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Economic growth and carbon causality: A three-step analysis for Hungary.

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Abstract

The present study explores the relationship between economic growth, electricity consumption, carbon emissions and urbanization in Hungary over the period of 1974-2014. We use three-step model for testing stationarity, cointegration and causality in VECM framework. First, we employ ARDL bounds testing methodology to investigate the long run relationship among the series in the presence of structural breaks. Secondly, to overcome the issue of different integrated order of variables, we applied Toda-Yamamoto procedure to test causality. Our results indicate the existence of long run relationships. The impact of electricity consumption and urbanization are positive on carbon emissions and statistically significant in the long run. The empirical results show that bidirectional causality is running from electricity consumption to economic growth. We further found evidence in the case of bidirectional causality between carbon emissions and economic growth. The causality analysis validates conservation hypothesis meaning that electricity consumption, economic growth and urbanization Granger cause carbon emissions. We conclude that increasing electricity consumption is an indicator of economy growth in Hungary therefore economic policy and energy policy interrelating coordination are vital for maintaining sustainable development.

JEL-codes: O04, Q40, Q54, Q56, R11

Keywords: energy, economic growth, Granger causality, Toda-Yamamoto approach, energy policy, ARDL, conservation hypothesis.

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1 INTRODUCTION

During the economic crises, the emerging European countries suffered a larger decline in production than other European countries. The crisis will have an impact for a long time (EBRD, 2009). Hungary's regime change history differs from other CEE countries because it achieved limited political liberalization with economic reforms in 1980s but major reforms occurring only after 1988. Therefore, the Hungarian transition was more even compared to those e.g. in Bulgaria (Iorgulescu and Polimeni, 2009, pp. 342.). Therefore, extended research is required on the role that policy differentiation has on economic growth for emerging countries as regard to primary energy consumption by sources (Caraiani et al. 2015, p.199.). This relationship is influenced by numerous factors, e.g. the countries' demographic characteristics, different indigenous energy supplies, political and economic histories, cultures, and different institutional arrangements (Chen et al. 2007). Regarding the optimal energy use and the emission reduction, countries are recommended to follow stringency strategies according to their level of development and in order to meet the emission targets optimizing strategies for growth. As it energy consumption and economic growth are intrinsically linked, the European challenge is to create and meet interrelated regulatory requirements in the newly competitive environment.

Located Central Europe, Hungary is a European Union member economy with a high income (Worldbank, 2020). Before 1990, Hungary was a socialist, plan-based economy. With the collapse of the Soviet Union, the Eastern Bloc countries suffered loss in both markets for goods, and subsidies from the Soviet Union. Hungary lost nearly 70% of its export markets in Eastern and Central Europe (CIA, 2017). With the wave of regime change in 1989, a new period began in the economies of Central and Eastern European countries as well as in Hungary. The development of the open market system also brought about a structural change in the energy sector as an important element of the economy (Gros-Steinherr, 2004). Manser (1993) said the energy problems of Central and Eastern European countries may be connected to a period of regime change. The major problem that the efficiency of electricity generation underperforms compared with competitors and incentives to saving energy are weak. Further, the energy sector has a vulnerable position due to its high energy import dependence (Iorgulescu and Polimeni, 2009).

The actual Hungarian economy is mostly based on services, which represent 64% of the GDP. Industry and agriculture represent 32% of the GDP and 4% of the GDP respectively (CIA, 2017). The Hungarian economy is the 50th-largest economy in the world (out of 188 countries measured by IMF) with $265.037 billion annual output and ranks 49th in the world in terms of GDP per capita measured by purchasing power parity. The energy consumption is increased by 30% between 1974 and 2014 (IEA, 2018). This value is 20% higher than the world average consumption, but 30% lower than in Europe and Central Asia. The per capita carbon emissions are 4.19 metric tons.

The air pollution decreased but the pollution caused death-rate in Hungary is the second highest in the world followed by China. Tens of thousands people lose their lives every year to diseases related to air pollution (WHO, 2018). The top environmental issue said to be air pollution by the half of the answers in Hungarian people (IPSOS, 2020; Statista, 2018) The largest greenhouse gas emitting sector is the energy production (Hungarian Central Statistical Office, 2015). Energy is responsible for about a third of the output. The manufacturing industry was still mostly responsible for greenhouse gases in the second half of the 1980s and its output was reduced by the downsizing of the heavy industry, followed by the modernization of the chemical industry and the financial and economic crisis of 2008. Since then, energy production has fallen sharply, yet environmental indicators have not clearly improved. Hungary should improve in the reduction of pollution (OECD, 2018). Figure 1 illustrates scaling on the left side along a timeline for economic growth (2011 US million dollar per capita) while we can see scaling on the left side for electricity consumption (kt of oil equivalent per capita) and carbon emission (metric kilotons per capita) between 1974-2014 in Hungary. The figure shows the percentage change and the base year is 1990 after the year of regime change.

In the existing empirical literature, there are numerous studies which are currently investigating the challenges presented by energy management, economic growth, energy consumption, the process of urbanization and their interrelated or causality effects. The first study by Kraft and Kraft (1978) focuses on the relationship between economic growth and energy consumption. They revealed Granger causality relationship using a panel of US data in the period of 1947-1974. Gross National Product contributing to energy consumption has been empirically proven. That paper was the basis for further extended research. Confirming the importance of the topic, more than 15,000 studies have been published on this research issue since 1978 (Sanches-Pereira et al. 2016).

The research area of classical energy-gdp relationship is nowadays less studied (Belke et al., 2011; Szép, 2014; Caraiani et al., 2015;) than in earlier stages. In a globalized world, the focus is on a widespread models that eliminates the economic, financial, and demographic impacts are more relevant extended carbon emissions (Shahbaz et al., 2014; Ajmi et al., 2015; Dogan-Seker, 2016; Saidi-Hammami, 2016), urbanization (Sharma, 2011; Shahbaz et al., 2014; Saidi-Hammami, 2016; Zhou et al., 2019; Munoz et al., 2020), financial development (Dogan-Seker, 2016; Saidi-Hammami, 2016; Pata, 2018; Jiang-Ma, 2019; Acheampong et al., 2020) and trade openness (Shahzad et al, 2017; Shahbaz et al, 2019; Zmami-Salha, 2020).

Empirical results has also confirmed the responsibility of urbanization in increasing carbon emissions and energy use. Urbanization contributes to enhance economic growth and energy use (Lariviére-Lafrance, 1999; Poumayong-Kaneko, 2010; Yang et al., 2019), increasing carbon emissions (Taale and Kyeremeh, 2016; Gupta-Gregg, 2018; Yang et al., 2019) with a trends of growing urban population, the number of cities, or population density. Another group of empirical studies (Shammin et al., 2010; Poumayong-Kaneko, 2010; Yang et al., 2019) justify the opposite with economies of scale because cities show an improvement in per capita energy use and emissions compared to the village (Lenzen et al., 2004; Shammin et al., 2010; Ye at al., 2017), so the urbanization sprawl in these countries can also identify as a key to enforce environmental protection.

A poor or rich country react to quite differently on the amount of carbon emissions. In poorer countries, carbon emissions increase with economic growth and energy consumption, while in richer countries, due to the process of decoupling, the energy-intensive sector cannot harm the environment. The indicator of wealth and poverty in literature is the annual change of economic growth as measured by gross domestic product (GDP). Countries are divided according to economic growth, the low-emission production is reached earlier by higher-income countries (Mazur et al., 2015; Pablo-Romero and Sánchez-Braza; 2017). Other comparative statistical results (Cayla et al., 2011; Sharma, 2011; Vassileva-Campillo, 2014; Yang et al., 2019) show that at least middle-income countries are much more open to trade, more urbanized, and larger energy consumers (Sharma, 2011). Richer countries are able to reduce their per capita energy consumption and emissions with higher incomes, while poorer countries may have higher specific energy consumption despite lower incomes. The income situation of the wealthier population allows for practical solutions such as the purchase of energy-saving machines and equipment, and the construction of energy-efficient houses. At a lower income level, there may be limits to these purchases (Vassileva-Campillo, 2014). Consumers in lower-income countries find it difficult to invest in energy-efficient equipment, which would be particularly important, for example, when purchasing heating systems (Cayla et al., 2011).

Not only are the environmental-income differences sharp between developed and developing countries, but we also find differences within groups of countries. However, they are considered more homogeneous (Vassileva and Campillo, 2014; Cayla et al., 2011). Hungary is a Member States of the European Union therefore it may be important to introduce the result of European Union countries. To support the achievement of EU targets in connection with energy consumption and carbon dioxide emissions, it is essential to reveal EU member states' contribution in order to establish more country-specific and effective energy policies (Bianco et al., 2018). However, there is no unified position how to effect economic growth, urbanization or energy consumption to carbon emissions. Pablo-Romero and Sánchez-Braza (2017) observed that for the 28 Member States of the European Union, only four of them managed to decrease carbon emissions with increasing economic grow. All four countries are older founding countries of the European Union and produce higher GDP per capita than the other analyzed countries.

Significant income inequalities are indicated by the fact that values are more scattered among poorer European Union members, showing higher heterogeneity at lower income levels. Empirical evidence since the 1980s suggest that increase in economic growth results greater energy consumption because energy is the basis of economic growth, enhanced environmental pollution (Ciarreta and Zarraga, 2010). Carbon emissions are contributed to the increase in energy consumption (Ozturk - Acaravci, 2010) as in Eastern-Europe (Stolyarova, 2010). However, economic growth can be a good tool for improving the environment, but only after reaching a higher level of income (Atici, 2008). The increase in income is also increased by the consumption of renewable energy (Sadorsky, 2009).

The economic growth-pollution relationship is heterogeneous in the member states of the European Union. Overall, economic growth is associated with increased emissions, with the exception of a few Central-Eastern European countries, where more intensive economic growth has been achieved without significant environmental degradation between 1996 and 2015 (Lazar et al., 2019). Few studies examine emerging countries in Central and Eastern Europe and we can find even less with results in Hungary. Of these, only dozens papers outline results for Hungary, for example Hungary as the member of the European Union (Ozturk-Acaravci, 2010b; Karmellos et al., 2016; Gazi et al., 2016; Lazar et al., 2019) or as an emerging economy (Ozturk-Acaravci, 2010; Ronald et al., 2014) and a member state of Visegrad Group (V4 countries) (Streimikiene – Kasperowicz, 2016; Vavrek-Chovancova, 2016). Ozturk-Acaravci (2010), Ronald et al (2014) and Ozturk-Acaravci (2010) applied ARDL model to examine causality relationship between economic growth and energy consumption.

There are three types of results for Hungary, that is, bidirectional relationship between GDP and energy consumption in one case, in the second case there is no causal relationship between GDP and energy, and thirdly, there is no long-term relationship between the variables, respectively. On the other hand, conservation hypothesis was proven for Hungary (Narayan and Prasad, 2008; Ronald et al., 2014; Caraiani et al., 2015). They tested causality between economic growth and energy consumption and concluded that increasing in economic growth will increases energy consumption. Emissions were not investigated (Narayan and Prasad, 2008; Ronald et al., 2014; Caraiani et al., 2015). Ozturk-Acaravci (2010) found bidirectional relationships between economic growth and energy consumption. Piaggio-Padilla (2012) have evidence no causality but even a long-term relationship between carbon emissions and economic growth, confirming Ozturk-Acaravci (2010)b findings.

Strong decoupling has not been experienced in Visegrad countries among economic growth and emissions series. In Hungary, the carbon-economic growth relationship is time varying. Between 1994 and 1997, weak decoupling occurred meaning that economic growth and greenhouse gas emissions increase, but the economic growth increase faster than the emissions. Between 2009-2012 period brought change when „both GDP and greenhouse gas emissions decrease, but the emissions decrease more rapidly than the GDP. This relationship with decoupling was the similar in the Czech Republic, but in an earlier period, in the period of 1997-2000" (Vavrek-Chovancova, 2016). Using panel framework with VAR model, Szép (2014) shows for Hungary, Slovakia, the Czech Republic, energy consumption is Granger cause of economic growth so per capita income have a positive and statistically significant impact on per capita energy consumption in Hungary.

The above studies confirm that research in Hungary is based on panel data and that in most cases causal relationships between economic growth and energy use were found. Carbon emissions appear only in one third of the studies, causal relationship only to Gazi et al. (2016) discovered the use of biomass. However, when formulating energy policy recommendations, it is difficult to interpret in general for a panel group of countries, so it is more favorable to examine the polluting effect of economic growth to countries separately. Present study is the first as far as we know which only and exclusively for Hungarian conditions analyzes the causal relationship in an extended economic growth-energy nexus employing ARDL cointegration framework.

The first purpose and the novelty of this paper is fill a gap by presenting a relationship between economic growth, carbon emissions, electricity consumption and urbanization in a European emerging country, in the Hungarian conditions. This study the first to take into account the impact of urbanization for Hungary on carbon emissions and present study can be among the first for eastern European emerging country. Secondly, we measure the urbanization in the number of cities to find out real impact of the rapid urbanization implying increasing in the number of Hungarian cities on energy consumption and carbon emissions. Thirdly, in contrast to previous studies, this study analyzes the relationship with structural breaks in line with the specifics of Hungary (and an eastern European emerging country), which basically determine the relationships between energy-growth and environmental protection. Fourthly, the paper might contribute to the development of an energy policy which could ensure a sustainable and long-run economic growth and is suitable for the capabilities of Hungary and also to making macro level forecasts. Exploring the causal relationships is especially important for the political decision-makers to help them devise a proper energy strategy. To enhance economic growth and the conservation of the quality of the environment should be equally important goals.

The paper is structured as follows. Section 2 gives a review of the related mixed results of economic growth and environmental degradation literature with special regard to the conditions in Hungary and Central and Eastern European emerging countries. Section 3 discussing the model specification and methodology. Section 4 presents the empirical results, after which Section 5 concluded the policy implications and further research objectives.

2 METHODOLOGICAL FRAMEWORK

The study covers the time period of 1974-2014 in case of Hungary. International statistics and national data have been combined to obtain a long run effects. Annual data on carbon emissions and population have been collected from the World Bank (2018). Electricity consumption data are obtained from the Hungarian Energy and Public Utility Regulatory Authority (MEKH). Urbanization data come from Hungarian Statistical Office (KSH). Similarly, to Galli (1998) and Medlock and Soligo (2001) and Agovino et al (2018), using data for economic growth (real GDP) is sourced from Penn World Table by The Groningen Growth and Development Centre (GGDC). All series have been calculated into per capita. The general form based on the existing research studies, the empirical equation is the following:

$$CO2_t = f(\mathrm{E}C_t, GDP_t, URB_t)$$

where $CO2_t$ is the carbon emission per capita, EC_t is the electricity consumption per capita, GDP_t is the real GDP per capita, and URB_t shows the spread of urbanization. The double linear specification provides better results compared to simple specification (Solarin and Shahbaz, 2013). Numerous studies tested the nexus in logarithmic form in this context, for example Wang et al (2014), Liddle-Lung (2014) and Shahbaz et al (2012). Present study uses all of the variables are taken in logarithmic form to reduce the statistical failures of the raw data (such as skewed-to-the-right distributions), following Yang and Zhao (2014), Shahbaz et al., (2019) and others. The specification of the empirical equation as the following:

$$\ln CO2_t = \beta_0 + \beta \ln EC_t + \beta \ln GDP_t + \beta \ln URB_t + \varepsilon_t$$

where $\ln CO2_t$ is the natural log of carbon emission per capita (metric kilotons), $\ln EC_t$ is the natural log of electricity consumption per capita (kt of oil equivalent), $\ln GDP_t$ is the natural log of real income per capita (in constant 2011 US million dollar), $\ln URB_t$ is the urbanization rate (expressed in the number of the cities) and ε_t is the error term assumed to be normally distributed in time period t. The model can be interpreted as elasticities due to the series being in logarithmic form.

In this study, the Autoregressive Distributed Lag (ARDL) approach to cointegration was employed to test the existence of long-run relationship between carbon emissions, electricity consumption, economic growth and urbanization in Hungary using annual time series data for the period of 1974 and 2014. The ARDL method was developed by Pesaran et al. (2001). The ARDL bounds testing has several econometrics advantages over other cointegration tests (Pesaran et al., 2001). Firstly, the bounds test approach is applicable when variables have mixed stationarity properties (Pesaran et al., 2001). Although the bounds test approach does not require the same integrated order, however, it is necessary to check that none of the variables surpassed the order of integration I(2). In the presence of I(2) variables, the relationship by indicating F-statistics would be spurious (Pesaran et al, 2001). Secondly, the ARDL cointegration method is suitable for small sample size data and also provides better estimates for small sample data (Haug, 2002;) such as in this study. Differently from the ARDL method, employing the Johansen cointegration is recommended only to use for large data sets. Thirdly, the ARDL technique is free from residual correlation therefore there is no endogeneity problem between variables. Fourthly, causal relationship is simultaneously analyzed both in the short-run and in the long run.

For the bounds test approach, we composed the Vector Error Correction model (VECM). The VECM has short run dynamics with the long run equilibrium without losing any long run information (Shahbaz et al., 2014).

Having found long-run coefficient, the cointegrating vector of the ARDL model is reparametrized into error correction mechanism (ECM). The reparametrized result gives short-run dynamics (i.e. traditional ARDL) and long-run relationship of the variables of a single model. Distributed lag model simply means the inclusion of unrestricted lag of the regressors in a regression function (Pesaran et al., 2001; Nkoro –Uko, 2016). One advantages of the ARDL approach that short-run and long-run parameters can be estimated simultaneously and error correction model can integrate short-run adjustment and long-run equilibrium without losing long-run information (Jalil and Mahmud, 2009).

In the case of cointegration vector founding between series, Granger causality is most likely to exist. However, the reverse is not true (Giles, 2011; Rahman-Kashem, 2017). The most economic time series do not have the same stationarity properties. Series might have different integrated orders (I(0), I(1) or I(0)/I(1)) and mutually cointegrated or non-cointegrated. Therefore, conventional Granger causality test based on ECM does not perform without bias and spurious results. However, calculating only correlation does not confirm causality relationship between series. Toda and Yamamoto (1995) developed a test to check Granger causality regardless the stationarity level of the variables. The Toda-Yamamoto approach estimates causality between variables at levels under an augmented Vector Autoregression (VAR) framework.

3 EMPIRICAL RESULTS AND ANALYSIS

The prerequisite of the ARDL bounds testing is that time series should be integrated at level (I(0)) or after taking first difference (I(1)) because none of variables can be integrated at I(2). In the presence of the I(2) variable, the relationship by indicating F-statistics would be spurious. To avoid this issue, we have applied not only traditional unit root tests such as ADF test but also the Zivot-Andrews (ZA) test with single unknown break to ascertain all the variables to meet requirements of the ARDL bounds test. Series are the mixture of I(0) and I(1) meaning that some series are stationary at level and some series are stationary at first difference. Results inform us that none of the variables is I(2) confirmed by both ADF and ZA tests. The presence of such mixed orders of integration results permitted us to use ARDL model technique to test cointegration.

The ARDL cointegration test requires correct lag length should be chosen. The Akaike Information Criteria (AIC) is more suitable for small sample sizes than the Schwarz Information Criteria (SIC), therefore, the optimal lag order is determined by AIC. The appropriate lag is selected as 3 but the VAR model suffered from serial correlation. By raising the lags to 5, the serial correlation disappeared.

The ARDL bounds test analyzing whether evidence for a long-run relationship between the variables. The decision depends on the value of the calculated F-statistic. If the value exceeds the upper bound, the hypothesis of no long-run relationship is rejected meaning that there is long run relationship between variables. It is important to notice that for a small sample, the Narayan critical values are preferred to be used.

The calculated F-statistic for the ARDL bounds test is 7.2591 for k=3 (k is the number of the independent variables) implying that there is cointegration between carbon emissions, electricity consumption, economic growth and urbanization in Hungary. The null hypothesis of no cointegration can be rejected at 1% level of significance in case of the F_{lnCO2t}, F_{lnECt}, F_{lnGDPt} and F_{lnURBt} models. The calculated F-statistics are 7.2591, 7.0414, 6.6750 and 16.005 respectively, which are above the critical values not only from Narayan (2005) but also Pesaran (2001) and the statistical program's too. Results of critical values significantly suggest that all the models should be involve cointegration vectors (Table 1).

Table 1
Results of ARDL cointegration test

ARDL estimates			**diagnostic test**		
Dependent variable	optimal lag	F-stat.	serial corr.	normality	heteroskeda.
$lnCO2_t$	2,1,5,5	7.2591***	0.4863 [0.486]	0.6454 [0.724]	0.03207 [0.858]
$lnEC_t$	3,3,5,5	7.0414***	0.6688 [0.413]	0.6688 [0.413]	0.02667 [0.870]
$lnGDP_t$	4,0,2,3	6.6750***	2.2956 [0.130]	0.94443 [0.624]	0.012992 [0.909]
$lnURB_t$	5,2,2,5	16.005***	3.5859 [0.158]	1.5053 [0.471]	0.0129 [0.909]

Significant level/ Critical value of F-statistics	**Lower bounds (I0)**	**Upper bunds (I1)**
5%	4.5289	5.7671
10%	3.7730	4.8812

Note: *** denotes the significance at 1% level. Lag lengths are decided by evaluating Akaike Information Criterion. The diagnostics tests are Breusch-Godfrey LM test for serial correlation and White test for heteroscedasticity. Lower and upper bonds are calculated by statistical program.

The empirical models passed the three major diagnostic tests. The results of diagnostic tests indicate that the error term is free from serial correlation, the error terms has normal distribution and heteroscedasticity exists when the dependent variables are $lnCO2_t$, $lnEC_t$, lnGDP and $lnURB_t$. The null hypothesis of ARCH, non-normality and heteroscedasticity problems is fail to reject leading us to the conclusion that the parameter stability of the model is ensured.

After identifying the cointegration relationship, the next step is to reveal the long-run equilibrium relationship between the variables by using the ARDL specification (2,1,5,5). The estimated coefficients of $lnECP_t$ and $lnURB_t$ are positive and significant indicating electricity consumption and urbanization raises carbon emissions. We find that a 1% raise in electricity consumption is linked with 2.507% increase in carbon emissions in the long run. If 1% increase occurs in urbanization, increases carbon emissions by 2.138% in the analyzed period. Only GDP per capita decreases carbon emissions, holding electricity consumption and urbanization constant. However, the impact is not significant.

The long run analysis (Table 2) shows that the impact of electricity consumption and urbanization on carbon emissions is positive, whereas economic growth has negative insignificance effect on carbon emissions which can be explained by two reasons. Firstly, the Hungary's economy became an open economy and started to grow after 1989 (Gros-Steinherr, 2004; Iorgulescu and Polimeni, 2009), in the middle of the sample period. Second, the new economy model mostly based on service sector (IEA, 2018) requiring less energy production than before as an industry-driven economy (KSH, 2015).

Table 2
Long-run analysis result

Dependent variable: $lnCO2_t$			
Variable	Coefficient	T-statistics	Probability
$lnEC_t$	2.507***	3.698	0.002
$lnGDP_t$	-0.076	-0.123	0.903
$lnURB_t$	2.138**	2.523	0.021
C	-19.057**	-2.306	0.033

Note: *,**,*** denote significance at 10%, 5% and 1% levels, respectively.

Similarly to our results, Richmond and Kaufmann (2006) employing OLS method in levels concluded that significant relationship does not exist between economic growth and carbon emissions series. Piaggio-Padilla (2012) and Ozturk-Acaravci (2010)b also found no evidence of a long-run relationship for Hungary between economic growth and carbon emissions. Present results are partly the same to the results of Gazi et al. (2016) who reported that energy use promotes carbon emissions. The findings of urbanization effect on carbon emissions are in a line with Poumayong and Kaneko (2010) and contrary to Sadorsky (2014). Poumayong and Kaneko (2010) analyzed the effects of urbanization on carbon emissions in different development stages and founded positive relationship for all the income groups, but it is more significant in the middle-income group country as Hungary than in the other income groups. Sadorsky (2014) refuted and empirically proven in emerging countries that urbanization has a statistically insignificant impact on carbon emissions.

Engle and Granger (1987) suggest that if cointegration exists between the variables in the long run, then, there must be either unidirectional or bidirectional Granger causality between variables. Finally, causal relationship between carbon emissions and independent variables were tested by using the Toda-Yamamoto Granger causality test in VAR framework. The result shows that carbon emissions were caused by all other variables in Hungary but we do not find any significant evidence that carbon emissions Granger cause economic growth, electricity consumption or urbanization.

The null hypothesis of no causality should be rejected when carbon emissions are the dependent variable at 1% level of significance. There is evidence of unidirectional causality running from electricity consumption, economic growth and urbanization to carbon emissions. All the selected series Granger cause carbon emissions in the long run but the inverse does not true since the causality is not bi-directional. The results of Ajmi et al. (2015) are partially confirmed by the present study meaning that economic growth and electricity consumption determine the carbon emissions. Similarly to studies of Stolyarova (2010) and Ozturk-Acaravci (2010)b, causal effect of economic growth and electricity consumption on carbon emissions is corroborated by present study, respectively.

Feedback hypothesis was partially proved between economic growth and energy consumption similarly to Ozturk-Acaravci (2010) for Hungary. Unidirectional Granger causality exists from economic growth to electricity consumption implying that the neutrality hypothesis does not hold for these variables unlike Piaggio-Padilla (2012), Ozturk-Acaravci (2010)b and Menegaki (2011). Failed to detect a causal relationship for urbanization with any macroeconomic series. However, urbanization Granger cause carbon emissions (Figure 1.). The Granger causality of urbanization has not been tested on Hungarian data so far therefore obtained results about urbanization cannot be compared with the results of previous literature.

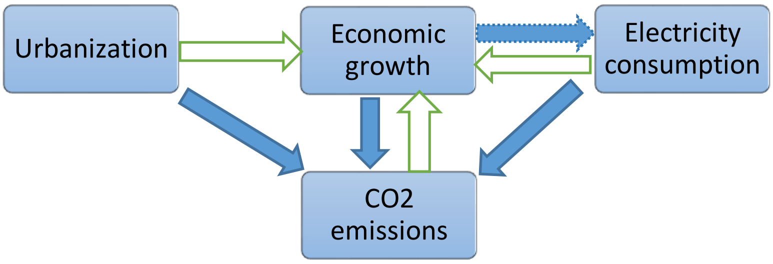
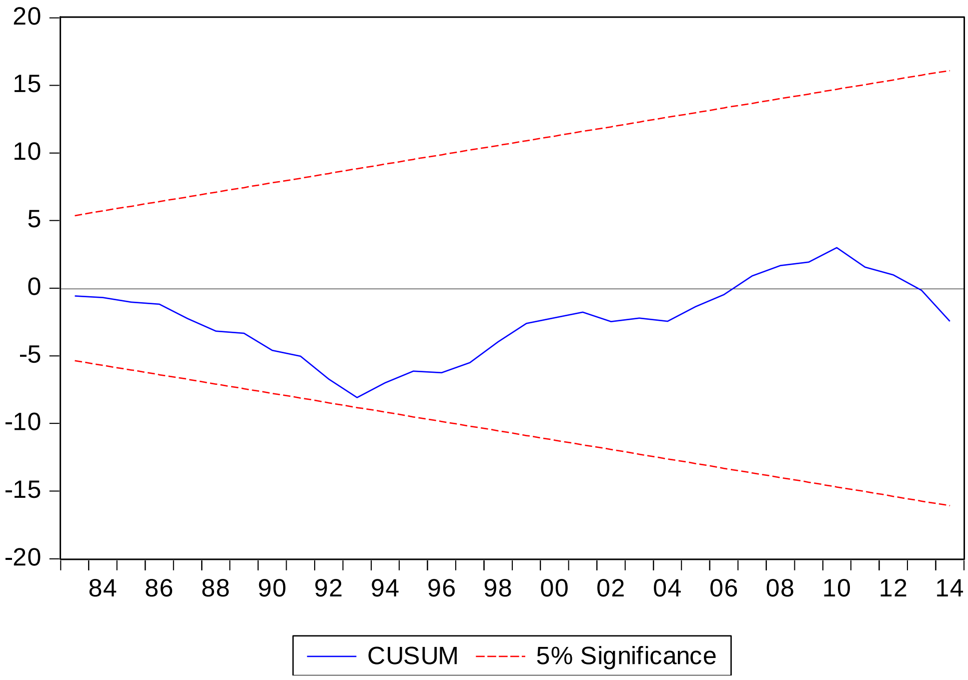


Figure 1
Causal Channels
Note: The line means 1% and the dotted line and the frame mean 10% level of significance, respectively.

The results of diagnostic and stability tests indicate that the ARDL model is well fitted proved by the value of R^2 and the value of adjusted R^2 (0.841 and 0.691 respectively). The high value of R^2 and adjusted R^2 means that 70-80% of variations in the dependent variable explained by the model. The value of the Durbin-Watson test statistics is 1.85 which implies that spurious regression does not exist in the model. Several diagnostic tests were passed on the estimated ARDL models confirming that do not have problems with phenomena of either autocorrelation or heteroscedasticity and the model does not suffer from non-normality.

The graphical representations of CUSUM and CUSUMSQ statistics are presented in Figure 2. Plots verified the stability of the ARDL model because residuals of both diagrams remain within the critical bounds at 5% level of significance.



4 CONCLUSIONS

Our study has some contributions to the literature focusing on the relationship of carbon emissions function by incorporating economic growth, electricity consumption and urbanization in an Eastern-European emerging country with rapid economic growth and high air pollution, in Hungary. The number of cities has tripled in recent decades in Hungary and 70% of the population now lives in cities, so unlike to previous studies, we taken into account the environmental effect of urbanization on Hungary's carbon emissions in order to measure the rapid expansion of cities on environmental degradation.

The study investigates long run and causal relationship between carbon emissions, electricity consumption economic growth and urbanization in Hungary over the period of 1974-2014. The ARDL bounds testing method revealed cointegration vectors and the long run results confirmed the dynamics relationship between the variables in the presence of structural breaks. The findings show that electricity consumption and urbanization have positive and significant effect on carbon emissions in the long run while the impact of economic growth on carbon emission is negative and insignificant. From the result of error correction term, the short-run deviations in carbon emissions are corrected in every year toward the long equilibrium meaning that carbon emissions return to its original equilibrium state in less than three years in Hungary.

The basis of policy recommendations is to found causality relationship between carbon emissions and electricity consumption, economic growth and urbanization at the same time. These outcomes have some interesting policy implications for Hungary. The long-term estimates show that electricity consumption is responsible for the raising of carbon emissions despite. This indicates that energy efficiency programs and improvements have been to develop for reaching environmental and social benefits also for economic actors and society. Moreover, the feedback hypothesis is valid for energy-economic growth nexus electricity consumption is a good indicator of economic development therefore not directly recommending to reduce electricity consumption because then economic growth may decline.

Considering the results reported above, the study implicates that in order to reduce carbon emissions in Hungary, measures need to be taken in all the field of energy and socio-economic area. Regarding urbanization, the long-term and the causality results imply that urbanization cause and increase carbon emissions pressure on the environment. Based on this evidence, supporting rural life is proposed from an environmental point of view. Increasing rural employment opportunities and improving housing conditions can make the rural lifestyle more attractive to young couples designating a good future direction. The 2019 government decree proposing support for the purchase of housing in villages (namely the village family housing benefit 'csok') may also have environmental benefits, providing a non-refundable grant for purchasing a family home for young families with children willing to a settle with maximum 5,000 inhabitants in the countryside (Kormany.hu, 2020).

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