Pritchett (2000) developed the idea of *changes in growth regimes*, which are experienced mainly by developing economies due to big shocks recorded in these countries, as oppose to a consistent convergence process, characteristic for developed countries (OECD countries in his study).

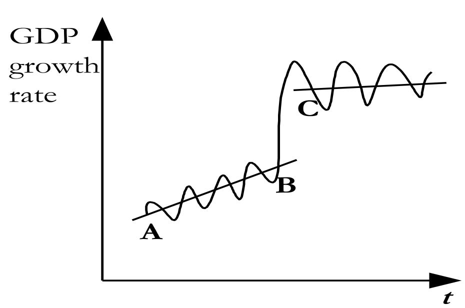
In order to examine the differentiation among growth in developed and developing countries, firstly he tested how much of the country's time-series behaviour is just a trend, interpreting the

R^2 of the simple regression line as an indicator of fit, i.e. fitting a single time trend through *y* for the whole period in the case of 111 developed and developing countries. The time horizon is 1960-92, and the frequency of data is quarterly in Pritchett's analysis (2000). His findings are appealing. In the developed–country sample the median R^2 is 0.95, with standard deviation of only 0.03; while for the developing-country sample the median R^2 is only 0.67, with a standard deviation of 0.32. Hence, for nearly all industrial countries the total variance of the time series is almost completely summarized in a single number – the average growth rate, while in contrast in developing countries the R^2 values are distributed over the entire (0,1) range. After summarizing the results into two groups, developed and developing countries, he concluded that OECD countries have business cycle fluctuations, but these are not the dominant features of the evolution of their GDP. In contrast, for the developing countries, "growth" is not just the trend, but it is characterized by *sudden changes*, which cause shifts in growth. In the long run, even small shifts in growth turn into huge shifts in living standards and even more sustained large differences into seismic shifts. Hence, he deepened the analysis into two more dimensions of growth, which are more visible in the case of developing countries:

- Instability of growth defined as shifts in the growth trend; and
- Volatility of growth defined by the deviations from the trend.

Instability refers mainly to the shifts of bigger size, which lead to change of regime, while volatility refers to the frequency of the shifts but still within the same trend line. Presented graphically in Figure 2 below, volatility encompasses the period between points A and B, while instability refers to the shift in the GDP growth rate between points B and C (In Figure the y-axis represents GDP growth rates).

Figure 2. Stylized depiction of instability and volatility of the GDP growth rate



Assessing the instability, Pritchett (2000) firstly tested structural breaks and shifts in the growth rates data for the industrial and developing countries, related to the Crisis of 1973. Growth rates are calculated as first differences of log real GDP data series. In order to test the instability he calculated and depicted in graphs the mean growth rates for the periods 1960-73 (before the Crisis),1973-82, and 1982-92. His graphs of mean growth rates for certain periods confirmed that growth in some of the countries was indeed localized in episodes of discrete trends separated by shifts in growth rates. Hence, in the second step he used a specific calculation in order to determine the growth differences based on the best single breakpoint in trend (*t**) from the data. Namely, if

Equation 1 $$y_t = a_I I_I (t \le t^*) + b_I t^* I_I (t \le t^*) + a_{II} I_{II} (t > t^*) + b_{II} t^* I_{II} (t > t^*) + e$$

where *I*(.) is an indicator function and *t** ischosen to minimize the sum of squared errorsover all *t*, such that $t^* - t_0 \ge 6$ and $T - t \ge 6$; the year of breakpoint is *t**; and growth before the break is g_b, while growth after the break is $g_a$and the difference in growth rates is (g_b– g_a). The estimations confirmed the idea of shifts in growth rates, with different points in time identified by the algorithm for each country depending on the economic conditions within the country. These shifts are especially emphasized and much larger in developing or less developed countries as compared to the size of shift for developed countries. Namely, among the developing countries the average group shift (i.e. difference in growth rates (g_b– g_a)is 3.85 percentage points, while the average shift in developed countries is only 1.46 percentage points. Big shifts are mainly deceleration of growth in both groups of countries; in the developed countries these are related to the impact of the oil shocks, while in the developing countries shifts are mainly country specific. The shifts in growth observed in various countries created distinct growth patterns Pritchett (2000, p.2):

TESTING PROCEDURE

The theme of univariate analysis of time series has gained an increasing amount of attention in terms of theoretical and applied research over the last three decades, starting with the seminal works by Perron (1989) and Perron (1990). By applying a testing procedure that is an extension of the Dickey-Fuller methodology, Perron (1990) tries to separate “outlying” exogenous events, which happens on a known date, from the noise function and to model it into the deterministic part of the general time series model. In general, he develops two types of models for testing the unit root in a time series, which are:

- characterised by a structural change in its mean level; and,
- time series which are characterised by a presence of a one-time change in the level or/and in the slope of the trend function.

For both cases, he develops sets of models and corresponding regressions as given in the following table, with the last rows adding explanations. In the table below the two types of models developed in the two papers (Perron, 1989) and Perron (1990) are given in the two columns. In addition, another classification is made by setting out the additive and innovative outlier models in two main rows. The brief explanations for each of the models and notation are given:

- for the additive outlier models in row 6; and
- for the innovative outlier models in row 7.

Table 1. Main models developed by Perron (1989, 1990) for testing for a unit root in a time series with intercept or/and trend breaks

		I) Structural change in mean level of the series (Perron, 1990, p. 14) (1)		**II) Structural change in the level or in the slope of the trend function (Perron, 1989, p.1373, 1380) (2)**
Additive outlier	1	Extension of Phillips procedure (1987) (for details see p.13)	1	Extension of Phillips procedure (1987) (for details see p.1378)
	2	$\tilde{y}_t = \tilde{\alpha}\tilde{y}_{t-1} + \sum_{j=1}^{k} c_j \Delta\tilde{y}_{t-j} + v_t$ where *(t=k+1,…T)* and $\Delta\tilde{y}_t = \tilde{y}_t - \tilde{y}_{t-1}$ (Perron, 1990, p.12)	2	$\tilde{y}_t^i = \tilde{\alpha}^i \tilde{y}^i{}_{t-1} + \sum_{j=1}^{k} \tilde{c}_i \Delta\tilde{y}^i{}_{t-1} + \tilde{e}_t$ where *(i=A,B,C)* and $\Delta y_t^i = \tilde{y}_t^i - \tilde{y}^i{}_{t-1}$
Innovation outlier models	3	Model AM ("crash mean hypothesis")	3	3. Model A ("crash hypothesis")
		$y_t = \hat{\mu} + \hat{\gamma} DU_t + \hat{d} D(TB)_t + \hat{\alpha} y_{t-1} + \sum_{j=1}^{k} \hat{c}_j \Delta y_{t-1} + \hat{v}_t$		$y_t = \hat{\mu}^A + \hat{\theta}^A DU_t + \hat{\beta}^A t + \hat{d}^A D(TB)_t + \hat{\alpha}^A y_{t-1} + \sum_{i=1}^{k} \hat{c}_i \Delta y_{t-1} + \hat{e}_t$
	4		4	Model B ("breaking slope with no crash")
				$y_t = \hat{\mu}^B + \hat{\theta}^B DU_t + \hat{\beta}^B t + \hat{\gamma}^B DT^*{}_t + \hat{\alpha}^B y_{t-1} + \sum_{i=1}^{k} \hat{c}_i \Delta y_{t-1} + \hat{e}_t$
	5		5	Model C (both hypotheses are allowed)
				$y_t = \hat{\mu}^C + \hat{\theta}^C DU_t + \hat{\beta}^c t + \hat{\gamma}^C DT_t + \hat{d}^C D(TB)_t + \hat{\alpha}^C y_{t-1} + \sum_{i=1}^{k} \hat{c}_i \Delta y_{t-1} + \hat{e}_t$
	6	**Explanation and notation of the additive outlier model (row 2):**	6	**Explanation and notation of the additive outlier model (row 2):**
		Perron 1990, p.7sets out this additive outlier test as a two steps regression procedure in which the first step - detrending – is to subtract the mean from the raw series (y_t) by allowing a change at time T_B . The two steps are: a regression of y_t on a constant and DU_t (defined in Row 7); and the residuals from the first step regression are denoted $\tilde{y}_t$; and $\tilde{\alpha}$is the least squares estimator of α in the following regression: $\tilde{y}_t = \tilde{\alpha}\tilde{y}_{t-1} + \tilde{e}_t$. This approach adopts the procedure suggested by Dickey and Fuller (1979) and Said and Dickey (1984) which adds extra lags of the first differences of the data as regressors in the equation: $\tilde{y}_t = \tilde{\alpha}\tilde{y}_{t-1} + \tilde{e}_t$, resulting in the equation given above in row 2.		Perron (1990, p. 1373) suggest that this additive outlier test is a two steps regression procedure whereby: Firstly, the raw series (y_t) are detrended according to either model A, B or C. In the second-stage regression, the residuals ($\tilde{y}_t$) from a regression of y_t on (1) i=A: a constant, a time trend, and DU_t ; (2) *i=B*: a constant, a time trend and DT_t^*; (3) *i=C:* a constant, a time trend, $DU_t$and DT_t; and $\tilde{\alpha}$is the least squares estimator of α in the following regression: $\hat{y}_t^i = \tilde{\alpha}^i \tilde{y}^i{}_{t-1} + \tilde{e}_t$. This approach adopts the procedure suggested by Dickey and Fuller (1979) and Said and Dickey (1984) which adds extra lags of the first differences of the data as regressors in the equation: $\hat{y}_t^i = \tilde{\alpha}^i \tilde{y}^i{}_{t-1} + \tilde{e}_t$ resulting in the equation given above in row 2.

	7	**Explanation and notation of the innovative outlier model (row 3):**	7	**Explanation and notation of the innovative outlier models A, B and C (rows 3, 4 and 5):**
		This approach involves only a one-step regression. $\hat{\mu}$ is the constant term, $y_{t-1}$the first lag of the level of the left-hand side variable and Δy_{t-1} lagged differences to ensure that the residual e_t is free of autocorrelation. The equation takes into account the existence of two possible kinds of structural breaks, where *TB* is the break date: a "crash" effect, which allows for a break in the mean of the series, such that the crash dummy *D(TB)* = 1 if *t* = *TB* +1, and zero otherwise; the intercept shift dummy DU_t allows for a once-and-for-all change in the mean such that $DU_t =1$ if ($t > TB$) and zero otherwise. The model has a unit root with a break under the null hypothesis, as the deterministic components are incorporated in the regression under the null. The alternative hypothesis is a broken mean stationary process.		This approach involves only a one-step regression. $\hat{\mu}$ is the constant or estimated drift term, $\hat{\beta}$ is the coefficient to be estimated on the deterministic time trend *t*, $y_{t-1}$the first lag of the level of the left-hand side variable and Δy_{t-1} lagged differences to ensure that the residual e_t is free of autocorrelation. Model C takes into account the existence of three possible kinds of structural breaks, where *TB* is the break date: a "crash" effect, which allows for a break in the level (or intercept) of the series, such that the crash dummy *D(TB)* = 1 if *t* = *TB* +1, and zero otherwise; the intercept shift dummy DU_t allows for a once-and-for-all change in the level, such that $DU_t =1$ if $t > TB$ and zero otherwise; the slope dummy DT_t represents a trend "shift", which allows for a once-and-for-all break in the slope (or the rate of growth) of the trend function, such that $DT = t-TB$ if $t > TB$ and zero otherwise. Other models (A and B) take into account fewer breaks; however the notation is the same. The model has a unit root in the presence of breaks under the null hypothesis, as the deterministic components are incorporated in the regression under the null. The alternative hypothesis is a broken trend stationary process.

According to Perron (1989, p.1380), these models fall into two main groups: the so called "additive outlier model"; and the "innovation outlier model". While the former model is a two-steps regression, whereby the residuals from the first regression are used as a dependant variable in the second regression, the latter involves only a one-step regression, estimating the trend function and the dynamics of the process simultaneously. In addition, the former imply that the change in the mean/or trend function of the data series occurs instantaneously, while the later model allows for a gradual change in the mean and/or the trend function. In general, Perron (1989, p.1380) suggests that this distinction is a "possible drawback" of the former models, given for instance that it is more realistic to assume that the economy reacts over time to some shock. In addition, he derives the critical values which are the same for both the additive and innovation outlier models, thereby allowing for hypothesis testing.

When comparing the two groups of innovation outlier models, that is the Model AM (row 3, column 1) with the models A, B and C (rows 3,4 and 5, column 2), it is noticeable that the latter ones include a deterministic time trend *t* with $\hat{\beta}$ as the coefficient to be estimated. In addition, the most extensive Model C includes a slope dummy DT_tthat represents a trend "shift", which allows for a once-and-for-all break in the slope (or the rate of growth) of the trend function. In sum, Model C is an encompassing model. Having the most extensive specification, Model C permits testing for the presence of a unit root in a "quite general time series process which allows for a one-time break in the mean of the series or its rate of growth (or both)" (Perron,1989, p.1381).

Perron uses the Model AM (row 3, column 1) to apply his testing procedure to three types of series: interest rate series; unemployment rate series; and terms of trade index series. The Models A,B and C (rows 3,4 and 5, column 2) are used to test the post-war quarterly real GDP series and the other 14 macroeconomic variables sampled annually by Nelson and Plosser (1982).

Following Perron's argument, we have two reasons to use innovative outlier models, and Model C in particular, for our testing procedure.

1. Firstly, we believe that it is more realistic to model changes in the real economy as occurring over time, even when they are initiated by some sudden or shock event.
2. Secondly, as mentioned, Model C is an encompassing model, which allows for a one-time break in the mean of the series or its rate of growth (or both). In our analysis of regime switches, we want to allow for intercept shift and trend shifts.

In summary, following Perron's argument that most macroeconomic time series are characterized by deterministic trends broken by large shocks that determine a particular country's long-run growth, this section aims to identify similar structural breaks in data series in transition countries by using the most extensive – encompassing - Model C. In addition, this strategy is adopted, because there is an affinity between Perron's innovations in the analysis of univariate time series and the later growth literature emphasizing regime changes.

Several caveats to the testing procedure

Before applying the testing procedure, several caveats should be mentioned at this instance:

- Firstly, this test is derived from asymptotic principles and so requires a large sample for implementation; hence, the results in this analysis should be considered as suggestive only.
- Secondly, the break points are assumed in advance, based on visual inspection of the data, as Perron (1990, p17) suggests, and informed by the historical knowledge, which may not fully represent reality.

This second caveat deserves additional consideration. A perquisite for applying this procedure is that the test can be conducted conditional on a change occurring at a fixed known date. However, in the case of transition countries, there are often easily identifiable turning points after which growth behaves differently, mostly related to the wars, conflicts or to recent historical facts, which are well known. These inform the choice of structural break points to be investigated. However, issues of concern may still arise over the choice of the break point. In this case, Perron (1990, p.17) suggests that "usually visual inspection is sufficient since the method is better suited for sudden changes". However, in a subsequent paper, Perron (1990) further discusses this issue suggesting that the general idea of these tests is not to provide an unconditional representation of the time series properties of the variables, but to remove from the noise function the events that occurred at specific dates when shocks happened and by modelling them by means of the trend function. In our analysis, in order to reduce the possibility of data mining, the events tested are the ones that can be considered – following Perron (1989 and 1990) - as exogenous and major. Table 2 below gives the possible turning points to be investigated for the various countries, based on the details given in transition literature and history facts (CIA, 2017). Reported are the tests for the points that were regarded as exogenous and major such as wars, conflicts and dissolutions that were given priority. These "major" visual events are taken to be the breaking points for which the results are presented. The question to investigate is whether the shocks observed in historical facts can be classified as major, in the sense that they thereby affect subsequent growth in transition countries.

Table 2. Possible turning points of growth in various transition countries

Country	Albania	Armenia	Azerbaijan	Belarus	B&H	Bulgaria	Czech Rep.	Croatia
Turning point (year)	1997	1994	1995	1996	Short data	1997	1997	1995
Country	Estonia	Hungary	Georgia	Kazakhstan	Kyrgyz Rep.	Kosovo	Latvia	Lithuania
Turning point (year)	1999	1994	1995	2000	1995	Short data Series	1994	1994
Country	Poland	Romania	Russia	Serbia	Slovenia	Slovak Rep.	Macedonia	Moldova
Turning point (year)	1993	1999	1998	Short data series	1993	1998	2001	1993
Country	Montenegro	Turkmenistan	Tajikistan	Ukraine	Uzbekistan			
Turning point (year)	Short data series	1997	1997	1995	1995			

Estimation on instability

Perron's modified ADF test is used in order to locate and test for structural breaks within each time series. Beginning with the scan of output (in levels), defined as the logarithm of real GDP per capita, and after applying the test in first differences – i.e. growth rates - for the series for which the unit root could not be rejected, the test should assess whether the structural breaks were statistically significant.

The equation tested here is:

Equation 2 $\Delta y_t = \hat{u} + \hat{\theta} DU_t + \hat{\beta} t + \hat{\gamma} DT_t + \hat{d} D(TB)_t + \hat{\beta}_1 y_{t-1} + \sum_{i=1}^{k} \hat{c}_i \Delta y_{t-i} + \hat{e}_t$,

where $\hat{u}$ is the constant or estimated drift term, $\hat{\beta}$ is a coefficient to be estimated on the deterministic time trend *t*, $y_{t-1}$the first lag of the level of the left-hand side variable and Δy_{t-1} lagged differences to ensure that the residual e_t is free of autocorrelation. The coefficient of interest is $\hat{\beta}_t$ and we test the unit root null hypothesis according to whether it is not statistically different from zero (unit root rejected). Due to the standard Dickey- Fuller reparametrisation this is the same as we were to test whether α=1. As mentioned, the equation takes into account the existence of three kinds of structural breaks, as explained in row7, column 2 in Table 1 above. The model has a unit root in the presence of breaks under the null hypothesis, as the deterministic components are incorporated in the regression under the null. The alternative hypothesis is a broken trend stationary process. The order of Perron's modified ADF test – i.e. the number of lags of the differenced variable to include on the left-hand side of the testing equation – was decided by examining model diagnostics and choosing the testing equation with the minimum number of lagged differences consistent with ensuring a white noise error term (hence free from autocorrelation). This minimises loss of degrees of freedom in context of already short time series.

EMPIRICAL RESULTS

The results with respect to testing for the presence of unit root in the natural logarithm of GDP for each country are given in the table and the estimates in full are available from the author. The coefficients are estimated by OLS regression using Microfit. For the coefficient β_1(column 7 in the table), for which the T-Ratio and p-value are reported, the t-statistic is compared to the critical values given in Perron's tables (Perron, 1989, p.1377), having deciding first the size of the test, which is taken to be the 10% level of significance, and the time break relative to the total sample size. If t-statistic < critical value, the unit root can be rejected. In the table the coefficients for the cases where the unit root was not rejected are not marked for significance at all (in those cases the countries are highlighted in light grey). Given that critical values are non-standard in the presence of a unit root, these countries and their results are not discussed. However, in cases where the unit root null is rejected, then the usual (standard) critical values are used. Hence, in these cases the estimated coefficients and their appropriate p-values in parentheses are presented for further comment. In addition, for the countries for which the unit root could not be rejected, we conducted further testing.

In Table 3 each row presents one transition country. The columns (2-7) give the appropriate estimated coefficients with the p-values in parentheses, with the first column (1) giving the turning points tested, column (8) the R-squared of the estimated regression, column (9) the diagnostic test brief description, and the final column (10) the judgment as to whether the assumption of a unit root is/or is not rejected.

Table 3. Testing the unit root hypothesis for the lnGDP

Country		$\Delta y_t = \hat{u} + \hat{\theta} DU_t + \hat{\beta} t + \hat{\gamma} DT_t + \hat{d} D(TB)_t + \hat{\beta}_1 y_{t-1} + \sum_{i=1}^{k} \hat{c}_i \Delta y_{t-i} + \hat{e}_t$ The dependant variable is the first difference of lnGDP								
	Turning point tested (1)	**Constant (2)**	**Trend (3)**	$\hat{\theta}(DU_t$ **level effect) (4)**	$\hat{\gamma}(DT_t$ **trend effect) (5)**	$\hat{d}(D(TB)_t$ **crash effect) (6)**	$\hat{\beta}_1 y_{t-1}$ **(T-ratio, p-value) (7)**	**R^2 (8)**	**Diag. tests (9)**	**Unit root rejected/not rejected (10)**
Armenia	1994	1.58 [.131]	-.42 [.000]	-.81 [.002]	.43[.000]	-.11 [.025]	-.90728[.382]	.98	Fun. form	Unit root can NOT be rejected
Azerbaijan	1995	2.12 [.114]	-.11 [.016]	-.65 [.087]	.15 [.013]	-.05[.617]	-1.6925[.116]	.89	All fine	Unit root can NOT be rejected
Albania	1997	5.03 [.000]*	.07 [.000]*	.26 [.000]*	-.04[.000]*	-.14[.000]*	-15.55[.000]	.98	All fine.	Unit root can be rejected
Belarus	1996	2.43 [.211]	-.049 [.019]	-.30 [.230]	.072[.040]	-.10[.072]	-1.3064[.216]	.93	Fun. form	Unit root can NOT be rejected
Bulgaria	1997	4.73 [.000]*	.013 [.030]**	-.29 [.002]*	.02 [.035]**	.02[.318]	-5.7109[.000]	.96	Fun. form	Unit root can be rejected
Croatia	1995	3.12 [.003]*	.03 [.000]*	.10 [.207]	-.02[.078]***	-.054[.178]	-3.9549[.002]	.88	All fine	Unit root can be rejected
Czech Rep.	1997	4.65 [.000]*	.03 [.000]*	-.05 [.179]	-.004[.380]	.03[.098]**	-5.56[.000]	.93	All fine.	Unit root can be rejected
Estonia	1999	1.39 [.757]	.033 [.008]	.48 [.079]	-.046[.079]	-.142[.113]	-.36545[.422]	.73	Func. form	Unit root can NOT be rejected
Georgia	1995	2.12 [.232]	.17 [.021]	.53 [.265]	-.14[.069]	.033[.742]	-2.07[.062]	.98	All fine	Unit root can NOT be rejected
Hungary (2 lags)	1994	6.25 [.005]*	-.06 [.073]***	-.39 [.037]**	.08[.037]**	.04[.053]***	-3.5464[.005]	.83	Func. form	Unit root can be rejected
Kazakhstan	2000	5.79 [.044]	-.035 [.201]	-.738 [.127]	.087[.103]	-.018[.798]	-2.3476[.039]	.89	All fine	Unit root can NOT be rejected

Kyrgyz Rep.	1995	6.80 [.013]	-.16 [.003]	-.96 [.018]	.18[.004]	-.047[.178]	-2.93[.013]	.95	All fine	Unit root can NOT be rejected
Latvia	1993	5.05 [.017]	-.31 [.000]	-.94 [.005]	.35[.000]	.018[.751]	-2.59[.024]	.94	All fine	Unit root can NOT be rejected
Lithuania	1994	5.11 [.024]	-.13 [.004]	-.67 [.034]	.17[.005]	-.035[.540]	-2.57[.025]	.92	Func. form	Unit root can NOT be rejected
Macedonia	2001	0.60 [.293]	.013 [.000]	-.01 [.854]	-.003[.400]	-.049[.014]	-1.30[.217]	.91	Fun. form	Unit root can NOT be rejected
Moldova	1993	3.96 [.000]*	-.25 [.005]*	-.99 [.001]*	.27[.002]*	.32[.000]*	-5.56[.000]	.91	Func. form	Unit root can be rejected
Poland	1993	6.22 [.000]*	.039 [.000]*	-.05 [.061]***	-.001[.361]	.031[.018]**	- 11.7351[.000]	.95	All fine	Unit root can be rejected
Slovak Rep.	1998	3.67 [.000]*	.030 [.000]*	-.09 [.072]***	-.50[.914]	.023[.307]	-6.5435[.000]	.95	All fine	Unit root can be rejected
Slovenia	1993	4.84 [.078]	-.006 [.808]	-.036 [.787]	.027[.474]	.003[.759]	-1.99[.069]	.96	All fine	Unit root can NOT be rejected
Romania	1999	2.49 [.004]*	-.007 [.459]	-.24 [.005]*	.024[.045]*	-.037[.115]	-3.76[.004]	.85	All fine	Unit root can be rejected
Russian Federation	1998	2.86 [.013]	-.05 [.059]	-.35 [.020]	.07[.017]	-.003[.939]	-2.9691[.012]	.91	All fine	Unit root can NOT be rejected
Tajikistan	1997	9.38 [.002]*	-.25 [.002]*	-2.43 [.004]*	.33[.002]*	.068[.250]	-4.012[.002]	.98	All fine	Unit root can be rejected
Turkmenistan	1997	1.66 [.018]	.004 [.793]	-.06 [.735]	.016[.428]	-.163[.007]	-3.3212[.008]	.96	All fine	Unit root can NOT be rejected
Uzbekistan	1995 (2lags)	-3.246 [.012]	.06 [.001]	.53 [.002]	-.07[.002]	-.0[.036]	2.56[.026]	.95	All fine	Unit root can NOT be rejected
Ukraine	1995	6.06 [.075]	-.07 [.161]	-1.09 [.163]	.12[.130]	.004[.955]	-2.05[.065]	.94	All fine	Unit root can NOT be rejected

Notes: * - indicates significant at the 1% level, ** - indicates significant at the 5% level, and ***-indicates significant at the 10% level of significance.

In darker shading the countries for which the unit root null was not rejected are marked. In addition, column 9 in each table gives a short assessment of the diagnostic tests: “All fine” is used to mark estimations for which all diagnostic tests were acceptable, while “Func. form” marks the cases where problems with Functional form test were identified.

The coefficients are estimated by OLS regression using Microfit. For the coefficient β1(column 7 in the table), for which the T-Ratio and p-value are reported, the t-statistic is compared to the critical values given in Perron’s tables (Perron, 1989, p.1377), having deciding first the size of the test, which is taken to be the 10% level of significance, and the time break relative to the total sample size. If t-statistic < critical

Before interpreting the results, it should be noted again that the results are only indicative, for the reasons given above. Several main conclusions can be made:

- Namely, when implementing Perron's modified augmented Dickey-Fuller Test on the lnGDP series, there are 10 series for which the unit root null can be rejected but which yield significant intercept break and/or trend break terms (respectively, nine and seven from 10).
- In general, examination of the test results for the countries for which the unit root was rejected reveals various types of shifts in GDP. We can gain insight into real GDP effects after the respective break points for those 10 countries for which the unit root null was rejected. The estimated coefficients measuring the level (constant) and the trend are combined with the corresponding interaction terms, respectively the level break dummy and the trend break dummy. While the summation of the estimated coefficient on the constant plus the level break dummy represents the combined level change effect after the break, the summation of the estimated coefficient on the trend plus the trend break dummy represents the combined trend change effect after the break in the data series. Depending on the sign and size of the estimated coefficients and their appropriate interactive terms, the combined effects in level and trend after the break can be described as mainly positive or negative.

As expected, for those countries for which the unit root hypothesis was not rejected for the levels of lnGDP, unit root testing of the first differences of the lnGDP series revealed that for most of these countries the unit root hypothesis could not be rejected. We proceed by testing the first differences of lnGDP for a unit root. The idea is to investigate whether the growth rates in the various countries are stationary and also whether they have experienced structural breaks.

The estimations are available from the author, while the results with respect to testing for the presence of unit root in the first difference of the natural logaritham of GDP for each country are summarized in following Table 4. Each first-differenced series is tested for the presence of a unit root using the same procedure as was applied to the levels of lnGDP; however, in each case the trend and trend-break terms were excluded from the testing equations on the grounds that the implied quadratic effects in the levels have no sensible economic interpretation (certainly not for real economic series like GDP) and therefore played no part in testing the levels series. The crash term was also excluded on the grounds that a one-period crash effect in the lnGDP series is self-cancelling in successive periods of the differenced lnGDP – i.e. growth rate – series (so that it has no permanent effect on the growth rate).

Table 4. Testing the unit root hypothesis for the first-differences of lnGDP

Country	The dependant variable is the second difference of ln GDP						
	Turning point tested (1)	Constant (2)	$\hat{\theta}(DU_t$ level effect) (4)	$\hat{\beta}_1 y_{t-1}$ (T-ratio, p-value) (7)	R^2 (8)	Diag. tests (9)	Unit root rejected/ not rejected (10)
Estonia	1999	4.62[.025]**	.58[.268]	-3.45[.005]	.53	Func.form	Unit root can be rejected
Slovenia	1993	-.06[.072]***	.103[032]**	-3.51[.004]	.88	All fine	Unit root can be rejected
Armenia	1993	-.49[.000]*	.56[.000]*	-15.89[.000]	.97	All fine	Unit root can be rejected
Azerbaijan	1995	-.16[.002]*	.21[.001]*	-3.88[.002]	.59	Func.form	Unit root can be rejected
Belarus	1996	-.066[.012]**	.10[.002]*	-3.48[.004]	.53	Func.form	Unit root can be rejected
Kazakhstan (2 lags)	2000	-.035[.098]***	.08[.031]**	-3.033[.010]	.41	All fine	Unit root can NOT be rejected
Latvia	1993	-.345[.000]*	.39[.000]*	-8.644[.000]	.89	All fine	Unit root can be rejected
Lithuania	1994	-.21[.000]*	.27[.000]*	-7.21[.000]	.83	All fine	Unit root can be rejected
Macedonia	2001	.004[.739]	.005[.765]	-1.60[.131]	.18	All fine	Unit root can NOT be rejected
Russia	1998	-.05[.015]**	.12[.003]*	-4.027[.001]	.54	All fine	Unit root can be rejected
Turkmenistan	1997	-.095[.001]*	.19[.000]*	-5.79[.000]	.71	All fine	Unit root can be rejected
Uzbekistan	1995	-.067[.012]**	.105[.004]*	-3.86[.002]	.52	All fine	Unit root can be rejected
Georgia	1995	-.402[.007]*	.49[.005]*	-3.95[.001]	.53	Func. form	Unit root can be rejected
Kyrgyz Rep.	1995	- .14227[.000]*	.17[.000]*	-5.88[.000]	.75	All fine	Unit root can be rejected
Ukraine	1995	-.054[.169]	.092[.113]	-2.11[.052]	.24	All fine	Unit root can NOT be rejected

Notes: * - indicates significant at 1% level, ** - indicates significant at 5% level, and ***-indicates significant at 10% level of significance. In addition, column 9 in each table gives short description of diagnostic tests: “All fine” is used to mark estimations for which all diagnostic tests were fine, while “Func. form” marks the cases where problems with Functional form test were identified.

When implementing Perron’s modified augmented Dickey-Fuller Test on the first differences of the lnGDP series, the unit root was rejected for the rest of the countries, except for three, such as Macedonia, Kazahstan and Ukraine. This indicates that the first differences of lnGDP, or growth rates of GDP, in most of these cases are stationary variables. However, the results of unit root testing are often ambiguous and conclusions involve judgements that take into account a range of evidence, including formal unit root tests and examining the plots of times series.

This would seem to be the implication of the conclusion of Harris and Sollis (2003, p.77) to their exposition of “testing for unit roots”: *Clearly, the most important problem faced when applying unit root tests is their probable poor size and power properties (i.e. the tendency to over-reject the null when it is true and under-reject the null when it is false, respectively). This problem occurs because of the near equivalence of non-stationary and stationary processes in finite samples, which makes it difficult to distinguish between tend-stationary and difference-stationary processes. It is not really possible to make definitive statements like ‘real GDP is non-stationary’; rather, unit root tests are more useful for indicating whether the finite sample data used exhibit stationary or non-stationary attributes.*

CONCLUSION

The variety of results regarding rejection/non-rejection of the unit root hypothesis and of break points suggested by the deterministic components in the testing equations makes it difficult to draw general conclusions. In addition, for some of the countries the unit root hypothesis was not rejected for lnGDP, while for some it was rejected even for the first differences, which additionally complicates attempts to draw general conclusions. However, in general, it can be confirmed that economic development in these transition countries was often interrupted sufficiently severely to give rise to a detectable break. Moreover, it can also be confirmed that upon differencing the data series generally exhibit stationary attributes, although with the caveat of the small sample size problem. With respect to the in lnGDP levels, while in some cases these breaks are characterised by long-lasting “level” and “trend” effects. Similarly, most of the differenced lnGDP series exhibit breaks in the level of growth (shown by significant intercept shift terms in Table 4.

The procedure itself has limitations in several aspects:

- Firstly, it identifies breaks that are presumed from previous knowledge. Although it could be be argued that this feature might be the strength of the procedure, since it determines the breaking points based on historical knowledge and theory. The alternative is to identify “turning points” using a statistical algorithm, which of course is a completely a-theoretical approach.
- Additionally, it allows for only one break in the data series that is not on the tails of the data series.
- It does not separate the instability from the volatility of growth; and,
- Finally, it is suggestive rather than definitive in a small sample.

However, beside limitations, the testing procedure was useful in the sense that it does reveal evidence of structural breaks in economic development under transition and, thereby, directs attention towards further search for more effective and appropriate methods of analysis. Hence, an approach that can model jointly both structural shifts and volatility in data series is needed to allow for better identification of both instability and volatility in the course of transition. Statistically, such a model will give the possibility of replacing the familiar picture of long-run growth now and then impacted by business cycle fluctuations with a growth concept allowing for shifts or breaks in trend and characterized by varying degrees of volatility around each new trend line. Hence, in these cases, the analysis of economic growth must be matched with a non-linear modelling approach that will allow the parameters to adjust to reflect structural changes, but will be also informative on the dynamics around each particular trend line. As Durlauf et al. (2004) suggest many of the difficulties that face growth researchers could be addressed in ways that are now standard in the macro econometrics literature or business cycle literature. This can be done using interaction terms, nonlinearities or semi parametric methods, so that the marginal effect of a given explanatory variable can differ across countries or over time.

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