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New Insights Into Electricity Consumption and Economic Growth Nexus in Transition Economies

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Abstract

This paper explores the long-run and the short-run causality relationships between electricity consumption, economic growth, and inflows of foreign direct investments in 17 transition economies in the period between 1992 and 2009 for the purpose of designing an optimal energy policy in these countries. This paper employs the newly developed dynamic panel cointegration techniques to explore the direction of the causality links between the selected variables. The results do not confirm the existence of the long-run equilibrium relationship in the transition economies between electricity consumption, economic growth, and foreign direct investment. Therefore, the direction of the long-run causalities between the variables could not be identified either. The estimation of the short run causalities showed that interrelationships between electricity consumption and economic growth are country specific, and should be evaluated with caution when designing energy policy. Overall, the results of this study show that the long-run equilibrium relationship between electricity use and economic growth in this region deserves further attention in future research.

Keywords: Energy Consumption, Panel Unit Root Tests, Panel Cointegration,
Granger Causality, Transition Economies

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The flaws and the errors that remain are fully our responsibility.

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Glossary

ADF	Augmented Dickey Fuller test
Cointegration	a long-run equilibrium relationship among a set of nonstationary variables, whose stochastic trends are linked (Enders, 2010, p.356);
DGP	Data Generating Process;
ELC	Electricity consumption measured in kilowatts;
Equilibrium	in this study it refers to any long-run relationship among non-stationary variables;
FDI	Foreign Direct Investment: in this study refers to inflows of foreign direct investments;
GDP	Gross Domestic Product;
Granger Causality	a statistical hypothesis test that determines if past realizations of one variable improve the forecasting performance of another variable (Enders, 2010, p.318);
Non-Stationary Variables	variables that include unit roots; variables whose means and variances change with time origin;
Spurious Regressions	regression models that include non-stationary variables; often produce statistically significant results, but without meaningful economic interpretation (Enders, 2010, p.196);
Stationary Variables	Variables whose means and variances do not change with time;
Unit Root	a feature of processes that evolve through time with time-varying mean and variance;
VAR	Vector Auto-regressive models;
VECM	vector error correction models, in which “the short-term dynamics of the variables in the system are influenced by the deviation from the long-run equilibrium” (Enders, 2010, p.366);
White Noise Process	a sequence of residuals is said to follow a white noise process if each residual in a sequence has a mean of zero, has a constant variance, and is uncorrelated with all other realizations (Enders, 2010, p.51);

1. Introduction

The current international debate on global warming, reduction of greenhouse gas emissions, and overall air pollution has reintroduced the interest in the question of whether or not energy conservation policies affect economic activity. This question has been widely studied before, and defines the whole class of economic literature on energy consumption-growth nexus. Even though the question is not novel, its focus has shifted from developed countries to developing and transition economies that are currently facing the pressure to restructure their energy sectors to ensure sustainable economic growth. However, despite the wide range of econometric techniques and availability of data, the results of these studies remain inconclusive and mixed.

The main focus of the energy consumption-growth nexus studies has been the direction of causality between energy and economic growth. The so far identified directions of causality can be classified into four general categories. The first category of results finds no causality relationship between energy consumption and GDP. These results formulate the 'neutrality hypothesis', and state that policies that influence energy consumption do not have any effects on economic growth. A second category of results identifies the uni-directional causality from economic growth to energy consumption, which defines the 'conservation hypothesis.' According to this hypothesis, the conservation policies on energy consumption are viewed as having little or no adverse effect on GDP. A third category of results is known as 'growth hypothesis,' which assumes a uni-directional causality from energy consumption to economic growth. This hypothesis suggests that any restrictions on energy consumption will hinder the growth of the economy. Finally, the 'feedback' hypothesis identifies the bi-directional causality between energy consumption and GDP. Under this hypothesis, energy consumption and GDP affect each other simultaneously. From these results it is evident that the direction of causality has an important implication for the energy policies and economic growth.

We find these causality links between energy and economic growth especially important for transition economies. Most of these countries were formed after the collapse of the Soviet Union in 1990, followed by two decades of fundamental changes in their economic and political systems, which lead to restructuring of the energy sector with a special focus on electricity market. The electricity sector in transition economies have undergone major changes in terms of liberalization and efficiency upgrades; however, even today it faces many challenges in the forms of diverse political and economic interventions, outdated infrastructures and production facilities, inadequate legal systems, dependence on natural resource suppliers, and lack of capital (EBRD, 1999; 2001; 2004; 2008). Therefore, it is especially important to investigate the causality links between electricity consumption and economic growth in these countries for the purpose of designing an optimal long-run energy policy that will keep electricity markets and economies sustainable.

Moreover, it is important to note that the transformation of the electricity markets and the reconstruction of the economic systems in these economies did not happen without support of foreign investors. The domestic savings in the transition economies have not been substantial enough to cover the large scale replacements of outdated capital stocks, liberalization of transmission and distribution settings, expansion of market connections, and other transformations (Johnson, 2006). Therefore, in these countries foreign direct investments have played the detrimental role in fulfilling the transformation of the energy markets.

Therefore, in this study we seek to investigate the long-run and the short-run causalities between electricity consumption, economic growth, and inflows of foreign direct investments for the purpose of identifying an optimal strategy for the energy conservation policies in these markets. We base our analysis on seventeen transition economies on the period from 1992 to 2009, which fully covers the institutional and economic transformation period in these countries. In our analysis we employ the newly developed dynamic panel cointegration techniques to estimate the causality links between electricity use and economic growth across all countries. We introduce inflows of foreign direct investments as a potential additional channel of causality, which can connect electricity consumption and economic growth through technology spill-over effects, capital formation, and improved production efficiencies.

To our knowledge there is only one previous study that investigated the causality relationships between electricity consumption and growth in the transition economies. Therefore, this study aims to add to this group of literature and provide more insights on the integration analysis for these countries, and on the long-run and the short-run relationships between electricity consumption and economic growth.

The remainder of the paper is organized as follows. Section 2 provides short overview of current state of knowledge on this topic. Section 3 presents summary of data. Section 4 briefly reviews empirical model and methodologies employed in this study. Section 5 gives an overview of the empirical results. Section 6 concludes and provides suggestions for future research.

2. Literature Review

The relationship between energy use and economic growth as well as electricity consumption and economic growth has been well-studied in the energy economics literature. The current literature on this topic includes a wide variety of studies that explore these relationships in different countries, time periods, by using different econometric methodologies and multivariate frameworks. However, the empirical outcomes of these studies are widely mixed and inconclusive. Chen, et al. (2007) identify several explanations for the variety of the results. According to them, the actual causality relationship between energy and growth is different in different countries due to the heterogeneous country characteristics, different national energy policies, political and economic histories, institutional setups, and different cultures. Lütkepohl (1982) identifies omitted variable bias as another reason for divergent causality results in the studies. Belke, et al. (2011) emphasize the variety of econometric methods employed to investigate causality relationships between energy and growth as the main reason for the discrepancies in the existing results.

According to Belke, et al. (2011) the methodological approaches used in the energy-growth nexus literature can be classified into four generations. The first generation studies applied the traditional vector autoregressive (VAR) models. For example, the seminal work of Kraft and Kraft (1978), who were first to introduce the idea of causal relationship between energy consumption and economic growth, used the VAR model to identify causality between income and energy consumption in the United States. Second generation explored nonstationarity in the variables that form long-run equilibrium relationship by using Engel and Granger (1987) cointegration [3] procedure. Those studies focused on bivariate frameworks, and used error-correction techniques to estimate Granger causalities between energy and growth. Third generation expanded the bivariate framework to multivariate approach that allowed for more than two variables to be cointegrated (Johansen, 1991). Finally, the fourth generation studies focus on panel-econometric techniques that allow to increase the power of unit root and cointegration tests by employing cross-section dimension of the panels. These studies estimate Granger causality through panel error-correction models.

The variability of methodological approaches and the interest in energy consumption-growth relationship produced a long list of studies that focused not only on the use of total energy, but also on different types of energy, which include oil, natural gas, coal, nuclear energy, renewable energy, and electricity. Since the main focus of this paper is electricity consumption-growth relationship, we will mainly present the overviews of the empirical studies with the same focus. We present short summaries of the studies that focus on the causal relationship between energy consumption and growth in the transition economies in Table 1.

We survey the literature on electricity consumption-growth nexus under three sections. In the first section we present country specific studies. In the second section the multi-country studies are

[3] A long-run equilibrium relationship among a set of nonstationary variables, whose stochastic trends are linked (Enders, 2010, p.356).

given. The final section presents a short literature survey on panel studies that explore the electricity consumption-growth and energy-growth nexus specifically in the transition economies.

2.1. Country Specific Studies

Country specific studies that investigated the direction of causality between electricity consumption and economic growth produced quite diverse and often contradicting results depending on the region, the selected time period, and the methodologies employed. Gosh (2009) investigated the relationship between electricity supply, employment and real GDP in India. He employed the autoregressive distributed lag (ARDL) approach to estimate cointegration, and found causality running from real GDP and electricity supply to employment, but found no causality relationships between real GDP and electricity use.

Table 1: Summary of empirical studies on energy consumption-growth nexus

Authors	Period	Country	Methodology	Causality Result
Jobert and Karanfil (2007)	1960–2003	Turkey	Granger causality test	①
Lise and Van Montfort (2007)	1970–2003	Turkey	Cointegration test	②
Karanfil (2008)	1970–2005	Turkey	Granger causality test; Cointegration test	② ① (when unrecorded economy is taken into account)
Erdal, et al.(2008)	1970–2006	Turkey	Pair-wise Granger causality, Johansen cointegration	③
Soytas and Sari (2009)	1960–2000	Turkey	Toda–Yamamoto causality test	①
Acaravci and Ozturk (2010b)	1980-2006	Albania, Bulgaria, Hungary and Romania	Granger causality, ARDL, Cointegration, Error Correction Model.	③ (Hungry) ① (Albania, Bulgaria, and Romania)

Note: *① means - no causality between energy consumption and GDP;*
② means-uni-directional causality from economic growth to energy consumption;
③ means- bi-directional causality between energy consumption and GDP;

Altinay and Karagol (2005) investigate Granger causality between electricity use and national income in Turkey for the time period between 1950 and 2000. They find a uni-directional causality running from electricity consumption to growth. However, a study by Halicioglu (2007) on Turkey for the period 1968- 2005 find a uni-directional causality in the opposite direction, running from GDP to electricity consumption, by employing the bounds testing methodology.

Tang (2009) studies the relationship between electricity consumption and growth in a multivariate framework on the example of Malaysia. He investigates Granger causalities between electricity consumption, income, foreign direct investment, and population, by employing bounds-testing procedure and Granger causality tests. His findings suggest the existence of bilateral causal relationships between electricity consumption and income, when FDI is introduced as an additional causality channel into the model.

Zhang (2011) study the relationship between energy consumption and growth in Russia between 1970 and 2008 by using Engel and Granger (1987) two-step procedure. They find bi-directional causality between energy consumption and GDP. A study by Gurgul, et al. (2012) on Poland between first quarter of 2000 and the last quarter of 2009, find the same causality direction between energy and growth.

Yang (2000) studies the relationship between electricity consumption and growth in Taiwan for the period between 1954 and 1997, and finds a bi-directional causality between electricity and GDP. However, Hu and Lin (2008) find causality running from GDP to electricity consumption in Taiwan between 1982-2006, by using Hansen-Seo threshold co-integration approach and vector error correction (VEC) model.

These country specific studies represent just a short list of studies on energy/electricity consumption – growth nexus. A lot of these studies produced contradictory results even for the same countries, when different time periods, and econometric methodologies were chosen for the research.

2.2. Multi-Country Studies

In case of the multi-country studies the results are as diverse as they are for the single country studies. Ferguson, et al. (2000) perform a study on more than 100 countries to investigates the relationship between electricity consumption and development. They conclude that wealthy countries have a stronger correlation between electricity use and income generation, than poor countries. They also find a stronger correlation between wealth generation and electricity consumption, than between total energy and wealth.

Narayan and Smyth (2009) employ panel unit root and panel cointegration techniques to investigate the causality between electricity consumption, exports and GDP for Middle Eastern countries. They discover a feedback effect between the variables, and therefore suggest implementation of steady electricity conservation policies.

Chen, et al. (2007) perform a panel estimation study on ten Asian countries: China, Indonesia, Hong Kong, India, Malaysia, Korea, Taiwan, Philippines, Singapore and Thailand. They employ Pedroni (1999, 2004) panel cointegration test and panel error-correction model to estimate the Granger causality between electricity use and economic growth. For all countries in the panel, they find bi-directional long-run causality between electricity consumption and growth.

2.3. Panel Studies on Transition Economies

In case of transition economies, the studies on electricity consumption-growth nexus are scarce. In country specific studies, out of all the transition economies, Turkey received the most attention, but with a primary focus on energy rather than electricity use.

In multiple country studies, Apergis and Payne (2009b) conduct a study on a set of countries from the Commonwealth of Independent States (Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Ukraine, and Uzbekistan). They investigate the causality relationship between energy consumption, national income, real gross fixed national formation, and labor force on the period between 1991 and 2005. They find bi-directional causality running between energy consumption and economic growth in the long run and a unidirectional causality between energy consumption and growth in the short run.

Apergis and Payne (2010) also explored the relationship between renewable energy consumption and economic growth in thirteen Eurasian countries over the period 1992-2007. Their results indicate bi-directional causality between renewable energy and economic growth in the short and the long run in these countries.

To our knowledge, the relationship between electricity consumption, rather than energy use, and economic growth in transition economies has been investigated so far only in one study by Acaravci and Ozturk (2010). Acaravci and Ozturk explore the causality relationships between electricity use and growth in fifteen transition economies, which include Albania, Belarus, Bulgaria, Czech Republic, Estonia, Latvia, Lithuania, Macedonia, Moldova, Poland, Romania, Russia, Serbia, Slovak Republic, and Ukraine, between 1990 and 2006. Their results show no cointegrating relationship between electricity consumption and economic growth in these countries. Moreover, rejection of cointegration hypothesis prevented them from investigating further the causality relationships between growth and electricity consumption.

In this paper, we seek to explore the cointegration and the causality relationships between electricity consumption, economic growth and foreign direct investments inflows in seventeen transition economies by employing dynamic panel methodologies. To some extent, this study can be considered similar to the study by Acaravci and Ozturk (2010), since we also seek to investigate the short and the long-run causality relationships between electricity use and economic growth in the transition economies. However, our study differs from the latter one, as we include more countries in the panel and consider a different time period from 1992 to 2009. Moreover, we employ different unit root techniques and seek to circumvent the omitted variable bias in the cointegration relationship by exploring the multivariate framework with the foreign direct investment variable. Therefore, our study can be considered a unique, and a conceptually different study on electricity consumption-growth nexus in the transition economies.

3. Empirical Study

3.1. Empirical Specification

In order to investigate the causal relationships between electricity consumption, economic growth and inflows of foreign direct investment in transition economies we employ cointegration and Granger causality methods for panels. Following the empirical literature on this topic, the log-linear specification of the long-run relationship between electricity consumption, GDP and FDI can be specified in the following way:

$$ELC_{i,t} = \alpha_{1i} + \delta_{1i}\, t + \beta_{1i}GDP_{i,t} + \gamma_{1i}FDI_{i,t} + \upsilon_{i,t}; \tag{1}$$

$$GDP_{i,t} = \alpha_{2i} + \delta_{2i}\, t + \beta_{2i}ELC_{i,t} + \gamma_{2i}FDI_{i,t} + \varepsilon_{i,t}; \tag{2}$$

$$FDI_{i,t} = \alpha_{3i} + \delta_{3i}\, t + \beta_{3i}ELC_{i,t} + \gamma_{3i}GDP_{i,t} + \eta_{i,t}; \tag{3}$$

Here, $i = 1, \cdots, N$ refers to each country in the panel and $t = 1, \cdots, T$ denotes the time period. GDP denotes gross domestic product; FDI represents the inflows of foreign direct investments, and ELC stands for electricity consumption. Each equation allows for country - specific fixed effects and time trends, which are denoted by α_i and δ_{it} respectively. The inclusion of the cross-sectional dimension (i) into the model identifies the panel characteristics of our approach, which is different from a single time-series approach. It also imposes a restriction on the investigated results to exist in all countries in the panel.

All variables are transformed into natural logarithms to reduce heteroscedasticity in error terms and to obtain the growth rates of the variables by applying first differences. Coefficients $\beta_1, \beta_2, \beta_3, \gamma_1, \gamma_2, \gamma_3$ are allowed to vary by country and can be interpreted as elasticities.

3.2. Data

The data set we obtain is a strongly balanced panel of 17 countries followed over the years of 1992-2009. It consists of annual observations for electricity consumption, gross domestic product, and foreign direct investment inflows. The dimensions of the panel data are chosen to include as many countries as possible given the availability and the sensibility of data for the chosen variables. All the observations with missing values were deleted from the panel. We identified year 1992 as the start year for our panel, since it is the first year, for which all variables have full data sets for all countries. Therefore, we adjust each time-series to start in 1992 to achieve a balanced panel. The transition economies included in the panel are: Albania (ALB), Armenia (ARM), Belarus (BLR), Bulgaria (BGR), Croatia (HRV), Estonia (EST), Hungary (HUN), Kazakhstan (KAZ), Latvia (LVA), Lithuania (LTH), Moldova (MDA), Poland (POL), Romania (ROM), Russian Federation (RUS), Tajikistan (TJK), Turkey (TUR), and Ukraine (UKR).

Data on electricity consumption and gross domestic product was obtained from the World Bank, World Development Indicators online database (WDI, 2012). Data on the inflows of foreign direct investment was obtained from United Nations Conference on Trade and Development statistical online database (UNCTADSTAT, 2012).

Gross Domestic Product is measured in current US dollars. Dollar figures for GDP are converted from domestic currencies using a current year official exchange rate. Electricity consumption is measured in billion kilowatt hours. Foreign Direct Investment inflows are measured in US dollars at current prices and current exchange rates in millions.

Figures 1, 2, and 3 in Appendix G present time series plots of the variables by country. Figure 1 shows time series plots of logarithm GDP for each country. All countries exhibit an upward trending GDP, even though the slopes of these trends vary by country. Some countries also exhibit a drop in GDP between 1997 and 2000, which corresponds with the Asian Financial crisis of 1997-1998. Out of all the countries, Russia and Turkey have the highest economic performance, while Latvia presents the strongest economic performance; its GDP has been steadily increasing along a linear trend without much variation along this trend.

Figure 2 shows plots of logarithm FDI inflows by country. All countries experienced increasing inflows of foreign capital over the years. The variance of the inflows varies by country. The graphs confirm that FDI is highly sensitive to common and idiosyncratic shocks. Most countries experienced contraction of FDI inflows in 1997-1998 and 2008-2009; the global economic crises. Poland, Latvia, and Lithuania exhibit a rapid increase in FDI inflows around 2003, when they became members of the European Union. Out of all countries, Bulgaria received the highest volumes of FDI, and these inflows have been quite stable over the years.

Figure 3 exhibits natural logarithm of electricity consumption by country. All countries have an upward trend of electricity consumption after year 2000. Between 1992 and 2000 most countries experienced a drastic drop in electricity consumption with the exception of Albania, Croatia, Poland, and Turkey. This drop can be associated with the aftermath of the collapse of the Soviet Union, when all countries started to restructure the energy sector. Besides Russia, Turkey and Poland are by far the biggest consumers of electricity. Turkey's electricity consumption has been increasing quite steadily over the years without any major variations around the mean.

Table 2: 1993-2009: Average annual growth rates (percent)

Countries	ΔGDP	ΔFDI	ΔELC
Albania	6.4	22.9	8.0
Armenia	6.4	34.0	-2.0
Belarus	4.0	32.9	-1.4
Bulgaria	2.7	26.1	0.3
Croatia	2.9	31.8	2.8
Estonia	3.9	18.3	0.5
Hungary	2.2	1.9	0.9
Kazakhstan	3.5	29.0	-1.2
Latvia	3.8	6.4	-0.4
Lithuania	2.6	16.7	-0.1
Moldova	0.01	11.9	-6.5
Poland	4.6	17.7	1.1
Romania	2.9	24.4	-0.5
Russia	1.9	20.3	-0.2
Tajikistan	0.2	3.3	-1.2
Turkey	3.7	13.5	6.1
Ukraine	-1.02	19.4	0.4
Total:	***2.98***	***19.4***	***0.4***

Table 2 presents average annual growth rates of national income, foreign direct investments, and electricity consumption. The growth rates of electricity consumption vary by country and range from as low as -6,5% (Moldova) to as high as 8% (Albania) and 6.1% (Turkey). Cross-comparisons of growth rates in national income, foreign direct investments and electricity consumption show that there is no clear relationship between these variables. For most of these countries electricity consumption is not growing at the same rate as national income, and growth in inflows of foreign direct investments does not translate into higher GDP or electricity consumption rates either.

Table 3: Panel correlations between variables in growth rates

obs(323)	ΔGDP	ΔFDI	ΔELC
ΔGDP	1.0000		
ΔFDI	0.3857	1.0000	
ΔELC	0.9229	0.3423	1.0000

Table 3 presents the correlation matrix between the average annual growth rates in GDP, FDI and electricity consumption for the entire panel. All the variables exhibit positive correlations between each other. The growth rate of electricity consumption is most highly correlated with the change in

GDP growth, and less with the change in foreign direct investment. Growth rate in foreign direct investment is positively correlated with the national income. However, this correlation is weaker than the correlation between GDP and electricity consumption. Nevertheless, these relationships are of interest to explore, especially if these variables form a long-run equilibrium relationship, and if changes in these variables have a short-run and a long-run causal effect on each other.

4. Methodology

The panel estimation techniques that are employed in this paper have been widely used in the recent growth-nexus literature. In comparison to individual country time-series approach, panel estimation provides an improvement in terms of including information on cross-sectional dimension and improving efficiency of the tests by eliminating the problem of low degrees of freedom. Campbell and Perron (1991), and Choi (2001) among others showed that the unit root tests and the cointegration tests based on individual time series have low statistical power when time series are short, and that pooling cross-sections and time-series produces significantly better results. Pedroni (1997, 1999, 2004) also demonstrated that the power of cointegration test significantly improves with the panel approach.

In this study we employ heterogeneous panel techniques for 17 transition economies that have limited time series data and exhibit heterogeneous economic conditions. Before identifying the causal relationship between electricity consumption, GDP, and FDI, we check the data for cross-sectional dependence and order of integration in the variables. A heterogeneous cointegration test is employed afterwards to identify the long-run relationship between the variables. Finally, panel error correction models are used to identify the long-run and the strong Granger causality between the variables. Vector autoregressive (VAR) models are employed to identify the short-run causalities by country.

4.1. Cross-Sectional Dependence

The implication of cross-sectional dependence on panel unit root testing has been thoroughly investigated by several authors. Banerjee, et al. (2005) demonstrates how panel unit root tests become oversized in the presence of cross-sectional dependence. Pesaran (2004) showed by the means of Monte Carlo experiments that unit root tests that do not account for cross-sectional dependence result in serious size distortions of the tests if the degree of dependence is sufficiently large (Bai et al., 2009).

There are several reasons to suspect cross-sectional dependence in our panel. First, the group of selected countries shares a common history of the communist regimes, with the exception of Turkey. Most of these countries even today, rely on the electricity infrastructure and electricity production facilities that were installed during the Soviet times. Moreover, electric interconnectedness of this region remains very high, with a high reliance on supplies of natural resources and electricity from Russia (Vilemas, 2012). Therefore, a common shock to electricity production or transmission even in one country, that is a large exporter of electricity, is very likely to affect the rest of the region. Furthermore, the data also shows that most countries in the panel were affected by the global crises: the Asian Financial crisis of 1997-1998 and the recent crisis of 2008-2009.

In order to account for this interconnectedness between countries, and ensure that the results of integration analysis are not distorted, we employ Pesaran (2004) Cross-Sectional Dependence test. The proposed test is based on the average of all pair-wise correlation coefficients of the Ordinary Least Squares (OLS) from individual regressions, and can be used as with stationary panels, as with unit root dynamic heterogeneous panel with short T and large N. Pesaran (2004) considers a simple panel model:

$$y_{it} = \alpha_i + \beta_i^{'} x_{it} + u_{it}; \tag{4}$$

where i denotes the cross-section dimension and t denotes the time-series of the panel, x_{it} is a k ×1 vector of observed individual-specific and common regressors that vary by time, and intercepts and slope coefficients ($\beta_i^{'}$) are allowed to vary by i. For each i, the error terms $u_{it} \sim IID\left(0, \sigma_{iu}^2\right)$, for all t. Pesaran (2004) identifies several reasons for cross-sectional dependence of u_{it} : spatial dependence, omitted unobserved common components, and random idiosyncratic pair-wise dependence of u_{it} and u_{jt} $(i \neq j)$. Under the null hypothesis the test checks for cross-sectional independence across panels, and calculates test statistics from the following specification:

$$CD = \sqrt{\frac{2T}{N(N-1)}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\rho_{ij}\right)} \rightarrow N\ (0,\ 1) \tag{5}$$

where $\rho_{ij} = \frac{\sum_{t=1}^{T} e_{it} e_{jt}}{\sqrt{\left(\sum_{t=1}^{T} e_{it}^2\right)}\sqrt{\left(\sum_{t=1}^{T} e_{jt}^2\right)}}$, and e_{it} denotes the OLS residuals from the individual regressions based on T observations for each panel. The Monte Carlo experiments confirm that this test performs well even in the conditions of structural breaks.

4.2. Integration Analysis

For our integration analysis, we perform two unit root tests to account for structural breaks and cross-sectional dependence in the region.

4.2.1. Unit Root Test with Cross-Sectional Dependence

Inability to account for cross-sectional dependence in the panel unit root tests poses a significant bias on the results, as it excludes the possibility of the reforms or any other economic changes in one country to spread and impact other economies. Inability to account for this effect will impose a high penalty on our results given the history and the current economic interconnectedness of the selected region.

Therefore, we employ Pesaran (2007) unit root test that allows for cross-sectional dependence. Pesaran (2007) suggests to augment the standard Dickey-Fuller (DF) regressions with the lagged cross-sectional means and the first-difference of the lagged means to capture the cross-sectional dependence. This test is called the cross-sectionally augmented Dickey-Fuller (CADF) test. One shortcoming of the test is the assumption of the existence of only one common factor in the residual. This assumption is restrictive, especially if variables are affected by several factors simultaneously.[4]

Pesaran (2007) considers a simple dynamic linear heterogeneous panel data model: $y_{it} = (1-\varphi_i)\mu_i + \varphi_i y_{i,t-1} + u_{it}, i = 1,\ldots,N; t = 1,\ldots,T$, where error term u_{it} has a single-factor structure $u_{it} = \gamma_i f_t + \varepsilon_{it}$, where f_t denotes an unobserved common factor, and ε_{it} denotes idiosyncratic error. In this setting, the unobserved common factor defines the cross-sectional dependence in the panel. If we combine both conditions and transform y_{it} into its first difference Δy_{it}, we can rewrite the model specification as $\Delta y_{it} = \alpha_i + \beta_i y_{i,t-1} + \gamma_i f_t + \varepsilon_{it}$;

where $\alpha_i = (1-\varphi_i)\mu_i, \beta_i = -(1-\varphi_i), \Delta y_{it} = y_{it} - y_{i,t-1.}$ Under this specification, the unit root hypothesis of interest can be defined as $H_0 : \beta_i = 0$ for all i, while the alternative hypothesis of at least one series being stationary in the panel is determined as $H_1 : \beta_i < 0, i = 1, 2,\ldots, N; \beta_i = 0, i = N_1 + 1, N_1 + 2,\ldots, N$

Pesaran (2007) proxies the common factor f_t by the cross-section mean of y_{it}, i.e , $\overline{y_t} = N^{-1}\sum_{i=1}^{N} y_{it}$ and its lagged values , $\overline{y_{t-1,}}\overline{y_{t-2}},\ldots$ He shows that $\overline{y_t}$ and $\overline{y_{t-1}}$ are sufficient for asymptotically eliminating the unobserved common factor (f_t) in case if error terms are serially uncorrelated. Following this adjustment, the CADF regression can be specified in the following form:

$$\Delta y_{it} = \alpha_i + b_i y_{i,t-1} + d_0 \overline{y_{t-1}} + d_1 \Delta \overline{y_t} + \varepsilon_{it} \tag{6}$$

[4] In this study we do not extend our analysis to several factors for simplicity reasons and due to data limitations. Therefore, we use the original test, with one factor assumption to test for unit root. We formulate our suggestions for the future research of the topic with multiple factors in the conclusion and discussions parts.

Pesaran (2007) test runs the CADF regression for each *i* in the panel to collect the individual t-statistics called CADF*i*. The averages of these individual CADF*i* tests constitute the cross-sectionally augmented IPS test statistics, that reports the test statistics associated with the null hypothesis:

$$CIPS = N^{-1}\sum_{i=1}^{N} CADF_i \tag{7}$$

The distribution of CIPS is nonstandard even for sufficiently large N. The critical values are calculated through Monte Carlo experiments for different values of N and T. The critical values are calculated for three cases: I) no intercept and no trend; II) intercept only; and III) intercept and trend. For all three cases, the densities depart from normality, but the level of these departures depends on the presence of intercept or trend in the model. The critical values are presented in the Appendix A. The experimental results show that this test performs well for panel where T>N and N>T. The power of the test increases significantly with T>10.

4.2.2. Unit Root Rest with One Structural Break

The 1982 article by Plosser and Nelson challenged the traditional view of shocks having only a transitory effect on the long-run level of economic variables. Using Dickey Fuller techniques Nelson and Plosser showed that shocks have a permanent effect on the long-run levels in the presence of non-stationarity in the series (Sandberg, 2012). As a response, Perron (1988,1989) argued that such conclusions were doubtful, since Dickey Fuller tests did not account for structural breaks in the series (Sandberg, 2012). Perron (1989) designed a test, which accounts for a single exogenously determined structural break, and checks for a unit root with a structural break under the null hypothesis against the alternative of trend-stationarity with a structural break. Perron's unit root test showed 11 out 14 macroeconomic series that were analyzed by Nelson and Plosser to be trend-stationary (Zivot and Andrews, 1992). Therefore, Perron's test showed that inability to account for structural breaks lead to non-rejection of the null hypothesis of unit root even if series are stationary.

Nevertheless, Perron testing procedures were criticized for 'data mining,' since the time of the structural break was determined exogenously. Zivot and Andrews (1992) build on Perron's test to allow for structural break to be selected endogenously. They formulate the null hypothesis for series $\{y_t\}$ to be integrated without an exogenous structural break: $y_t = \mu + y_{t-1} + \varepsilon_t$ (random walk with a drift). In this case the selection of the breakpoint becomes an outcome of the estimation procedure designed to fit $\{y_t\}$ to a certain trend- stationary representation (Zivot and Andrews, 1992). Thus, the alternative hypothesis of the tests assumes that $\{y_t\}$ can be represented by a trend-stationary process with a one-time break in the trend occurring at unknown point in time (Zivot and

Andrews, 1992). The goal of Zivot and Andrew's test is to identify the breakpoint that supports the alternative hypothesis. The time of the break is determined by the minimum t-statistics from the ADF test of unit root, which holds the strongest evidence against the null hypothesis of the presence of unit root.

Similar to Perron's ADF testing strategy, Zivot and Andrews define three regression equations that include estimated values of the breakpoints and define different specification of the alternative hypothesis as follows:

$$y_t = \hat{\mu}^A + \hat{\theta}^A DU_t(\hat{\lambda}) + \hat{\beta}^A t + \hat{\alpha}^A y_{t-1} + \sum_{j=1}^{k} \hat{c}_j^A \Delta y_{t-j} + \hat{e}_t \tag{9}$$

$$y_t = \hat{\mu}^B + \hat{\gamma}_t{}^B DT^*{}_t(\hat{\lambda}) + \hat{\beta}^B t + \hat{\alpha}^B y_{t-1} + \sum_{j=1}^{k} \hat{c}_j^B \Delta y_{t-j} + \hat{e}_t \tag{10}$$

$$y_t = \hat{\mu}^C + \hat{\gamma}_t{}^C DT^*{}_t(\hat{\lambda}) + \hat{\beta}^C t + \hat{\alpha}^C y_{t-1} + \sum_{j=1}^{k} \hat{c}_j^C \Delta y_{t-j} + \hat{e}_t \tag{11}$$

where $DU_t(\hat{\lambda})$ represents a level dummy that reflects the change in the intercept of a trend, and it depends on the function of the estimated breakpoints; $DU_t(\hat{\lambda})$ =1 if t=$T\lambda$, 0 otherwise. $DT^*{}_t(\hat{\lambda})$ is a trend dummy that represents a change in the slope of the trend and it is also dependent on the estimated break points; $DT^*{}_t(\hat{\lambda}) = t - T\lambda$, 0 otherwise. When selection of breakpoint is conditional on estimation procedure, critical values from Perron's test are not valid (Zivot and Andrews, 1992). Therefore, Zivot and Andrews compile critical values for the three models based on the time of a break relative to the sample size. Critical values are presented in the Results section.

Zivot Andrews test is especially useful for our analysis given the turbulent nature of the economic, political, institutional, and energy reforms in the transition economies. Moreover, its feature of endogenously identifying the break point also proves its usefulness given the saturation of multiple reforms over a short period of time in these countries. One shortcoming of the test is that it identifies only one structural break in the series, even though our series include more than one structural break. However, we consider this test to be reliable in identifying unit roots in the true data generating process, since adaptation of any other unit root test that allows for multiple structural breaks would require significantly longer time series to produce reliable results.

4.3. Cointegration Analysis

When dealing with non-stationary variables, the estimation of the long-run relationships between these variables by the means of OLS is not possible due to spurious results, non-constant means and time-varying variances. However, when the non-stationary variables share a common stochastic term, they can form a linear combination that is stationary, ie. they form a long-run equilibrium that ‘binds’ their movements together. Such linear stationary combination of the non-stationary variables is known as cointegration. The cointegration is the core interest of our study since it ensures that co-movements and interrelations between the variables are stationary, and predictable, and therefore can be used for the design and the formulation of long-run energy policies.

The original cointegration concept was developed for single time-series analysis and bi-variate models. In the dynamic panel methods, the application of the concept is similar to the time-series. However, the interpretation of cointegration in panel setting requires some clarification. In the case of panel cointegration, the identified long-run equilibrium relationship should hold in all the selected countries. Therefore, the selection of the panel is usually guided by the expectations of the countries to be similar in some ways. We selected our panel of countries by the same principle.

The concept of cointegration was introduced by Engle and Granger in 1987. We expand his concept for the panel approach, for which the formal analysis of cointegration begins by considering a set of economic variables in a long-run equilibrium $\beta_{1i}x_{1i,t} + \beta_{2i}x_{2i,t} + \cdots + \beta_{ni}x_{ni,t} = 0$.

Letting β_i and $x_{i,t}$ denote the vectors $\left(\beta_{1i}, \beta_{2i} \cdots \beta_{ni}\right)$ and $(x_{1i}, x_{2i}, \cdots x_{ni})'$, the system is said to be in the long-run equilibrium when $\beta_i x_{it} = 0$. The deviations from the long-run equilibrium-called the equilibrium error is designed by e_{it}, so that $e_{it} = \beta_i x_{it}$ (Enders, 2010, p.359). Therefore, if the equilibrium exists, the equilibrium error process must be stationary. Only in this case the deviations from the equilibrium, meaning local or global shocks, will be transitory and have a temporary effect on the economy.

To check for cointegration, we employ Pedroni (1997, 1999, 2004) cointegration test. He proposed several tests that account for heterogeneous intercepts and trend coefficients across cross-sections. Pedroni test is based on Engle-Granger (1987) two-step procedure. In the first step the residuals are extracted from the spurious regression with $I(1)$ variables, and tested for stationarity. When stationarity of the residuals is confirmed, the VAR model in first differences is augmented by the lagged residuals to construct the linear stationary combination of these variables.

Pedroni (1999, 2004) extends the Engle-Granger framework to heterogeneous panels and considers the following model:

$$y_{it} = \alpha_i + \delta_i t + \beta_{1i}x_{1i,t} + \beta_{2i}x_{2i,t} + \cdots + \beta_{Mi}x_{Mi,t} + e_{i,t} \qquad (1)$$

where $t = 1,\ldots T; i = 1,\ldots N; m = 1,\ldots M;$ where y and x are assumed to be integrated of order one, i.e. $I(1)$. The parameters α_i and δ_i are individual and trend effects which may be set to zero if desired.

Under the null hypothesis of no cointegration, the residuals $e_{i,t}$ will be $I(1)$. As in Engel Granger methodology, the first step is to obtain residuals from the equation (1) and then to test whether residuals are $I(1)$ by running the auxiliary regressions:

$$e_{it} = \rho_i e_{it-1} + u_{it} \tag{2}$$

$$e_{it} = \rho_i e_{it-1} + \sum_{j-1}^{p_i} \psi_{ij} \square e_{it-j} + \nu_{it} \tag{3}$$

for each cross-section. Pedroni designs seven various methods of constructing statistics for testing the null hypothesis of no cointegration $(\rho_i = 1)$. He considers two alternative hypotheses: the homogenous alternative, $(\rho_i = \rho) < 1$ for all i, which Pedroni identifies as within-dimension test or panel statistics test, and the heterogeneous alternative, $\rho_i < 1$ for all i is also referred to as the between-dimension or group statistics tests. The Pedroni panel cointegration statistic $\aleph_{N,T}$ is constructed from the residuals from either equation (2) or equation (3). Based on Pedroni (1999), seven statistics with varying degree of properties in size and power for different N and T are generated.

Following Pedroni (1999), heterogeneous panel and heterogeneous group mean panel cointegration statistics are calculated as follows:

$$Panel\ \upsilon - statistic : Z_{\upsilon} = \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{e}_{it-1}^{2} \right)^{-1} \tag{5.1}$$

$$Panel\ \rho - statistic : Z_{\rho} = \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{e}_{it-1}^{2} \right)^{-1} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \left(\hat{e}_{it-1} \Delta \hat{e}_{it} - \hat{\lambda}_i \right) \tag{5.2}$$

$$Panel\ PP - statistic : Z_{t} = \left(\hat{\sigma}^2 \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{e}_{it-1}^{2} \right)^{-\frac{1}{2}} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \left(\hat{e}_{it-1} \Delta \hat{e}_{it} - \hat{\lambda}_i \right) \tag{5.3}$$

$$Panel\ ADF - statistic : Z_{t}^{*} = \left(\hat{s}^{*2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{e}_{it-1}^{2} \right)^{-\frac{1}{2}} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{e}_{it-1}^{*} \Delta \hat{e}_{it}^{*} \tag{5.4}$$

$$Group\ \rho - statistic : \hat{Z}_{\rho} = \sum_{i=1}^{N} \left(\sum_{t=1}^{T} \hat{e}_{it-1}^{2} \right)^{-1} \sum_{t=1}^{T} \left(\hat{e}_{it-1} \Delta \hat{e}_{it} - \hat{\lambda}_i \right) \tag{5.5}$$

$$Group\ PP - statistic : \hat{Z}_{t} = \sum_{i=1}^{N} \left(\hat{\sigma}^2 \sum_{t=1}^{T} \hat{e}_{it-1}^{2} \right)^{-\frac{1}{2}} \sum_{t=1}^{T} \left(\hat{e}_{it-1} \Delta \hat{e}_{it} - \hat{\lambda}_i \right) \tag{5.6}$$

$$Group\ ADF - statistic : \hat{Z}_{t}^{*} = \sum_{i=1}^{N} \left(\sum_{t=1}^{T} \hat{s}_i^2 \hat{e}_{it-1}^{*2} \right)^{-\frac{1}{2}} \sum_{t=1}^{T} \hat{e}_{it-1}^{*} \Delta \hat{e}_{it}^{*} \tag{5.7}$$

where $\hat{e}_{it}$ is the estimated residual from model (1) and $\hat{L}_{11i}^{2}$ is the long-run covariance matrix for $\Delta \hat{e}_{it}$.

The group rho, group PP, and group-ADF statistics are based on averages of the individual autoregressive coefficients associated with the unit root tests of the residuals. Panel v, Panel rho, Panel PP, and panel ADF pools the autoregressive coefficients across different members for the unit root on the estimated residuals.

The Monte Carlo simulations of these tests showed that the power of the seven statistics decreases significantly in the small samples. For N=20, the group rho statistics is found to be the most powerful in identifying the stationarity in the error terms, followed by the panel rho and panel ADF statistics. Considering the short time span of our panel, these three test statistics will be used to evaluate the presence of cointegration.

4.4. Causality Analysis

Panel cointegration tests verify or reject the existence of the long-run relationships between the integrated variables. However, it does not provide any information regarding the causal relationship between the variables and the direction of these causalities. If the variables are found to be cointegrated, then variables can be tested on Granger causality. The panel-based error-correction model is used to account for the long-run relationship using the two-step procedure developed by Engle and Granger (1987). The first step involves estimating the residuals from the long-run equations specified in the models (1, 2, 3) in the empirical specification part. These residuals $(v_{it}, \varepsilon_{it}, \eta_{it})$ represent the deviations from the long-run equilibrium.

$$\mathrm{ELC}_{i,t} = \alpha_{1i} + \delta_{1i}\, t + \beta_{1i}\mathrm{GDP}_{i,t} + \gamma_{1i}\mathrm{FDI}_{i,t} + \upsilon_{i,t}; \tag{1}$$

$$\mathrm{GDP}_{i,t} = \alpha_{2i} + \delta_{2i}\, t + \beta_{2i}\mathrm{ELC}_{i,t} + \gamma_{2i}\mathrm{FDI}_{i,t} + \varepsilon_{i,t}; \tag{2}$$

$$\mathrm{FDI}_{i,t} = \alpha_{3i} + \delta_{3i}\, t + \beta_{3i}\mathrm{ELC}_{i,t} + \gamma_{3i}\mathrm{GDP}_{i,t} + \eta_{i,t}; \tag{3}$$

In the second step, the error-correction model is augmented with one period lagged residuals that were estimated from the first step. By introducing one lag in the residuals, we transform them into their dynamic form, which is referred to as dynamic error correction term (ECT's). The ECT's capture the long-run equilibrium relationship among variables. This way, the original model specifications get transformed in the following manner:

$$\Delta \mathrm{ELC}_{\mathrm{it}} = \alpha_{1t} + \sum_{k=1}^{m} \alpha_{11ik} \Delta GDP_{it-k} + \sum_{k=1}^{m} \alpha_{12ik} \Delta FDI_{it-k} + \sum_{k=1}^{m} \alpha_{13ik} \Delta ELC_{i,t-k} + \psi_{1i} ECT_{it-1} + u_{1it};$$

$$\Delta GDP_{\mathrm{it}} = \alpha_{2t} + \sum_{k=1}^{m} \alpha_{21ik} \Delta ELC_{it-k} + \sum_{k=1}^{m} \alpha_{22ik} \Delta FDI_{it-k} + \sum_{k=1}^{m} \alpha_{23ik} \Delta GDP_{i,t-k} + \psi_{2i} ECT_{it-1} + u_{2it};$$

$$\Delta FDI_{\mathrm{it}} = \alpha_{3t} + \sum_{k=1}^{m} \alpha_{31ik} \Delta ELC_{it-k} + \sum_{k=1}^{m} \alpha_{32ik} \Delta GDP_{it-k} + \sum_{k=1}^{m} \alpha_{33ik} \Delta FDI_{i,t-k} + \psi_{3i} ECT_{it-1} + u_{3it};$$

Where Δ is the difference operator, k is the lag length, and ψ is speed of adjustment parameter.

In these regressions, the lagged error correction terms and the lagged dependent variables become correlated, which creates a problem of simultaneity. The instrumental variable in the form of lagged dependent variables are applied in such instances to resolve the simultaneity problem.

4.4.1. Granger Causality

The causality and its direction can be tested directly from the specifications above by testing for Granger causality, which checks whether past values of one variable have an effect on the future values of the other variable. Thus, if GDP improves the forecasting performance of electricity consumption, it is said to Granger cause electricity consumption (Enders, 2010, p.318). The direct way of testing for Granger causality is to test for the significance of the coefficients for the dependent variables. Rejecting the null hypothesis indicates that there is Granger causality between the variables.

From these equations we can estimate three different types of causality:

a) Short-run causalities by testing: H_0: $\alpha_{11ik}=0$; $\alpha_{12ik}=0$; $\alpha_{21ik}=0$; $\alpha_{22ik}=0$; $\alpha_{31ik}=0$; $\alpha_{32ik}=0$

b) The long-run causalities are identified by testing the speed of adjustment coefficients: H_0: $\psi_{1i}=0$; $\psi_{2i}=0; \psi_{3i}=0$ for all i

c) Strong Granger causalities are identified by joined tests: H_0: $\alpha_{11ik}=\alpha_{12ik}=\psi_{1i}=0$; H_0: $\alpha_{21ik}=\alpha_{22ik}=\psi_{2i}=0$; H_0: $\alpha_{31ik}=\alpha_{32ik}=\psi_{3i}=0$.

5. Empirical Results

Table 4 presents results of the Pesaran cross-sectional dependence test. The results on all three variables suggest that the panel is cross-sectionally dependent. Therefore, we conclude that the error terms in the models are codependent, which can be explained by spatial dependence between the transition economies, omitted unobserved common components, or random idiosyncratic pair-wise dependence that might exist between countries in this region.

Table 4: Pesaran Cross-Sectional Dependence Test

Variables	CD-test	p-value	Correlation
GDP	44.29***	0.000	0.895
FDI	39.27***	0.000	0.794
ELC	17.4***	0.000	0.352

Under the null hypothesis: cross-sectional independence.
Results with *** indicate results that are significant at 1% significant level,
**- 5% significance level, *- 10%.

Table 5: Pesaran Unit Root Test with Cross-Sectional Dependence

	GDP	**FDI**	**ELC**
Pesaran CADF statistics	-2.681*	-3.526***	-2.549
p-values	(-0.051)	(0.00)	(0.136)

Null hypothesis: unit root in each series in the panel.
Alternative hypothesis: at least one series is stationary in the panel.
Results with *** indicate 1% significance level,*- 10%.

Since we identify our panel to be cross-sectionally dependent, we employ unit root test that allows for cross-sectional dependence. Table 5 presents the results from the Pesaran CADF test that checks for unit root in each panel under the assumption of cross sectional dependence.

Before we performed CADF test, we identified the appropriate number of lags for each panel by the means of Schwarz Information Criteria (SIC). In statistics information criteria are used to select the most fitting model for the given data generating process from a finite set of models. We use SIC as opposed to Akaika Information Criterion (AIC), as it imposes a higher penalty on the model selection criteria, and thus, eliminates overfitting issues. Moreover, given the short span of our time-series data, SIC identifies lags that do not significantly reduce degrees of freedom. The formulation of SIC is presented in Appendix B. We also check each lag selected by the SIC on the issue of white noise residuals. We confirm that the lags selected by SIC produce residuals without autocorrelation. This indicates that we use all the information available in the data for our modeling, unit root and cointegration evaluations. Results on lags selected by SIC and the white noise test are presented in Appendix B.

The results of the Pesaran CADF test suggest that for the GDP variable all series are integrated at 10% significance level, meaning they include unit root. At 5% significance level though, we conclude that some series are stationary in this variable. We also strongly reject the null hypothesis of unit root for FDI variable and conclude that some series appear to be stationary. Electricity consumption appears to be integrated across all countries at all significance levels.

Since Pesaran CADF test builds on Augmented Dickey Fuller test, it does not have the power to account for the structural breaks that we observe in the data. In this case, it is logical to assume that some of the series that were identified as integrated could actually be trend-stationary with a break in the mean or a trend. In order to check this hypothesis, we employ Zivot Andrews unit root test that allows for one structural break in the series.

The results for this test are presented in Tables: 6-8. Since all countries exhibit a growth trend in all variables, we run the test under the assumption of a break in both an intercept and a trend, or break in a trend only, depending on the individual country's fluctuations. We also identified the appropriate number of augmentations in the regressions by employing the SIC.

Table 6 presents the results of unit root for Electricity consumption by country. The test identifies a structural break date for each country. For majority of the countries, the Asian Financial crisis of 1997-1998 had a significant negative impact on the level of electricity consumption. In all countries, except Kazakhstan, electricity consumption series include unit root. Kazakhstan is the only country, where electricity consumption is a stationary process with structural breaks.

Table 6: Zivot-Andrews Test: Unit Root with one Structural Break
Electricity Consumption: Country by Country Statistics

Countries	Break	t-Statistics	1% Critical Values	5% Critical Values
Albania	1999	-3.252	-5.57	-5.08
Armenia	2001	-3.722	-5.57	-5.08
Belarus	2008	-4.713	-5.57	-5.08
Bulgaria	1997	-3.534	-5.57	-5.08
Croatia	2009	-3.434	-5.57	-5.08
Estonia	1999	-3.472	-5.57	-5.08
Hungary	2009	-2.621	-5.57	-5.08
Kazakhstan	1999	-7.226***	-5.57	-5.08
Latvia	1996	-2.149	-5.57	-5.08
Lithuania	1999	-4.056	-5.57	-5.08
Moldova	2000	-3.917	-4.93	-4.42
Poland	1999	-2.755	-5.57	-5.08
Romania	1997	-3.274	-5.57	-5.08
Russia	1994	-4.482	-5.57	-5.08
Tajikistan	1997	-2.889	-5.57	-5.08
Turkey	2001	-4.131	-5.57	-5.08
Ukraine	2008	-1.467	-5.57	-5.08

H_0: random walk with a drift ***- p<0,01

H_1: trend-stationary series with a break

Table 7 shows Zivot Andrews test results for foreign direct investment inflows. In this panel we observe quite a few series to be stationary with a break in a trend, or a trend and a mean. FDI in Albania, Armenia, and Moldova are stationary with structural breaks in the intercepts and a trend. In Croatia, Estonia, and Kazakhstan stationarity of the processes is confirmed at 1% significance level. Therefore, we conclude that FDI is also a mixed integrated panel that includes series that are I(1) and also series that are I(0), but with structural breaks.

Table 7: Zivot-Andrews Test: Unit Root with one Structural Break
Foreign Direct Investment: Country by Country Statistics

Countries	Break	t-Statistics	1% Critical Values	5% Critical Values
Albania	2000	-5.314**	-5.57	-5.08
Armenia	2000	-5.244**	-5.57	-5.08
Belarus	2000	-3.804	-5.57	-5.08
Bulgaria	2009	-2.799	-5.57	-5.08
Croatia	2000	-5.589***	-5.57	-5.08
Estonia	2005	-5.647***	-5.57	-5.08
Hungary	2005	-4.694	-5.57	-5.08
Kazakhstan	2007	-11.946***	-5.57	-5.08
Latvia	2009	-2.398	-4.93	-4.42
Lithuania	1999	-2.591	-5.57	-5.08
Moldova	1997	-4.523**	-4.93	-4.42
Poland	2001	-3.545	-5.57	-5.08
Romania	1999	-2.966	-5.57	-5.08
Russia	2000	-3.401	-5.57	-5.08
Tajikistan	2004	-3.697	-5.57	-5.08
Turkey	2005	-2.925	-5.57	-5.08
Ukraine	2001	-2.418	-4.93	-4.42

H0: random walk with a drift ***- p<0,01; ** - p<0,05
H1: trend-stationary series with a break

Table 8: Zivot-Andrews Test: Unit Root with one Structural Break
National Income: Country by Country Statistics

Countries	Break	t-Statistics	1% Critical Values	5% Critical Values
Albania	1997	-5.148**	-5.57	-5.08
Armenia	1999	-3.186	-5.57	-5.08
Belarus	2001	-3.67	-4.93	-4.42
Bulgaria	2001	-4.237	-5.57	-5.08
Croatia	1999	-4.332	-5.57	-5.08
Estonia	2000	-2.967	-4.93	-4.42
Hungary	2000	-2.521	-4.93	-4.42
Kazakhstan	1999	-3.881	-5.57	-5.08
Latvia	2003	-3.678	-4.93	-4.42
Lithuania	2000	-2.974	-5.57	-5.08
Moldova	1999	-5.391**	-5.57	-5.08
Poland	1999	-2.92	-5.57	-5.08
Romania	1999	-3.591	-5.57	-5.08
Russia	1998	-4.294	-5.57	-5.08
Tajikistan	2000	-4.336	-5.57	-5.08
Turkey	2001	-3.867	-5.57	-5.08
Ukraine	2002	-3.119	-4.93	-4.42

H_0: random walk with a drift

H_1: trend-stationary series with a break

Results of the Zivot Andrews unit root test for GDP series are presented in table 8. The test identifies Moldova and Albania to have stationary GDP series with a break in a trend and a mean.

The rest of the countries appear to have integrated GDP processes. This result also shows that GDP is a mixed panel with integrated and stationary series.

Since the Pesaran CADF test has a low power of identifying a stationary series in the presence of structural breaks, we rely on the results of the Zivot Andrews unit root test. The test shows that none of the variables are integrated across all series. Each variable constitutes a panel with is a mixture of $I(0)$ and $I(1)$ processes. This shows that in some countries, shocks have a permanent effect on growth, foreign direct investment, and electricity consumption; while for others shocks do not permanently change the growth path of the variables.

According to Engel and Granger's original definition, cointegration exists between variables that are integrated of the same order. Therefore, we conclude that GDP, electricity consumption and Foreign Direct Investment inflows cannot form a long-run equilibrium relationship, since they are integrated of different orders across countries.

As a robustness check for our results we perform Pedroni cointegration test on all variables. The lags length in cointegration test was determined by SIC and the maximum lag was set to 3. The appropriate probability density functions for the different test statistics is identified by the bartlett kernel Newey-West approach. The short overview of the approach can be found in Appendix D. Each series were allowed to have heterogeneous autoregressive components. The model deterministics included trend and a constant. The 7 Pedroni test statistics are reported in Table 9.

Table 9: Pedroni Panel Cointegration Test for *GDP FDI ELC*

Panel weighted statistics (probability)	**Test Statistics**	**P-Values**
Panle ν-statistic	1.020439	0.1538
Panel ρ-statistic	0.779689	0.7822
Panel PP-statistic	-3.770383	0.0001
Panel ADF-statistic	-5.709564	0.0000
Group statistics (probability)		
Group ρ-statistic	2.252689	0.9879
Group PP-statistic	-2.696317	0.0035
Group ADF-statistic	-5.046287	0.0000

Since the time-series dimension and the number of panels included in the data set are quite short, the existence of cointegration is best determined by group rho statistics, followed by panel rho and panel ADF (Pedroni, 2004). The probability values of these test statistics suggest a non-rejection of the null hypothesis of no cointegration in the relationship. Therefore, we confirm the results obtained in the Zivot Andrews test, and conclude that there is no long-run relationship between the electricity consumption, growth rate and foreign direct investments in the selected transition economies.

Since the unit roots we employ do not allow for simultaneous adjustment to structural breaks and cross-sectional dependence, we treat their results as approximation of the unit root processes in the data. Therefore, it is also of interest to explore the possible cointegrating relationship between GDP and electricity consumption identified by the Pesaran CADF test. Therefore, we perform Pedroni cointegration test for GDP and electricity consumption. The results are presented in table 10, and show that there is no cointegration between these variables either.

Since the cointegrating relationship cannot be determined, we cannot proceed to the next step of VEC model and Granger long-run causality estimation. Therefore, we conclude that Granger long-run causality cannot be determined within this panel; the long-run relationships might be country specific.

Table 10: Pedroni Panel Cointegration Test for *GDP ELC*

Panel weighted statistics (probability)	**Test Statistics**	**P-Values**
Panle ν-statistic	3.999497	0.0000
Panel ρ-statistic	1.837072	0.9669
Panel PP-statistic	0.671244	0.7490
Panel ADF-statistic	-1.978054	0.0240
Group statistics (probability)		
Group ρ-statistic	2.655446	0.9960
Group PP-statistic	0.561412	0.7127
Group ADF-statistic	-3.010262	0.0013

Nevertheless, we can identify the short-run Granger causalities that might exist between the variables from the vector autoregressive (VAR) specifications of the model. The three-variable error-correction model we constructed for cointegration is essentially the tri-variate VAR in first differences augmented by the error-correction terms (ECT's). Therefore, omission of the ECT's from the models, recreates the VAR specification of the empirical models:

$$\Delta ELC_{it} = \alpha_{1t} + \sum_{k=1}^{m} \alpha_{11ik}\Delta GDP_{it-k} + \sum_{k=1}^{m} \alpha_{12ik}\Delta FDI_{it-k} + \sum_{k=1}^{m} \alpha_{13ik}\Delta ELC_{it-k} + u_{1it};$$

$$\Delta GDP_{it} = \alpha_{2t} + \sum_{k=1}^{m} \alpha_{21ik}\Delta GDP_{it-k} + \sum_{k=1}^{m} \alpha_{22ik}\Delta FDI_{it-k} + \sum_{k=1}^{m} \alpha_{23ik}\Delta ELC_{it-k} + u_{2it};$$

$$\Delta FDI_{it} = \alpha_{3t} + \sum_{k=1}^{m} \alpha_{31ik}\Delta GDP_{it-k} + \sum_{k=1}^{m} \alpha_{32ik}\Delta FDI_{it-k} + \sum_{k=1}^{m} \alpha_{33ik}\Delta ELC_{it-k} + u_{3it};$$

Under these specification, the direct way to test for short-run Granger causality is to use a standard F-test or Chi2-test for the restrictions: $\alpha_{11} = \alpha_{12} = 0$; $\alpha_{31} = \alpha_{33} = 0$; and $\alpha_{22} = \alpha_{23} = 0$. However, these tests will produce reliable results only if all the variables that are presented in the VAR models are stationary. Stationarity of these variables ensures mean convergence of the process, and therefore, standard interpretation of the results that do not change with time origin.

5.1. Short Run Causality Results

Through previous tests we concluded that each variable is composed of series that are integrated of different orders. Therefore we cannot identify granger causality links between variables by the means of a panel approach. We have to consider data generating processes (DGP) country by country to produce reliable Granger causality results. Moreover, stationarity has to be checked on country by country level to identify the appropriate structural forms of the VAR models.

In order to check for stationarity, we employ Kwiatkowski, Phillips, Schmidt and Shin (KPSS) unit root test. Under the null hypothesis this test checks for stationarity rather than unit root like most other unit root tests. The specifications of the test are presented in Appendix C.

We check each variable for stationarity first in levels, and then transform variables into first and second differences if stationarity is rejected. For each variable we identify the appropriate lag lengths by utilizing Newey-West bandwidth selection procedure as in Pedroni test. The results of the KPSS tests are presented in Tables 11-13. Variables in levels are tested with trend, while first and second differences are tested for stationarity in levels.

Results in Table 11 for GDP suggest that in most countries GDP is non-stationary and are integrated of order one; I(1). In case of Tajikistan, GDP includes two stochastic trends, and transformation of this variable into stationary requires second differencing.

In Table 12 KPSS test reports FDI to be stationary across all countries, except Estonia. For Estonia, FDI includes one unit root, subtracted out by its first difference.

The results of KPSS test for electricity consumption are presented in Table 13. In most countries, electricity consumption follows a trend stationary process. In Croatia, Kazakhstan, Latvia, Lithuania, Moldova, Russia, and Ukraine, electricity consumption includes a unit root. In case of Kazakhstan, the process includes 2 stochastic components, which requires second differencing for stationary transformation.

According to our results from the KPSS tests, we identify six groups of structural forms of VAR models based on the similarities among stationarity results. The results of structural forms of VAR by country groups are presented in Appendix E.

From these structural forms we estimate the coefficients of interest and test them for Granger causality. The identified structural VAR models are checked for white noise residuals in order to confirm the relevance of the selected lags in the model. The results of the Lagrange Multiplier white noise test by country are presented in Appendix F. The results show that for all countries, except Turkey, the selected lags are optimal. In case of Turkey, the residuals are not white noise, which indicates that we are not using all the information presented in the data. Therefore, we estimate Granger causality with 3 lags for Turkey.

Table 11: KPSS test for Stationarity of GDP (optimal lag=2)

Country	GDP	ΔGDP	ΔΔGDP
Albania	0.0754		
Armenia	0.165**	0.204	
Belarus	0.179**	0.325	
Bulgaria	0.178**	0.348	
Croatia	0.157**	0.175	
Estonia	0.0801		
Hungary	0.142		
Kazakhstan	0.179**	0.376	
Latvia	0.161**	0.212	
Lithuania	0.166**	0.193	
Moldova	0.183**	0.411	
Poland	0.11		
Romania	0.158**	0.0984	
Russia	0.173**	0.286	
Tajikistan	0.186**	0.509***	0.206[5]
Turkey	0.121		
Ukraine	0.176**	0.114	

Critical Values (trend): 10%: 0.119- 5% : 0.146 - 1% : 0.216
Critical Values (no trend): 10%: 0.347 - 5% : 0.463 - 1% : 0.739
Ho: *Level or Trend Stationarity (by specification)*
H_1:*Unit Root*

[5] Even though this variable is stationary, the transformation of this variable into second difference has no economic interpretation. Therefore we do not estimate Granger causality for variables that include two stochastic trends.

Table 12: KPSS test for Stationarity of FDI (optimal lag=2)

Country	FDI	∆FDI	∆∆FDI
Albania	0.115		
Armenia	0.124		
Belarus	0.106		
Bulgaria	0.0895		
Croatia	0.0669		
Estonia	0.162**	0.456	
Hungary	0.0748		
Kazakhstan	0.0939		
Latvia	0.141		
Lithuania	0.0828		
Moldova	0.0755		
Poland	0.0957		
Romania	0.0801		
Russia	0.122		
Tajikistan	0.0825		
Turkey	0.133		
Ukraine	0.0958		
Critical Values (trend):	10%: 0.119- 5% : 0.146 - 1% : 0.216		
Critical Values (no trend):	10%: 0.347 - 5% : 0.463 - 1% : 0.739		

Ho: *Level or Trend Stationarity (by specification)*

H_1: *Unit Root*

Table 13: KPSS test for Stationarity of ELC (optimal lag=2)

Country	ELC	∆ELC	∆∆ELC
Albania	0.132		
Armenia	0.124		
Belarus	0.12		
Bulgaria	0.146		
Croatia	0.156**	0.233	
Estonia	0.0823		
Hungary	0.107		
Kazakhstan	0.176**	0.468***	0.222
Latvia	0.156**	0.278	
Lithuania	0.17**	0.358	
Moldova	0.147**	0.203	
Poland	0.0884		
Romania	0.139		
Russia	0.17**	0.393	
Tajikistan	0.137		
Turkey	0.0803		
Ukraine	0.177**	0.395	
Critical Values (trend):	10%: 0.119- 5% : 0.146 - 1% : 0.216		
Critical Values (no trend):	10%: 0.347 - 5% : 0.463 - 1% : 0.739		

Ho: *Level or Trend Stationarity (by specification)*

H_1: *Unit Root*

All the estimated coefficients that are not statistically significant are omitted from the Granger causality test. Moreover, all the coefficients for second-differenced variables are also removed due to absence of economic interpretation for these variables. The results of short-run Granger causality are reported in Table 14.

Table 14: Granger Causality Wald Tests

Country	Granger Causality Direction	χ^2	P-Value
Albania	GDP→FDI	4.02**	0.0451
	ELC→GDP	11.695***	0.0030
Armenia	ELC→FDI	24.18***	0.0000
	GDP→ELC	22.77***	0.0000
Belarus	FDI→GDP	19.906***	0.0000
Estonia	FDI→GDP	18.179***	0.0000
Hungary	ELC→FDI	7.66***	0.0056
Latvia	GDP→ELC	32.609***	0.0000
Lithuania	FDI→ELC	8.9684**	0.0110
Moldova	ELC→FDI	7.66***	0.0057
Poland	GDP→ELC	5.81***	0.0160
Russia	GDP→FDI	4.7**	0.0301
Turkey	GDP→FDI	11.97***	0.0005
	ELC→FDI	25.133***	0.0000
	FDI→ELC	40.917***	0.0000
Ukraine	ELC→GDP	6.16**	0.0131

H0:'No Granger Causality':estimated coefficients are jointly zero';
→identifies the direction of the short run causality;
'For Kazakhstan, Romania, Tajikistan, Bulgaria, Croatia short-run Granger Causality was not found'
***denotes p-values<0,01
**denotes p-values<0,05

The results show that in Ukraine electricity consumption Granger causes economic growth. This short-run causality shows that any restriction on electricity consumption will hinder economic growth in Ukraine. In Latvia and Poland, Granger causality runs from GDP to electricity consumption. This causal relationship falls under the 'conservation hypothesis,' and shows that electricity conservation policies will have little effect on GDP. In Armenia we see a bi-directional causality running simultaneously from GDP to electricity consumption and from electricity consumption to GDP.

In Russia, Turkey, and Albania, GDP Granger causes FDI. This indicates that increasing economic growth in these countries attracts foreign investors, and that contraction of economic activity is generally followed by capital flight. However, it also shows that reduction in inflows of FDI has little adverse impact on economic growth. In Belarus and Estonia the short run causalities between

GDP and FDI run in the opposite directions; from FDI to GDP. This shows that economic growth rates of these countries are highly dependent on the support of international investors.
In Lithuania FDI Granger causes ELC, which indicates that electricity consumption is dependent on the inflows of foreign investments into the country. However, conservation electricity policies will not have a strong impact on the inflows of FDI in the short-run.

In Turkey we observe a bi-directional causality between electricity consumption and FDI, which shows that electricity consumption and FDI affect each other simultaneously. In Turkey, market liberalization, expansion of electricity production or an improvement in production efficiency attracts foreign investors, and these new investments are directly translated into expansion of electricity use. In Hungary, Moldova and Armenia we see a uni-directional causality running from electricity consumption to FDI, which shows that any restrictions on electricity production will hinder the inflows of FDI into these countries.

In Kazakhstan, Romania, Tajikistan, Bulgaria, Croatia we did not find any Granger causalities between electricity consumption, economic growth, and FDI, which indicates a prevalence of 'neutrality hypothesis' in these countries. This means that electricity consumption policies will not have any effect on economic growth or inflows of foreign direct investments in these countries.

6. Discussion of Results

The significance of the results presented above depends heavily on the power and the structural construct of the selected unit root and cointegration tests. Most of the recent dynamic panel unit root and cointegration tests have some shortcomings, which do not allow to apply these tests to every panel. In our study we consider the shortcomings of different panel tests, and select only those tests that provide the most reliable results given the limitations of our data.

6.1. Unit Roots and Asymptotic Assumption

To obtain our results we selected unit root estimation techniques, which allowed for heterogeneity across cross-sections and time-series dimensions. One of the shortcomings of the applied unit roots tests is the asymptotic assumption about T and N. Most panel unit root tests provide consistent estimates of the true value of the parameter when N and T tend to infinity. Given the relatively small N and short T in our panel, the validity of our results can be questioned. However, in our contribution, we employ unit root tests that perform relatively well for small T and N. Zivot and Andrews (1992) report their findings on the size and the power of the test to be not very sensitive to the relaxation of the normality assumption. Pesaran CADF test also performs well in panels with

N>10 and T>10. Therefore, we conclude that the chosen unit root tests perform well in our panel with N=17 and T=18.

6.2. Structural Breaks and Cross-Sectional Dependence

Another shortcoming of the chosen tests lies in the possible size distortions and test biases that can arise from the structural limitations of these tests to simultaneously account for presence of structural breaks and cross-sectional dependence. The design of Pesaran CADF unit root test does not allow for a structural break. On the other hand, Zivot Andrews unit root test does not account for cross-sectional dependence, which can lead to significant size distortions of the tests, and therefore, produce unreliable results. Moreover, Zivot Andrews test allows for only one structural break in the series, which is a very restrictive assumption for our panel of countries, given their history of extensive economic, political, and institutional transformations in the 1990's. Visual inspection of the data indicates a presence of at least two structural breaks in the series; one in the 1990's, which is country specific, and the second in 2008-2009. Therefore, Zivot Andrews unit root tests in these settings can be criticized for producing spurious results. However, any unit root test that allows for two or more structural breaks will not perform well in our panel due to the short time-series dimension. Therefore, we rely on Zivot Andrews unit root to capture a structural break that had the most significant and pronounced effect on the series, and analyze whether the effect was temporary or permanent. Overall we do recognize the limitations of both tests. However, since the structural constructs of these tests do not allow to combine them together, and we did not find any other test that would allow for such combination, we consider the results of Pesaran CADF and Zivot Andrews unit root tests to be reliable and consistent approximations of the unit root processes in the series.

6.3. Economic Theory and Econometric Application

Our study does not rely on economic theories, which might be viewed as a disadvantage of our research. However, the primary goal of our study is to determine the interrelationships between the variables, rather than determine parameter estimates for them. Moreover, most of our variables are found to include non-stationary series, whose presence makes it impossible to employ standard OLS procedures, since the means and variances of such series are time dependent. Furthermore, any inferences on the interrelationships between integrated variables can produce valuable results only if these variables form a cointegrating relationship; meaning they form a long-run equilibrium relationship, around which they cannot move independently from each other. By Engel and Granger (1987) definition, "the long-run relationship among the non-stationary variables does not require to be generated by the market forces, or by behavioral rules of individuals" (Enders, 2010). Therefore, the prediction of the existence of cointegrating relationships is not possible by pure reliance on economic theory. Thus, the analysis and estimation of these linkages between the stochastic trends of the series is a matter of econometric analysis. However, the inclusion of different variables into cointegrating relationships should be driven by the rational of a researcher and economic theories that previously established relationships between variables. We include foreign direct investment variable into the cointegration relationship, because previous studies report a positive and a strong correlation between growth and investment inflows in transition economies (Krkosk, 2001).

7. Conclusion and Future Research

There exists an extensive body of literature that examines relationships between energy consumption and growth. The bulk of this literature focuses on the causality relationships between electricity consumption and national income. Empirical studies on these topics so far have covered most of the developed and developing countries. However, very little attention has been given to transition economies.

The main goal of this study was to investigate the long-run and the short-run causality relationships between electricity consumption, economic growth, and foreign direct investment for the seventeen transition economies for the purpose of advising and designing an optimal long-run energy policy for these countries. This study provides new empirical insights into the long-run equilibrium relationship in the multivariate framework and the order of integration for electricity consumption, economic growth, and foreign direct investment in the seventeen transition economies. We investigate the cross-sectional dependence between the countries by employing Pesaran (2004) cross-sectional dependence test, which confirms the presence of the cross country dependence in the region. By using a unit root test that allows for cross-sectional dependence, we conclude that foreign direct investment variable is not integrated of the same order across all series, and therefore, potential long-run equilibrium relationship can exist only between electricity consumption and growth.

Moreover, we also recognize that the turbulent economic, political, and institutional changes in these countries after the collapse of the communist regimes, could also significantly impact our integration analysis and estimation of the long-run relationship. By employing Zivot Andrews unit root test we confirm that all variables are comprised of stationary and non-stationary series, which makes it impossible for them to form a long-run equilibrium relationship that holds for all countries. By using Pedroni panel cointegration test for all three variables, and also for electricity consumption and growth only, we confirm that no long-run equilibrium relationship exists between electricity consumption, growth and foreign direct investment across all transition economies. Therefore, any attempts to estimate the long-run relationship between these variables will produce spurious results. Since cointegrating relationship was not found, we could not proceed to the estimation of Granger long-run causalities.

We did estimate the short-run causalities between electricity consumption, economic growth and foreign direct investment by country, which could be of use to the policy makers. However, these causalities are country based and therefore, only exist within the framework and environment of a specific country. Moreover, these causalities capture only the short run interrelations between the variables. Thus, their use in formulations of long-run energy policies should be evaluated with caution.

Overall our results show that electricity consumption, economic growth and foreign direct investment do not form any long-run equilibrium relationship that is prevalent across the region. Therefore, any question whether energy conservation policy could have a negative impact on economic growth in the transition economies remains open for further research. We hope that this study will spark the interest to investigate the electricity consumption-economic growth nexus through different multivariate frameworks and econometric techniques.

7.1. Future Research and Recommendations

Our study confirms the findings of Acaravi and Ozturk (2010) that no long-run equilibrium relationship exists between electricity consumption and growth in the selected transition economies on the period of 1992-2009. However, we do not reject the hypothesis of the existence of cointegration between electricity use and economic growth for these countries. We believe that future research on this question is necessary to identify the linkages between electricity consumption and economic growth in the transition economies for the purpose of formulating solid and reliable energy policy recommendations.

For the future research we recommend to expand the time-series dimension by using quarterly data for electricity consumption and national income growth. Most public source economic databases provide mainly annual data for these variables, which significantly limits the observations for the transition economies. Exploration of national accounts for quarterly data could provide a probable solution for the short time-series dimension. However, aggregation of the data from different national accounts could become a challenging task given the differences in inflation and methods of reporting the data in different countries.

We also suggest collecting data on foreign direct investments that targeted specifically the transformation of electricity sector. This type of data could provide better insights into the interrelationships between electricity generation, electricity consumption, and growth.

Moreover, we would advise to explore different unit root and cointegration methodologies that account for heterogeneous data generating processes; especially the ones that account for several structural breaks and multiple common factors in the residuals. Currently there are unit root and cointegration tests that allow for several structural breaks, but their applicability is strongly influenced by the asymptotic assumption and requires N and T to be significantly large. We also suggest employing Factor Analysis and cross-sectional dependence modeling suggested by Bai, et al. (2009) to check for unit roots in the presence of multiple common factors. At this point their methodology is quite new and it is being currently explored for future applications.

We also suggest investigating the relationship between electricity consumption and economic growth through a different framework. As mentioned before, the cointegration relationship might exist between the electricity consumption and growth if other channels of cointegration are included in the relationship. The potential variables of interest are gross capital formation, electricity prices, unrecorded economic activity, exports and imports of electricity.

Finally, it is also important to remember that policy implications of the direction of causality spread beyond the statistical analysis of causality between few selected variables, and are not as straightforward as they might seem. Therefore, the formulation of solid energy policies requires consideration of such factors as energy efficiency, institutional constraints, existing supply infrastructures that also should be evaluated together with the causality links.

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Appendix A

Critical Values for Pesaran (2007) CADF test:

Table II(a). Critical values of average of individual cross-sectionally augmented Dickey–Fuller distribution (Case I: no intercept and no trend)

T/N	10	15	20	30	50	70	100	200
1%($\overline{CADF}$)								
10	−2.16	−2.02	−1.93	−1.85	−1.78	−1.74	−1.71	−1.70
	(−2.14)	(−2.00)	(−1.91)	(−1.84)	(−1.77)	(−1.73)		(−1.69)
15	−2.03	−1.91	−1.84	−1.77	−1.71	−1.68	−1.66	−1.63
20	−2.00	−1.89	−1.83	−1.76	−1.70	−1.67	−1.65	−1.62
30	−1.98	−1.87	−1.80	−1.74	−1.69	−1.67	−1.64	−1.61
50	−1.97	−1.86	−1.80	−1.74	−1.69	−1.66	−1.63	−1.61
70	−1.95	−1.86	−1.80	−1.74	−1.68	−1.66	−1.63	−1.61
100	−1.94	−1.85	−1.79	−1.74	−1.68	−1.65	−1.63	−1.61
200	−1.95	−1.85	−1.79	−1.73	−1.68	−1.65	−1.63	−1.61
5%($\overline{CADF}$)								
10	−1.80	−1.71	−1.67	−1.61	−1.58	−1.56	−1.54	−1.53
	(−1.79)		(−1.66)		(−1.57)	(−1.55)	(−1.53)	(−1.52)
15	−1.74	−1.67	−1.63	−1.58	−1.55	−1.53	−1.52	−1.51
20	−1.72	−1.65	−1.62	−1.58	−1.54	−1.53	−1.52	−1.50
30	−1.72	−1.65	−1.61	−1.57	−1.55	−1.54	−1.52	−1.50
50	−1.72	−1.64	−1.61	−1.57	−1.54	−1.53	−1.52	−1.51
70	−1.71	−1.65	−1.61	−1.57	−1.54	−1.53	−1.52	−1.51
100	−1.71	−1.64	−1.61	−1.57	−1.54	−1.53	−1.52	−1.51
200	−1.71	−1.65	−1.61	−1.57	−1.54	−1.53	−1.52	−1.51
10%($\overline{CADF}$)								
10	−1.61	−1.56	−1.52	−1.49	−1.46	−1.45	−1.44	−1.43
		(−1.55)		(−1.48)			(−1.43)	
15	−1.58	−1.53	−1.50	−1.48	−1.45	−1.44	−1.44	−1.43
20	−1.58	−1.52	−1.50	−1.47	−1.45	−1.45	−1.44	−1.43
30	−1.57	−1.53	−1.50	−1.47	−1.46	−1.45	−1.44	−1.43
50	−1.58	−1.52	−1.50	−1.47	−1.45	−1.45	−1.44	−1.43
70	−1.57	−1.52	−1.50	−1.47	−1.46	−1.45	−1.44	−1.43
100	−1.56	−1.52	−1.50	−1.48	−1.46	−1.45	−1.44	−1.43
200	−1.57	−1.53	−1.50	−1.47	−1.45	−1.45	−1.44	−1.43

Note: $\overline{CADF}$ statistic is computed as the simple average of the individual-specific $CADF_i$ statistics. See notes to Table I(a).

Table II(b). Critical values of average of individual cross-sectionally augmented Dickey–Fuller distribution (Case II: intercept only)

T/N	10	15	20	30	50	70	100	200
1%($\overline{CADF}$)								
10	−2.97	−2.76	−2.64	−2.51	−2.41	−2.37	−2.33	−2.28
	(−2.85)	(−2.66)	(−2.56)	(−2.44)	(−2.36)	(−2.32)	(−2.29)	(−2.25)
15	−2.66	−2.52	−2.45	−2.34	−2.26	−2.23	−2.19	−2.16
20	−2.60	−2.47	−2.40	−2.32	−2.25	−2.20	−2.18	−2.14
30	−2.57	−2.45	−2.38	−2.30	−2.23	−2.19	−2.17	−2.14
50	−2.55	−2.44	−2.36	−2.30	−2.23	−2.20	−2.17	−2.14
70	−2.54	−2.43	−2.36	−2.30	−2.23	−2.20	−2.17	−2.14
100	−2.53	−2.42	−2.36	−2.30	−2.23	−2.20	−2.18	−2.15
200	−2.53	−2.43	−2.36	−2.30	−2.23	−2.21	−2.18	−2.15
5%($\overline{CADF}$)								
10	−2.52	−2.40	−2.33	−2.25	−2.19	−2.16	−2.14	−2.10
	(−2.47)	(−2.35)	(−2.29)	(−2.22)	(−2.16)	(−2.13)	(−2.11)	(−2.08)
15	−2.37	−2.28	−2.22	−2.17	−2.11	−2.09	−2.07	−2.04
20	−2.34	−2.26	−2.21	−2.15	−2.11	−2.08	−2.07	−2.04
30	−2.33	−2.25	−2.20	−2.15	−2.11	−2.08	−2.07	−2.05
50	−2.33	−2.25	−2.20	−2.16	−2.11	−2.10	−2.08	−2.06
70	−2.33	−2.25	−2.20	−2.15	−2.12	−2.10	−2.08	−2.06
100	−2.32	−2.25	−2.20	−2.16	−2.12	−2.10	−2.08	−2.07
200	−2.32	−2.25	−2.20	−2.16	−2.12	−2.10	−2.08	−2.07
10%($\overline{CADF}$)								
10	−2.31	−2.22	−2.18	−2.12	−2.07	−2.05	−2.03	−2.01
	(−2.28)	(−2.20)	(−2.15)	(−2.10)	(−2.05)	(−2.03)	(−2.01)	(−1.99)
15	−2.22	−2.16	−2.11	−2.07	−2.03	−2.01	−2.00	−1.98
20	−2.21	−2.14	−2.10	−2.07	−2.03	−2.01	−2.00	−1.99
30	−2.21	−2.14	−2.11	−2.07	−2.04	−2.02	−2.01	−2.00
50	−2.21	−2.14	−2.11	−2.08	−2.05	−2.03	−2.02	−2.01
70	−2.21	−2.15	−2.11	−2.08	−2.05	−2.03	−2.02	−2.01
100	−2.21	−2.15	−2.11	−2.08	−2.05	−2.03	−2.03	−2.02
200	−2.21	−2.15	−2.11	−2.08	−2.05	−2.04	−2.03	−2.02

Note: $\overline{CADF}$ statistic is computed as the simple average of the individual-specific $CADF_i$ statistics. See notes to Table I(b).

Table II(c). Critical values of average of individual cross-sectionally augmented Dickey–Fuller distribution (Case III: intercept and trend)

T/N	10	15	20	30	50	70	100	200
1%($\overline{CADF}$)								
10	−3.88	−3.61	−3.46	−3.30	−3.15	−3.10	−3.05	−2.98
	(−3.51)	(−3.31)	(−3.20)	(−3.10)	(−3.00)	(−2.96)	(−2.93)	(−2.88)
15	−3.24	−3.09	−3.00	−2.89	−2.81	−2.77	−2.74	−2.71
	(−3.21)	(−3.07)	(−2.98)	(−2.88)	(−2.80)	(−2.76)		(−2.70)
20	−3.15	−3.01	−2.92	−2.83	−2.76	−2.72	−2.70	−2.65
30	−3.10	−2.96	−2.88	−2.81	−2.73	−2.69	−2.66	−2.63
50	−3.06	−2.93	−2.85	−2.78	−2.72	−2.68	−2.65	−2.62
70	−3.04	−2.93	−2.85	−2.78	−2.71	−2.68	−2.65	−2.62
100	−3.03	−2.92	−2.85	−2.77	−2.71	−2.68	−2.65	−2.62
200	−3.03	−2.91	−2.85	−2.77	−2.71	−2.67	−2.65	−2.62
5%($\overline{CADF}$)								
10	−3.27	−3.11	−3.02	−2.94	−2.86	−2.82	−2.79	−2.75
	(−3.10)	(−2.97)	(−2.89)	(−2.82)	(−2.75)	(−2.73)	(−2.70)	(−2.67)
15	−2.93	−2.83	−2.77	−2.70	−2.64	−2.62	−2.60	−2.57
	(−2.92)	(−2.82)	(−2.76)	(−2.69)			(−2.59)	
20	−2.88	−2.78	−2.73	−2.67	−2.62	−2.59	−2.57	−2.55
30	−2.86	−2.76	−2.72	−2.66	−2.61	−2.58	−2.56	−2.54
50	−2.84	−2.76	−2.71	−2.65	−2.60	−2.58	−2.56	−2.54
70	−2.83	−2.76	−2.70	−2.65	−2.61	−2.58	−2.57	−2.54
100	−2.83	−2.75	−2.70	−2.65	−2.61	−2.59	−2.56	−2.55
200	−2.83	−2.75	−2.70	−2.65	−2.61	−2.59	−2.57	−2.55
10%($\overline{CADF}$)								
10	−2.98	−2.89	−2.82	−2.76	−2.71	−2.68	−2.66	−2.63
	(−2.87)	(−2.78)	(−2.73)	(−2.67)	(−2.63)	(−2.60)	(−2.58)	(−2.56)
15	−2.76	−2.69	−2.65	−2.60	−2.56	−2.54	−2.52	−2.50
		(−2.68)	(−2.64)	(−2.59)	(−2.55)	(−2.53)	(−2.51)	
20	−2.74	−2.67	−2.63	−2.58	−2.54	−2.53	−2.51	−2.49
30	−2.73	−2.66	−2.63	−2.58	−2.54	−2.52	−2.51	−2.49
50	−2.73	−2.66	−2.63	−2.58	−2.55	−2.53	−2.51	−2.50
70	−2.72	−2.66	−2.62	−2.58	−2.55	−2.53	−2.52	−2.50
100	−2.72	−2.66	−2.63	−2.59	−2.55	−2.53	−2.52	−2.50
200	−2.73	−2.66	−2.63	−2.59	−2.55	−2.54	−2.52	−2.51

Note: $\overline{CADF}$ statistic is computed as the simple average of the individual-specific $CADF_i$ statistics. See notes to Table I(c).

Appendix B

Lag Selection for the Pesaran Unit Root Test that accounts for Cross-Sectional Dependence (CADF). The appropriate lag length for this test was chosen by Schwartz Information Criteria (SIC).The model deterministics include: a trend and a constant.

Countries	ELC(Lags)	FDI(Lags)	GDP(Lags)
Albania	0	1	0
Armenia	0	0	3
Belarus	0	0	0
Bulgaria	1	1	0
Croatia	0	0	3
Estonia	1	0	1
Hungary	0	0	3
Kazakhstan	1	0	1
Latvia	1	2	1
Lithuania	0	0	1
Moldova	2	0	0
Poland	0	0	3
Romania	1	0	3
Russia	1	0	0
Tajikistan	1	1	0
Turkey	1	0	0
Ukraine	2	0	1

SIC is employed to measure the overall fit of the alternative models (with different lag lengths). The marginal cost of adding regressors (additional lags) is greater with the SIC, therefore it always selects the most parsimonious model. $SIC = \ln(n)k - 2\ln(L_{\max})$; where n is number of observations, k is a number of parameters to be estimated, and L_{max} is the maximized value of log-Likelihood for the estimated model.

All residuals have been checked for white noise with the selected lags by employing Promanteau's White Noise Test:

Portmanteau Test for White Noise

Country	**GDP**	**FDI**	**ELC**
Albania	0.7636	0.1113	0.4725
Armenia	0.7375	0.3163	0.5316
Belarus	0.6059	0.6613	0.9716
Bulgaria	0.077	0.632	0.5765
Croatia	0.9841	0.1202	0.9123
Estonia	0.3625	0.6404	0.8802
Hungary	0.687	0.1226	0.8801
Kazakhstan	0.9724	0.2066	0.7864
Latvia	0.6701	0.9736	0.6583
Lithuania	0.2684	0.9227	0.4294
Moldova	0.4338	0.1843	0.6918
Poland	0.9515	0.9459	0.7665
Romania	0.9565	0.5195	0.9489
Russia	0.2299	0.8023	0.7409
Tajikistan	0.4081	0.7628	0.8562
Turkey	0.7551	0.9564	0.9436
Ukraine	0.7743	0.5318	0.99

Values presented are p-values for Portmanteau Q-statistics;
H_0:no autocorrelations in the residuals

Appendix C

KPSS Stationarity Test as a Unit Root Test (Shin and Schmidt, 1992)

Kwiatkowski, Phillips, Schmidt and Shin developed a residual based Lagrange Multiplier test that checks for stationary around a deterministic trend or around a level. Under the alternative hypothesis of the test, time-series includes a unit root. Kwiatkowski, Phillips,Schmidt and Shin consider the following model, where y_t is expressed as a sum of a linear deterministic trend, a random walk, and a stationary error term:

$$y_t = r_t + \beta t + \varepsilon_t \qquad (1)$$

where r_t represents a random walk: $r_t = r_{t-1} + u_t$;

and ε_t ~IIN$(0, \sigma_\varepsilon^2)$ and u_t ~IIN$(0, \sigma_u^2)$ are mutually independent normal distributions, that are IID over *t*. The initial value of r_0 is treated as fixed and serves a role of an intercept. Combining both models specification, we obtain the following model formulation

$$y_{it} = r_0 + \beta t + \sum_{s=1}^{t} u_t + \varepsilon_t = r_0 + \beta t + v_t \qquad (2)$$

Where $v_t = \sum_{s=1}^{t} u_t + \varepsilon_t$ .Under this specification, the null hypothesis is defined as $H_0 : \sigma_u^2 = 0$, under which r_t is constant over time and $v_t = \varepsilon_t$. The null hypothesis checks for the variance of the stochastic error component to be constant and equal to zero.

The KPSS test statistics is the Lagrangian Multiplier (LM) for testing $\sigma_u^2 = 0$ against the alternative of $\sigma_u^2 > 0$: $KPSS = \dfrac{\left(\dfrac{1}{T^2}\sum_{t=1}^{T}\hat{S}_t^2\right)}{\hat{\sigma}_\varepsilon^2} = \dfrac{\left(\dfrac{1}{T^2}\sum_{t=1}^{T}\sum_{k=1}^{T}\hat{\varepsilon}_k^2\right)}{\hat{\sigma}_\varepsilon^2}$; where $\hat{S}_t^2$ are the partial sum of OLS residuals $\hat{\varepsilon}_k$ fromequation2,and $\hat{\sigma}_\varepsilon^2$ is a consistent estimate of σ_ε^2 under the null hypothesis. The distribution of KPSS test statistics is not normal and critical values have to be obtained from the Monte Carlo simulations. The critical values depend on the deterministic components in the model and are reported in the table below.

KPSS Statistics Distribution

	Right Tail Quatiles		
Deterministics	0.90	0.95	0.99
Trend-Stationary	0.119	0.146	0.216
Level-Stationary	0.347	0.463	0.739

Appendix D

Newey-West Automatic Bandwidth Selection Method (Andrews, 1991)

Besides the specification on trend and the criteria on lag length selection, the spectral estimation methods are the things that also need to be specified when running Pedroni and KPSS tests. The spectral estimation method refers to the details that one needs to provide to be used in computing the test statistic or statistics.

Andrews (1991) compared different kernel based methods, and concluded that the differences between the kernels are not large. So we followed the default model that the software (STATA) offered us, which is Kernel (Bartlett). After the selection of the Kernel methods, we could specify either an automatic bandwidth selection method (Andrews, Newey-West) or user specified fixed bandwidth.

The Newey and West (1994) propose a nonparametric method for automatically selecting the number of autocovariances to use in computing a heteroskedasticity and autocorrelation consistent covariance matrix. Their procedure is asymptotically equivalent to one that is optimal under a mean-squared error loss function.

They propose the following procedure, where the kernel-based estimator is based on a weighted sum of the autocovariances, with the weights defined by a kernel function. The estimator takes the form

$$\hat{f}_0 = \sum_{j=-(T-1)}^{T-1} \hat{\gamma}(j) * K\left(\frac{j}{l}\right)$$

where l is a bandwidth parameter (which acts as a truncation lag in the covariance weighting), K is a kernel function, and where $\hat{\gamma}(j)$, the j-th sample autocovariance of the residuals $\hat{\mu}_t$, is defined as:

$$\hat{\gamma}(j) = \sum_{t=i+1}^{T} \left(\hat{\mu}_t \hat{\mu}_{t-j}\right) \Big/ T$$

The residual $\hat{\mu}_t$ for kernel estimator can be obtained from the specified OLS equation that can be expressed in the general form as:

$$y_t = x_t^{'}\delta + \mu_t$$

Kernel (Bartlett) function:

$$K(x) = \begin{cases} 1\text{-}|x| & if\ |x| \leq 1 \\ 0 & \end{cases}$$

Appendix E

Structural VAR Models by Country Group

Group1: **Albania** **Poland** **Turkey** **Hungary**	FDI, GDP and ELC are stationary in levels; $ELC_{it} = \alpha_{1t} + \sum_{k=1}^{m} \alpha_{11ik} \Delta GDP_{it-k} + \sum_{k=1}^{m} \alpha_{12ik} FDI_{it-k} + \sum_{k=1}^{m} \alpha_{13ik} ELC_{it-k} + u_{1it};$ $\Delta GDP_{it} = \alpha_{2t} + \sum_{k=1}^{m} \alpha_{21ik} \Delta GDP_{it-k} + \sum_{k=1}^{m} \alpha_{22ik} FDI_{it-k} + \sum_{k=1}^{m} \alpha_{23ik} ELC_{it-k} + u_{2it};$ $FDI_{it} = \alpha_{3t} + \sum_{k=1}^{m} \alpha_{31ik} \Delta GDP_{it-k} + \sum_{k=1}^{m} \alpha_{32ik} FDI_{it-k} + \sum_{k=1}^{m} \alpha_{33ik} ELC_{it-k} + u_{3it};$
Group2: **Romania** **Bulgaria** **Belarus** **Armenia**	ELC and FDI are stationary in levels, GDP includes 1 unit root $\Delta ELC_{it} = \alpha_{1t} + \sum_{k=1}^{m} \alpha_{11ik} \Delta GDP_{it-k} + \sum_{k=1}^{m} \alpha_{12ik} FDI_{it-k} + \sum_{k=1}^{m} \alpha_{13ik} \Delta ELC_{it-k} + u_{1it};$ $\Delta GDP_{it} = \alpha_{2t} + \sum_{k=1}^{m} \alpha_{21ik} \Delta GDP_{it-k} + \sum_{k=1}^{m} \alpha_{22ik} FDI_{it-k} + \sum_{k=1}^{m} \alpha_{23ik} \Delta ELC_{it-k} + u_{2it};$ $FDI_{it} = \alpha_{3t} + \sum_{k=1}^{m} \alpha_{31ik} \Delta GDP_{it-k} + \sum_{k=1}^{m} \alpha_{32ik} FDI_{it-k} + \sum_{k=1}^{m} \alpha_{33ik} \Delta ELC_{it-k} + u_{3it};$
Group3: **Croatia** **Moldova** **Lithuania** **Ukraine** **Russia** **Latvia**	FDI is stationary in levels, GDP and ELC are integrated of order 1 $ELC_{it} = \alpha_{1t} + \sum_{k=1}^{m} \alpha_{11ik} GDP_{it-k} + \sum_{k=1}^{m} \alpha_{12ik} \Delta FDI_{it-k} + \sum_{k=1}^{m} \alpha_{13ik} ELC_{it-k} + u_{1it};$ $GDP_{it} = \alpha_{2t} + \sum_{k=1}^{m} \alpha_{21ik} GDP_{it-k} + \sum_{k=1}^{m} \alpha_{22ik} \Delta FDI_{it-k} + \sum_{k=1}^{m} \alpha_{23ik} ELC_{it-k} + u_{2it};$ $\Delta FDI_{it} = \alpha_{3t} + \sum_{k=1}^{m} \alpha_{31ik} GDP_{it-k} + \sum_{k=1}^{m} \alpha_{32ik} \Delta FDI_{it-k} + \sum_{k=1}^{m} \alpha_{33ik} ELC_{it-k} + u_{3it};$
Group 4: **Estonia**	GDP and ELC are stationary; FDI includes 1 unit root $ELC_{it} = \alpha_{1t} + \sum_{k=1}^{m} \alpha_{11ik} GDP_{it-k} + \sum_{k=1}^{m} \alpha_{12ik} FDI_{it-k} + \sum_{k=1}^{m} \alpha_{13ik} ELC_{it-k} + u_{1it};$ $GDP_{it} = \alpha_{2t} + \sum_{k=1}^{m} \alpha_{21ik} GDP_{it-k} + \sum_{k=1}^{m} \alpha_{22ik} FDI_{it-k} + \sum_{k=1}^{m} \alpha_{23ik} ELC_{it-k} + u_{2it};$ $FDI_{it} = \alpha_{3t} + \sum_{k=1}^{m} \alpha_{31ik} GDP_{it-k} + \sum_{k=1}^{m} \alpha_{32ik} FDI_{it-k} + \sum_{k=1}^{m} \alpha_{33ik} ELC_{it-k} + u_{3it};$
Group 5 **Kazakhsatn**	FDI is stationary in level, GDP includes 1 unit root, ELC includes 2 unit roots $\Delta^2 ELC_{it} = \alpha_{1t} + \sum_{k=1}^{m} \alpha_{11ik} \Delta GDP_{it-k} + \sum_{k=1}^{m} \alpha_{12ik} FDI_{it-k} + \sum_{k=1}^{m} \alpha_{13ik} \Delta^2 ELC_{it-k} + u_{1it};$ $\Delta GDP_{it} = \alpha_{2t} + \sum_{k=1}^{m} \alpha_{21ik} \Delta GDP_{it-k} + \sum_{k=1}^{m} \alpha_{22ik} FDI_{it-k} + \sum_{k=1}^{m} \alpha_{23ik} \Delta^2 ELC_{it-k} + u_{2it};$ $FDI_{it} = \alpha_{3t} + \sum_{k=1}^{m} \alpha_{31ik} \Delta GDP_{it-k} + \sum_{k=1}^{m} \alpha_{32ik} FDI_{it-k} + \sum_{k=1}^{m} \alpha_{33ik} \Delta^2 ELC_{it-k} + u_{3it};$
Group 6 **Tajikistan**	FDI and ELC are stationary in levels, GDP includes 2 unit roots $ELC_{it} = \alpha_{1t} + \sum_{k=1}^{m} \alpha_{11ik} \Delta^2 GDP_{it-k} + \sum_{k=1}^{m} \alpha_{12ik} FDI_{it-k} + \sum_{k=1}^{m} \alpha_{13ik} ELC_{it-k} + u_{1it};$ $\Delta^2 GDP_{it} = \alpha_{2t} + \sum_{k=1}^{m} \alpha_{21ik} \Delta^2 GDP_{it-k} + \sum_{k=1}^{m} \alpha_{22ik} FDI_{it-k} + \sum_{k=1}^{m} \alpha_{23ik} ELC_{it-k} + u_{2it};$ $FDI_{it} = \alpha_{3t} + \sum_{k=1}^{m} \alpha_{31ik} \Delta^2 GDP_{it-k} + \sum_{k=1}^{m} \alpha_{32ik} FDI_{it-k} + \sum_{k=1}^{m} \alpha_{33ik} ELC_{it-k} + u_{3it};$

Appendix F

Lagrange Multiplier White Noise Test for VAR models:

Result: No autocorrelation in the residuals at the selected lags order.

Lagrange-multiplier test

Country	Lag	chi2	df	Prob>chi2
Albania	1	8.1248	9	0.52162
	2	11.807	9	0.22441
Armenia	1	8.4304	9	0.49142
	2	8.8406	9	0.45212
Belarus	1	11.2118	9	0.26147
	2	6.4717	9	0.69193
Bulgaria	1	8.8905	9	0.44745
	2	9.5069	9	0.39185
Croatia	1	5.7526	9	0.7644
	2	7.3405	9	0.60172
Estonia	1	2.3374	9	0.98494
	2	11.2095	9	0.26162
Hungary	1	5.4399	9	0.7944
	2	11.8325	9	0.22292
Kazakhstan	1	8.8401	9	0.45217
	2	20.8523	9	0.01332
Latvia	1	14.2701	9	0.11304
	2	16.5296	9	0.05661
Lithuania	1	5.6513	9	0.77425
	2	22.6935	9	0.00692
Moldova	1	11.7517	9	0.22767
	2	9.4152	9	0.39987
Poland	1	5.8666	9	0.75319
	2	3.6393	9	0.93351
Romania	1	7.7291	9	0.56166
	2	6.925	9	0.64493
Russia	1	9.208	9	0.4183
	2	4.4905	9	0.87627
Tajikistan	1	6.0423	9	0.73568
	2	7.502	9	0.585
Turkey	1	9.1373	9	0.4247
	2	27.7093	9	0.00107***[6]
Ukraine	1	4.612	9	0.86674
	2	16.5867	9	0.05559

H_0: no autocorrelation at lag order

[6] White Noise test for Turkey indicates a presence of autocorrelation in the error term under 2 lags model specification. We adjust VAR model by three lags, under which the error terms are white noise, and estimate Granger causality with 3 lags augmentation for Turkey.

Appendix G

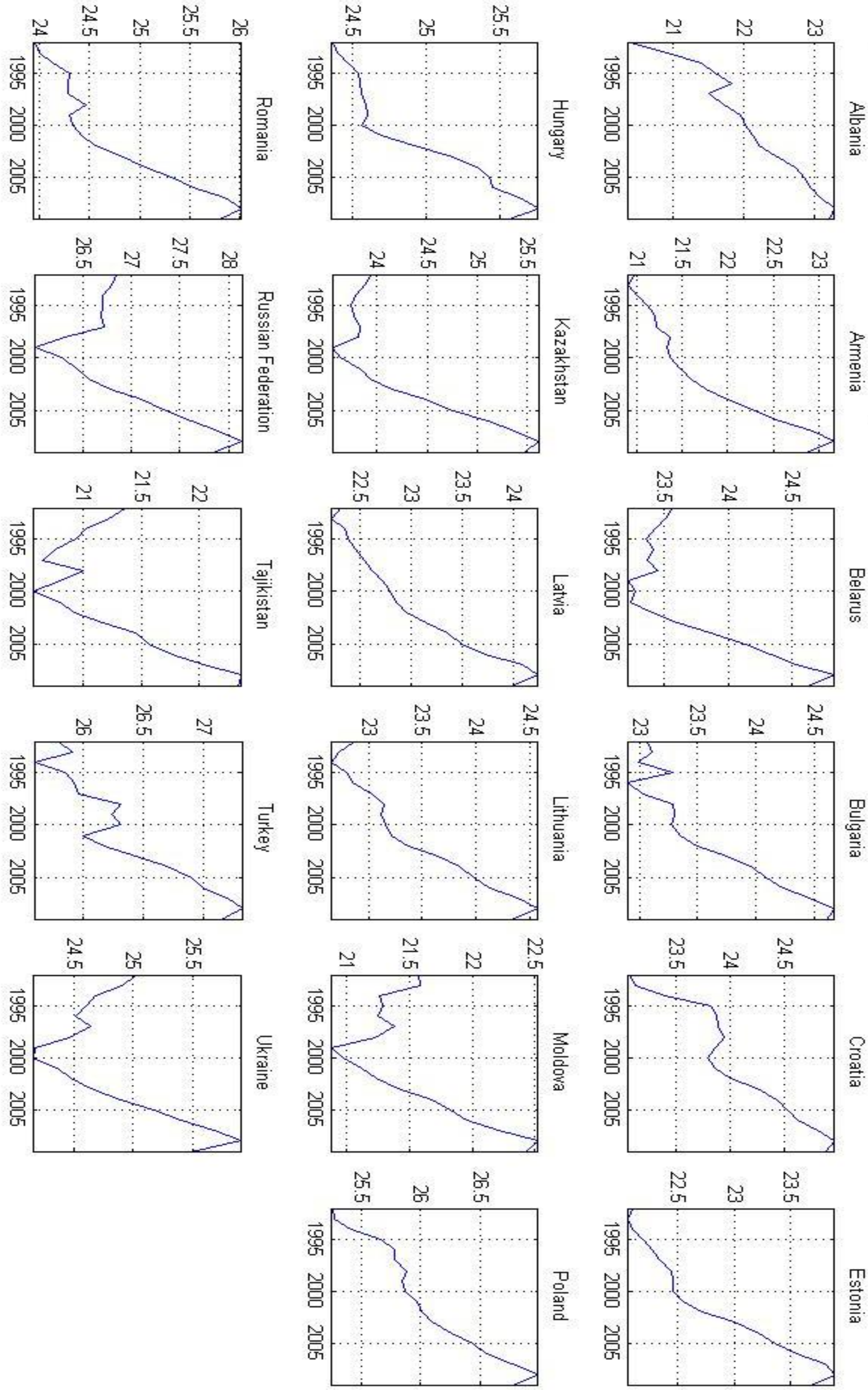

Figure 1. Natural Log of Gross Domestic Product

Figure 2. Natural Log of Foreign Direct Investment Inflows

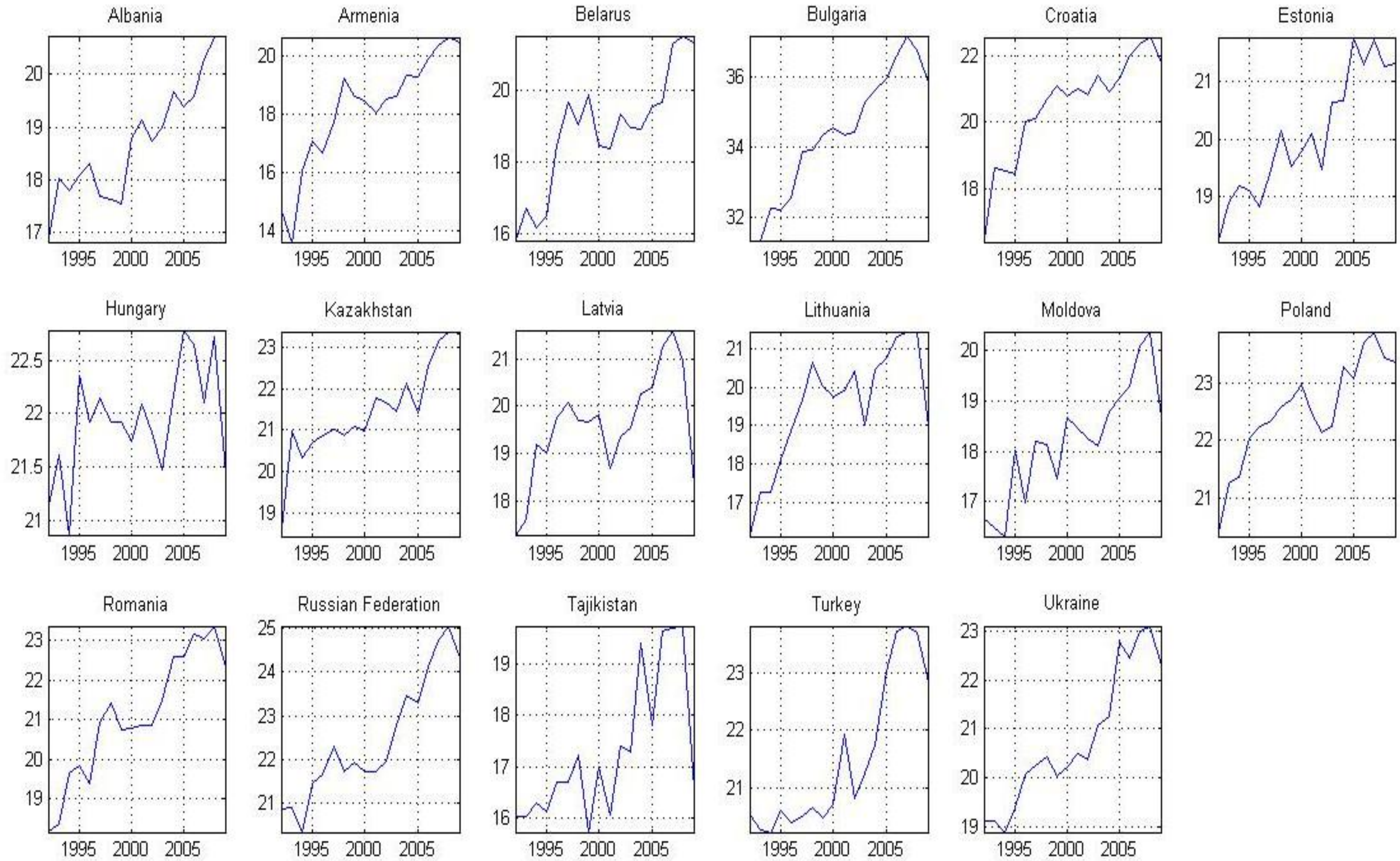

Figure 3. Natural Log of Electricity Consumption