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The Relationship between Urbanization, Energy Consumption and Carbon Dioxide Emissions: Panel Ardl Analysis for Newly Industrialized Countries

Şehirleşme, Enerji Tüketimi ve Karbondioksit Emisyonu Arasındaki İlişki: Yeni Endüstrileşen Ülkeler İçin Panel Ardl Analizi

Mehmet Akyol

Department of Economics, Gümüşhane University Faculty of Economics and Administrative Sciences, Gümüşhane, Turkey

ABSTRACT

An increase in the world population, technological advancement, and economic concerns bring along an increase in urbanization and energy consumption. Increasing urbanization speed and energy consumption cause environmental problems. The main hypothesis of this study is based on the idea that urbanization rate and energy consumption increase carbon dioxide emissions in developing countries. To test this hypothesis, the study analyzed the relationship between urbanization, energy consumption, and carbon dioxide emission specific to newly industrialized countries. Panel ARDL method was utilized in this study that scrutinized the years between 1990 and 2018. According to the long-term results of the analysis, urbanization negatively affects carbon dioxide emission in the country group aforementioned; energy consumption and economic growth that is control variable have a positive effect on carbon-dioxide emission. Regarding short-term results, only the energy consumption positively affects carbon dioxide emission while other variables are statistically insignificant. The results of the analysis reveal the necessity of policies towards smart city applications in reducing carbon dioxide emissions in newly industrialized countries. In addition, turning to renewable sources in energy consumption plays a key role in reducing carbon dioxide emissions.

Keywords: Energy consumption; carbon dioxide emissions; urbanization.

ÖZ

Dünya nüfusundaki artış, teknolojik ilerlemeler ve ekonomik kaygılar şehirleşme hızını ve enerji tüketimini arttırmaktadır. Artan şehirleşme hızı ve enerji tüketimi ise çevresel sorunları beraberinde getirmektedir. Bu çalışmanın temel hipotezi gelişmekte olan ülkelerde şehirleşme hızının ve enerji tüketiminin karbondioksit emisyonunu arttırdığı düşüncesi üzerine kurgulanmaktadır. Bu hipotezin sınanması adına çalışmada şehirleşme, enerji tüketimi ve karbondioksit emisyonu arasındaki ilişki yeni endüstrileşen ülkeler özelinde analiz edilmiştir. 1990-2018 yılları arası dönemin analiz edildiği çalışmada panel ARDL yönteminden yararlanılmıştır. Analizden elde edilen uzun dönem sonuçlar bahsi geçen ülke grubunda şehirleşmenin karbondioksit emisyonunu negatif yönde etkilediğini, enerji tüketimi ve kontrol değişkeni olan ekonomik büyümenin ise karbondioksit emisyonu üzerinde pozitif etkisi olduğunu ifade etmektedir. Kısa dönem sonuçlar ise sadece enerji tüketimin karbondioksit emisyonunu pozitif yönde etkilediğini, diğer değişkenlerin ise istatistiksel olarak anlamlı olmadığını belirtmektedir. Analiz sonuçları yeni endüstrileşen ülkelerde karbondioksit salınımının azaltılması açısından akıllı şehir uygulamalarına dönük politikaların gerekliliğini ortaya koymaktadır. Ayrıca enerji tüketiminde yenilenebilir kaynaklara yönelinmesi karbondioksit emisyonunun azaltılmasında kilit rol üstlenmektedir.

Anahtar sözcükler: Enerji tüketimi; karbondioksit emisyonu; şehirleşme.

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Correspondence: Mehmet Akyol
e-mail: mehmet_akyol81@hotmail.com

TMMOB
Şehir Plancıları Odası

Introduction

Urbanization has displayed a remarkable increase in the last fifty years. For the World Bank data, approximately 33% of the world population lived in cities in 1960 while this ratio is at 55% now (Worldbank, Ali et al., 2019). According to the report published by the United Nations Department of Economic and Social Affairs in 2018, approximately 68% of the total population will be living in cities by 2050. Again, it is highlighted in the same report that the global city population will increase by 2.5 billion between 2018–2050 and approximately 90% of this increase will be concentrated in Africa and Asia. Economic and social developments lie behind such a rapid increase in the urbanization ratio. On the other hand, advancements in technology have changed both production processes and social life and thus, this change affects the urbanization speed. Moreover, the factors such as the concentration of mass production in cities, relatively high wage levels, easier access to services such as public works, education, and health accelerate urbanization. Undoubtedly that the growing world population plays an important role in this matter. Advances in nutrition and health with developing technology in the last century have brought along an increase in life expectancy and a decrease in child mortality; this situation has increased the population of the city in parallel with the increase in the world population (Mazı and Tan, 2009; UN, 2021: 21). Urbanization which is one of the important components of economic development is also an indicator of social development levels of societies. Urbanization positively affects personal and social productivity. Urbanization paves the way for new opportunities and more earnings contributing to economic growth; it also enables scientific, artistic, and cultural activities to be designed and developed (Ali et al. 2017: 1967). Migration from rural to urban with urbanization causes changes in lifestyles and income levels; there are increases in consumption patterns and consequently consumption expenditures (Bekhet and Othman, 2017: 374). Rapid and unplanned urbanization brings along some environmental problems besides the opportunities that urbanization offers to individual and community life. Especially the concentration of industrial industries in cities or regions close to cities and also the utilization of fossil energy sources in production cause environmental problems (Ali et al., 2019: 1). These environmental negativities cause more permanent problems such as climate change in the long run. United Nation Secretariat Climate Action Plan (UNSCAP) has prepared an action plan covering the years 2020–2030 to prevent climate change. Within the plan, it is aimed to reduce carbon emissions by 25% until 2025 and by 45% until 2030. On the other hand, in parallel with the decrease in electricity consumption based on fossil resources by 20% until 2025 and 35% until 2030, it is aimed to provide 40% of the electricity consumed by 2025 and 80% until 2030 from renewable energy resources. In addition, it is planned to reduce emissions per capita due to commercial air transport by 10% until 2025 and by 15% until 2030 (UNSCAP, 2019). (UNSCAP, 2019). These negativities can be listed as water, soil, noise pollution, industrial solid waste, and carbon emissions (Al-mulali et al., 2012: 156). Carbon emission, among them, constitutes approximately 60% of global greenhouse gas emissions and it also is one of the leading factors causing global warming. Energy sources such as oil, coal, and gas, which are called fossil fuels, are the main source of carbon emissions (Abbasi et al., 2020:18029; Hossain, 2011:6991; Anwar et al, 2020; Azam and Khan, 2016: 823). Moreover, despite the population density, insufficient resources reveal the negative aspects of urbanization such as poverty, unemployment, insufficient infrastructure, and an increase in criminal tendency (Ali et al., 2019: 1).

Zhu and Peng (2012) classified the carbon emission increasing effect of urbanization under three titles. The first of them is that the energy consumption in the production process is concentrated in cities and the energy demand increases in parallel with the increase in consumption needs of the residents, and this situation causes carbon emission. The second one is the increasing need for housing with the growth in the urban population and also the increase in the demand for building materials, which is one of the important causes of carbon emissions. Finally, the third of them is the newly opened zoning areas in parallel with the increasing city population; the decrease of cultivated and planted areas, and the increase of carbon emission by bringing deforestation with it. It is foreseen that environmental pollution will create significant negative effects on the distribution rhythm of natural resources and suppress many economic activities, especially the agricultural sector (Azam and Khan, 2016: 823).

Environmental degradation in the early stages of economic development was low while environmental pollution has increased with the acceleration of industrialization in the following periods. Industrial production based on high pollution, especially in developing countries, is replaced by a technology-intensive production structure in developed countries. So, it can be expressed that environmental pollution has reached much more damaging dimensions in underdeveloped and developing countries where traditional production is predominant (Azam and Khan, 2016: 823). In this regard, population growth caused by the change in demographic structure accelerates rural to urban migration due to economic concerns; on the other hand, economic growth efforts combined with the speed of urbanization increase the energy need and bring environmental problems together (Zarzoso and Maruotti, 2011: 1344, Shahbaz et al. 2016: 84).

Another factor that harms nature is energy consumption. In addition to urbanization, the energy that is one of the important components of production is the locomotive of economic development and growth process. However, uncontrolled energy consumption causes environmental degradation (Azam and Khan, 2016:823; Omri, 2013). Power service products are one of the crucial cost elements of the production process in the modern world. The limitation of access to energy or failure to meet energy demand, which is both an important component of the production process and an important cost element, causes not only economic but also social, political, and military conflicts and disputes. Energy, at the same time, plays a significant role in shaping the supply and demand side of the economic system. It is a part of production function when we look from the supply side; it also is good to buy for the consumer trying to maximize her utility when it is looked from the demand side (Yıldırım, 2017: 247). The war between Ukraine and Russia today constitutes a current example of developments that negatively affect the supply and demand aspects of the economic system. The war between the two countries caused a crisis in the export markets of Russia, which is one of the most important fossil fuel and natural gas suppliers in the world. Again, the increase in energy prices due to the war has paved the way for social and financial pressures on many developing countries (UN, 2022).

Economic growth efforts of developing countries aiming at convergence with developed countries necessitate the use of more inputs to achieve more output. In conclusion, the necessity to meet the increasing energy demand comes into prominence (Aye and Edoja, 2017: 3). Increasing traditional resource use in meeting energy needs is one of the main triggers of industrial pollution. It is important to reduce energy consumption, which has significant effects on carbon emissions. However, at this point, the development dynamics of the economy should be analyzed well. It is necessary to be careful to protect the growth process while taking measures to limit energy use if the economy in question consists of export-based sectors and the share of exports in economic growth is high (Bosupeng, 2016: 21). It is important to turn to environmentally friendly renewable energy sources in such cases. For Kasperowicz (2020), the old-style energy sources with intense carbon emissions in energy consumption will be replaced by the new generation, energy-saving, and low-carbon technologies as a result of technologies developing with economic growth and development. Protocols such as the Kyoto Protocol and the Montreal Protocol have been signed and accepted by many countries around the world because of environmental problems threats (UNFCCC, 1997; UNEP, 1998). For example, the Kyoto Protocol is a protocol established in 1997 to prevent or reduce global warming caused by greenhouse gases. Countries that signed the Kyoto protocol accept the reduction of all greenhouse gases, including carbon emissions. The Montreal Protocol, similar to the Kyoto Protocol, focused on the environment and was signed in 1987 to draw attention to the depletion of the ozone layer. The goal of the protocol is to reduce environmental pollution and it also recommends the limitation of energy consumption for this purpose (Shaari et al., 2020: 2).

Carbon emissions arising from energy consumption in newly industrialized countries have increased rapidly after the 1990s compared to developed countries. There are similar approaches in other developing countries as well. Economic growth-oriented industrialization policies keep the pressures on global energy use and demand alive; and ultimately, greenhouse gas emissions based on carbon emissions continue to increase with each passing day. Environmental pollution, which is known to cause climate change and global warming, has reached alarming levels; it has brought up the investigation of the relationship between this problem and economic growth especially in developing countries. The relation between industrialization, production, and growth with the environment has become a topic that many researchers have been working on (Hossain, 2011: 699; Yazdi and Dariani, 2019: 510). Sustainability efforts, undoubtedly, have affected this situation. As a matter of fact, early growth theories emphasize labor and capital as the determinants of production but ignore the effect of energy use on the production process (Aye and Edoja, 2017: 3). The qualitative and quantitative development of production and the need for more energy use due to developing technology are the determining factors in putting environmental sensitivities into the foreground.

Based on the above discussion, this study attempts to answer some questions. First of all, is there a relationship between urbanization, energy consumption and co2, both in the NIC countries and in the country group? Second how does urbanization and energy consumption affect carbon dioxide emissions in NIC countries? Third Do the PMG and MG estimator provide interesting results in the NIC countries and in the country group? This study departs from the existing literature in one way. There are similar studies in the literature for many developing countries and country groups. however, there is no similar study for the NIC country group.

In the rest of the article, theoretical evaluations were given first; then, the previous studies on the subject and the literature on the results obtained as a result of these studies were reviewed. The methodology and data set used in the empirical study were defined in the next chapter. The results obtained from the empirical analysis were evaluated through a general discussion and policy recommendations were included in the final part.

Literature Review

Urbanization has been increasing rapidly in recent years, especially in developing countries. Population growth, social and economic concerns lie behind the increase in the rate of urbanization. On the other hand, concerns of economic growth in developing countries increased the energy demand, and thus, energy consumption accelerated. Both the intense energy consumption and increase in urbanization have brought along environmental problems. One of these adverse effects is carbon emission, which constitutes a significant part of greenhouse gas emissions. Literature has many studies regarding the relationship between urbanization, energy consumption, and carbon emission. The general part of related studies analyzed the issue through different variables such as trade openness, economic growth, foreign direct investment, productivity, and export. Again, some of the studies in the literature are country-based, while others are country-group-based. For the sake of example, the following studies concluded that urbanization creates negative impacts on carbon-dioxide emission: Bekhet and Othman (2017) in Malaysia; Ali et al. (2019) and Javid and Sharif (2013) in Pakistan; Azam and Khan (2016) in Bangladesh; and India, Zhang et al. (2015), in China; Zhang et al. (2015) in Beijing, China. Yazdi and Shakouri (2014) observed a causality relation from both energy consumption and urbanization to the carbon-dioxide emission for Iran's economy. Al-mulali et al. (2012), analyzed the presence of a long-termed cointegration relationship between urbanization, energy consumption, and carbon dioxide emission for 7 different regions. For the results, there is a long-termed relationship among variables in 84% of countries scrutinized while there is no relation in low-income country groups. Al-mulali, (2013) conducted a similar study for the MENA country group and his results jibe with the previous study. Abbasi et al. (2020) highlighted a long-termed relationship between urbanization, energy consumption, and carbon dioxide emission in 8 Asian countries; they also mentioned about the remarkable effect of urbanization and energy consumption on the carbon-dioxide emission. Concerning these results, urban development and high energy consumption urban development and high energy consumption constitute an impediment to improving environmental quality in the long term. Hossain (2012) evaluated the relationship between urbanization, carbon dioxide emission, economic growth, and foreign trade within the framework of short and long-term analyzes for Japan. According to the results, there is causality from energy consumption to commercial openness and carbon dioxide emission; trade openness to energy consumption, carbon dioxide emission to economic growth; economic growth to commercial openness in the short term. Again, it was concluded in the same survey that high energy consumption increases environmental problems by bringing along carbon dioxide emissions in time. Urbanization and energy consumption territorially affects carbon dioxide emission in different manners. For example, Zhang and Lin (2012) revealed that urbanization in the central regions of China is much more effective on carbon dioxide emissions compared to the eastern regions. This situation arises from the differences in regional development and urbanization levels. Wang et al. (2015) argued that energy consumption and urbanization cause carbon emissions in OECD countries.

On the other hand, implementing environmental policies in developed countries reduces the negative impacts of urbanization on the environment. In this regard, Ali et al. (2017) and Torrie (2015) conducted studies respectively in Singapore and Canada and they also mentioned that urbanization does not increase the carbon-dioxide emission. Sometimes, the development levels of countries change the course of the relationship between urbanization rates and carbon dioxide emissions. Urbanization in low-income countries has a negative effect on carbon dioxide emissions while it results in the opposite in high and middle-income countries. Behera and Dash (2017) revealed this situation in their study towards the south and southeast Asian countries; for the results, urbanization creates a negative effect on carbon dioxide emissions in countries with low-income levels while this effect is positive in high and middle-income countries. Another study was conducted by Sharma (2011); according to the results, urbanization has negative effects on carbon dioxide emissions in 69 countries with different income groups (high, medium, and low). Ali et al. (2016) performed a study with the same issue and also found the same result for 69 countries with different income groups (high, medium, and low). Again, Saidi and Mbarek (2017), too, concluded that urbanization creates negative effects on carbon dioxide emissions in 19 developing countries. The results obtained in studies analyzing the effect of fossil fuel-based energy consumption on carbon dioxide emission are similar to each other. Following studies analyzed the same issue and emphasized that energy consumption increases carbon dioxide emissions: Behera and Dash (2017) in the south and southeast Asian countries; Öztürk and Acaravcı (2010) in Turkey; Alshehry and Belloumi (2015) in Saudi Arabia; Shahbaz et al. (2013) in Indonesia. According to Doğan and Turkekul (2015), energy consumption and urbanization cause environmental degradation and there is a mutual relationship between energy consumption, urbanization, and carbon dioxide emissions. On the other hand, the study in question does not support the environmental Kuznets curve hypothesis for the USA. For Farhani et al. (2013), energy consumption increases carbon dioxide emissions in MENA countries, and this increase accelerates with urbanization. Acheampong (2018) researched MENA countries and concluded that energy consumption is the cause of carbon dioxide emissions. Wang et al. (2016) argued in their study for ASEAN countries that the increase in urban population increases carbon dioxide emissions, while urbanization and energy consumption are the causes of carbon dioxide emissions.

Data Set and Methodology

This study analyzed the relationship between urbanization, energy consumption, and carbon dioxide emission for 8 newly industrialized countries (NIC), including Brazil, China, Indonesia, India, Mexico, Thailand, Turkey, and South Africa. The group of newly industrialized countries is a socioeconomic classification applied worldwide by political scientists and economists. The economic growth rates of the countries in this group are much higher than other developing countries. NIC's economic development is between developing and developed countries classifications. As such, NIC countries constitute a subgroup of developing countries. On the other hand, NIC countries are places where the social consequences of urbanization, which has arisen due to industrialization, are also rearranged. The time constraint of the analysis was the 1990–2018 period. The lack of data before 1990 and after 2018 played an important role in determining the time constraint. Data regarding GDP and urbanization level (URBPOP) that is one of the variables of analysis can be accessed by the World Bank website. Data for energy consumption (ENER) and carbon-dioxide emission (CO2) were obtained from International Energy Agency (IEA). URBPOP means urbanization level that gives the urban population ratio in total population. Carbon dioxide emission was included in the analysis by calculating CO2 in million tons and energy consumption in tons of oil equivalent. Energy resources are mentioned in a single unit and correspond to 10 million kCal of energy with the calculation method used for energy consumption. The natural logarithms of the variables of GDP, carbon dioxide emission, and energy consumption were computed. This study utilized the Panel ARDL analysis method. The panel ARDL allows simultaneous long- and short-term analysis (Şengönül and Tekgün, 2021: 86). At the same time, the panel ardl tests the existence of a cointegration relationship when analyzing series that are stationary at different levels (Özdamar, 2015). Also, the variables in the panel ardl model allow short-term heterogeneity in connection with long-term homogeneity (Güler and Özyurt, 2011: 15). Studies on the environmental effects of the population started in the 1970s; Ehrlich and Holdren's (1971) study constitutes the preliminary study in this field. Moreover, the study belongs to Dietz and Roza (1997) has an important role to constitute the theoretical framework to reveal the relationship between urbanization, energy consumption, and carbon dioxide emission. In the related study, the effect of human factors on the environment is gathered together in the model below in the context of the variables of population, income, and technology.

$$I = P \times A \times T \tag{1}$$

I is the environmental effect; P is population; A is income; T is technology in the method that is formulated as IPAT. I that is defined as the environmental effect in this formulation represents carbon-dioxide emission. T is the environmental impact of economic activities per unit resulting from the technology used in the production of goods and services, and it also is a factor that shows how social, institutional, and cultural organizations are mobilized and how they create environmental problems by affecting human behavior (Dietz and Rosa, 1997: 175). It is emphasized in modeling that none of the variables alone affect the environment. IPAT heads for equality analysis with reference to mathematical modeling and it also is not suitable for hypothesis analysis (Yazdi and Dariani, 2019: 517). In this regard, the model that was established for the hypothesis test is defined with STIRPAT and formulated as follows:

$$I_i = \alpha P_i^b A_i^c T_i^d e_i \tag{2}$$

α is the constant term in the model above; b, c and d are exponential values and they also show environmental effect elasticities about P,A, and T (Yazdi and Dariani, 2019: 518). Error term is represented by e; observable units are expressed by i. IPAT proportionality assumption is α=b=c=d=e=1 (Abbasi et al., 2020: 18032). Econometric framework can be modelled as follows with reference to the mathematical stochastic equation above.

$$\ln I_{it} = \beta_0 + \beta_1 \ln P_{it} + \beta_2 \ln A_{it} + \beta_3 \ln T_{it} + e_{it} \tag{3}$$

The rearranged form of the above model according to the variables used in the study is as follows:

$$\ln CO2_{it} = \beta_1 URBPOP_{it} + \beta_2 \ln GDP_{it} + \beta_3 \ln ENER_{it} + e_{it} \tag{4}$$

Sub-subscript i in the model represents each country unit; t is the time. The main hypothesis of this study is that urbanization and energy consumption will have negative effects on carbon dioxide emissions in the group of newly industrialized countries. The results obtained from the literature studies were helpful in establishing the hypothesis in this direction. A significant number of literature studies conclude that urbanization and energy consumption have negative effects on carbon dioxide emissions, both individually and in the context of country groups. In this context, the goal of this study was to analyze the effect of urbanization, energy consumption, and income on the carbon-dioxide emission. The effect of technology was endeavored to be displayed through different variables in previous studies. Ali et al. (2017) used trade openness to measure the effect of technology on the environment. Shi (2003) utilized trade and service share in GDP to measure the effect of technology on the environment. Dai and Liu (2011) used manufacturing industry production for the same purpose. Finally, urbanization was used by Pourmanyvong et al. (2012) to measure the effect of technology on the environment.

The stationarity of series should be tested by unit root test before Panel ARDL analysis. Series should not be stationary at their first difference in the related analysis. In other words, it is okay if a part of the series is stationary at the level and another part is stationary at the first difference. The series that is stationary at the level and first difference can be used in panel ARDL analysis while this analysis cannot be performed if there are variables that become stationary at their second difference in the model. The stationary of series is an important factor for econometric analyses. Analyses that are applied with stationary series give reliable results. Therefore, the stationarity of the series needs to be tested via unit root tests. It is necessary to determine whether there is a correlation between the series to determine the stationarity of the series. In this sense, cross section dependence test is applied to series at first. Much as there are several correlations between cross section dependence tests in literature, Breusch Pagan LM test, which is more convenient to use in cases where time dimension (T) is bigger than unit size (N) (T>N), was used.

i ≠ j equation is valid for $H_0 : cov(u_{it}, u_{jt}) = p_{ij} = 0$ and all t values. The aforementioned hypothesis constitutes the basic hypothesis of the Breusch Pagan correlation test between units. The writing of the Breusch Pagan LM test statistics based on the basic hypothesis is as follows.

$$LM=T\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{p}_{ij}^{2} \quad (5)$$

$\hat{p}_{ij}^{2}$ in LM equality shows the sample estimator of binary correlation of i and j residuals; it also is computed by the formula below.

$$\hat{p}_{ij}=\hat{p}_{ji}=\frac{\sum_{t=1}^{T}e_{it}e_{jt}}{(\sum_{t=1}^{T}e_{it}^{2})^{1/2}\,(\sum_{t=1}^{T}e_{jt}^{2})^{1/2}} \quad (6)$$

e_{it} expression in equation is formulized as $e_{it}= y_{it}-\hat{\alpha}_i-\hat{\beta}'_i x_{it}$. e_{it} that represents EKK estimation of u_{it} error term is also represents residue estimations (Pesaran, 2004). Breusch Pagan (LM) inter-unit correlation test remains valid when T→∞ and where N is constant. It shows an asymptotic x^2 distribution at N (N-1) / 2 degrees of freedom (Baltagi et al., 2012: 165). Table 1 shows cross section correlation test results.

Table 1 shows the cross section dependence (LM) test results. As is seen in the Table, the probability value is lower than the critical value of 0.05. Thus, H0 hypothesis which assumes that there is no cross section dependence between units should be denied. After the determination of the presence of correlation between units, stationarity of series was determined by Panicca test that is one of the second generation unit root tests. Panicca test plays a role to reduce the effects of correlation between units and is frequently used in literature at the same time. This related test was developed by Reese and Westerlund (2016). Panicca test consists of the combination of single and multi-factor test based on getting difference from cross-sectional means (CA) and PC-based (PANIC) test (Bai and Ng (2004, 2010)) that tests the stability of residues and factors separately (Yerdelen Tatoğlu, 2017: 100). Below equation comes into question when Yi,t with common factor model is expressed as follows:

$$Y_{i,t} = \alpha'_i D_{t,p}+\lambda'_i F_t+e_{i,t} \quad (7)$$

$e_{i,t}$ in equation is the error term; F_t is the common factor vector with (rx1) dimension; λ_{i} is (rx1)-dimensional factor loads coefficient; $D_{t,p}=(1,\ldots..t^p)$ is (p+1)x1-dimensional deterministic components vector. It is with constant when there is (p=0);

Table 1. Cross section dependence test

Test	Statistics	Probability value
LM (Breusch Pagan)	67.57	0.000*

*: Means significance at 1% level. LM: Lagrange multiplier.

it is with constant and trend when (p=1) is valid. Moreover, (mx1) additional variable vector that is called $x_{i,t}$ is allowed.

$$x_{i,t}=\beta'_i D_{t,p}+\Lambda'_i F_t+u_{i,t} \quad (8)$$

$u_{i,t}$ in equation is mx1 vector of the original error term. The existence of the additional variable m is allowed in order to share the existence of common factors. Below equation can be written when the variables in equation (7) and (8) are expressed as follows:

$$Z_{i,t}= B'_i D_{t,p}+C'_i F_t+V_{i,t} \quad (9)$$

There is the equation of $B_i=(\alpha_i,\ \beta_i),C_i=(\lambda_i,\Lambda_i),\ V_{i,t}=(e_{i,t},u'_{i,t})'$ in (9) equation.

Factor loads coefficients vector is $C_i=r(m+1)$. The main idea behind the PANIC process is to calculate the first difference. Uncertainties regarding cointegration level of $Z_{i,t}$ disappear as the result of stagnation of the variables whose difference is computed.

The form of 9 numbered equation after its difference was computed as follows while there is $z_{i,t}=\Delta_{i,t}$, $d_{t,p}=\Delta D_{t,p}$, $f_t=\Delta F_t$ and $v_{i,t}=\Delta V_{i,t}$.

$$z_{i,t}= b'_i D_{t,p}+C'_i f_t+v_{i,t} \quad (10)$$

Matrix form of the equation is written below:

$$z_i=D_{p-1}b_i+f\,C_i+v_i \quad (11)$$

There is (T-1) x r if there is $zi=(z_{i,2},\ldots,z_{i,T})'$ and $v_i=(v_{i,2},\ldots,v_{i,T})'$ $(T-1)\times(m+1)$, $f=(f_2,\ldots\ldots..,f_T)'$. Finally, there also is $D_{p-1}=D_{2,p-1},\ldots$ $..,D_{T,p-1})'$ $(T-1)\times(p-1)$. 11 numbered equation can be written as an alternative as follows:

$$z_i^p=f^p\,C_i+v_i^p$$

If the CA estimator of $v_i^{p\prime}$ is CA estimator of f^p is $\hat{f}^p=M_p\bar{z}$ $=\bar{z}^p=N^{-1}\ \sum_{i=1}^{N}M_p z_i$,; $\hat{v}_i^p$ is accepted with reference to $\hat{C}_i=\left[(\hat{f}_p)'\hat{f}^p\right]^{-1}(\hat{f}_p)'z_i^p$.

$$\hat{v}_i^p=z_i^p-\hat{f}^p\hat{C}_i \quad (12)$$

$\hat{f}_i^p$ $(\hat{v}_{i,t}^p)$ in equation is the first difference estimator of F_t $(V_{i,t})$ version. In this regard, the presence of the unit root is tested by ADF test in 13 numbered equation if there is r=m+1=1 (Yerdelen Tatoğlu, 2017: 102).

Table 2. PANICCA unit root test results

PANICCA test	At level	Statistic	At difference	Statistic
LCO2 PCe_Choi	0.932	–1.493	0.000*	5.646
LCO2 PCe_MW	0.961	7.551	0.000*	47.937
LENER PCe_Choi	0.974	–1.943	0.000*	4.790
LENER PCe_MW	0.996	5.009	0.000*	43.095
LGDP PCe_Choi	0.955	–1.696	0.000*	3.846
LGDP PCe_MW	0.983	6.406	0.001*	37.755
URBPOP PCe_Choi	0.590	–0.228	0.041**	1.743
URBPOP PCe_MW	0.546	14.709	0.056***	25.859

*,**,***: Respectively show statistical significance at 1%, 5% and 10%.

$$\text{ADFp}=\frac{(\hat{F}^{p}_{-1})'\,M_{p+1}M_{W}M_{p+1}\Delta\hat{F}^{p}}{(\hat{\sigma}_{\eta}\sqrt{(\hat{F}^{p}_{-1})'\,M_{p+1}\,M_{W}M_{p+1}\hat{F}^{p}_{-1}}} \quad (13)$$

Pa, Pb and PMSB test were used to test the residue stationarity while MQ^c_f and MQ^c_c statistics that are observed in Bai and Ng's (2004, 2010) studies and also defined in PANIC test with reference to CA approach are used if there is r = m+1>1. Table 2 shows PANICCA unit root test results.

According to PANICCA unit root test results, LCO2, LENER, and LGDP variables are stationary at 1% level while URBPOP variable is stationary at 5% level for PCe_Choi; 10% level for PCe_MW. It can be said based on these results that the series is stationary at their differences in general. The next step is to review the cointegration relationship among the series. The long-termed relationship among the series is researched by the cointegration test. Cointegration tests are divided into two groups as the first and second generation tests based on the presence of the correlation between units. The first generation cointegration tests are utilized in situations where there is no cross-section dependence while the second generation panel cointegration tests are used for situations with cross-section dependence. This study utilized Westerlund (2007) panel cointegration test considering the presence of cross section dependence between units.

$$\Delta Y_{it}=\delta_i' d_t+\alpha_i\,(Y_{it-1}-\beta_i' X_{it-1})+\textstyle\sum_{j=1}^{pi}\alpha_{ij}\,\Delta Y_{it-j}+\sum_{j=-qi}^{pi}\gamma_{ij}\,\Delta X_{it-j}+e_{it} \quad (14)$$

t=1…… T is the time dimension; i=1…….N is the unit dimension and dt is the deterministic components. dt=0 means the situation without deterministic term (without constant and trend); dt=1 is the situation with constant; and finally, dt = (1,t) is the situation with constant and trend. Below equation can be written when the error correction model is readjusted:

$$\Delta Y_{it}=\delta_i' d_t+\alpha_i\,Y_{it-1}+\lambda_i' X_{it-1}+\textstyle\sum_{j=1}^{pi}\alpha_{ij}\,\Delta Y_{it-j}+\sum_{j=-qi}^{pi}\gamma_{ij}\,\Delta X_{it-j}+e_{it} \quad (15)$$

Here is the equation of $\lambda_i'=-\alpha_i\beta_i'$. α_i Parameter designates the speed of return to balance relationship in case of a sudden shock. There is talked about an error correction if $\alpha_i<0$; this position means a cointegration relation between y_{it} and x_{it}. There is no correction if $\alpha_i=0$; namely, there is no cointegration relation. The null hypothesis (H_0: $\alpha_i=0$) in Westerlund cointegration relation means there is no cointegration relation for all i while the same relation depends on the assumption about the homogeneity of alternative hypothesis, α_i. The first two of cointegration tests are called ensemble average test; it tests H_0 hypothesis for at least one i value against H^i_g: $\alpha_i<0$ without a need for equation of α_i. Another two tests that are called panel test assume that α_i values equal to all i; again, it tests H_0 hypothesis for all i values against H^i_g: $\alpha_i=\alpha<0$ (Persyn and Westerlund, 2008: 233). Westerlund cointegration tests consists of two groups of statistics. These are ensemble average variance and panel variance statistics. Below equation can be written for each unit with reference to the group mean statistics of variance least squares method.

$$\Delta y_{it}=\hat{\delta}_i' d_t+\hat{\alpha}_i y_{it-1}+\hat{\lambda}_i' x_{it-1}+\textstyle\sum_{j=1}^{pi}\hat{\alpha}_{ij}\,\Delta y_{it-j}+\sum_{j=0}^{pi}\hat{\gamma}_{ij}\,\Delta x_{it-j}+\hat{e}_{it} \quad (16)$$

Lag p_i can take value according to units. $\hat{\alpha}_i$ (1) is calculated in the second phase.

$$\hat{\alpha}_i(1)=1-\textstyle\sum_{j=1}^{pi}\hat{\alpha}_{ij} \quad (17)$$

Finally, ensemble average variance statistics (Gt and Ga) are calculated.

$$G_t=\frac{1}{N}\sum_{i=1}^{N}\frac{\hat{\alpha}_i}{SE(\hat{\alpha}_i)}\quad G_a=\frac{1}{N}\sum_{i=1}^{N}\frac{T\hat{\alpha}_i}{\hat{\alpha}_i\,(1)} \quad (18)$$

$SE(\hat{\alpha}_i)$ in above equation is the standard deviation of $\hat{\alpha}_i$. Panel statistics allow both parameters and dimension of equation (8) to differ between cross units. Lag length pi is determined just as being in group average variance statistics. After determining the lag length, d_t of Δy_{it} and y_{it-1}; lagged values of Δy_{it} and also lagged and current values of Δx_{it} are established as follows.

$$\Delta\tilde{y}_{it}=\Delta y_{it}-\hat{\delta}_i' d_t-\hat{\lambda}_i' x_{it-1}-\textstyle\sum_{j=1}^{pi}\hat{\alpha}_{ij}\,\Delta y_{it-j}-\sum_{j=0}^{pi}\hat{\gamma}_{ij}\,\Delta x_{it-j} \quad (19)$$

and

$$\tilde{y}_{it-1}=y_{it-1}-\tilde{\delta}_i' d_t-\tilde{\lambda}_i' x_{it-1}-\textstyle\sum_{j=1}^{pi}\tilde{\alpha}_{ij}\,\Delta y_{it-j}-\sum_{j=0}^{pi}\tilde{\gamma}_{ij}\,\Delta x_{it-j} \quad (20)$$

The common error correction parameter (α) and its standard error is estimated in the second phase using $\Delta\tilde{y}_{it}$ and $\tilde{y}_{it}-1$).

$$\hat{\alpha}=\Big(\textstyle\sum_{i=1}^{N}\sum_{t=2}^{T}\tilde{y}^2_{it-1}\Big)^{-1}\sum_{i=1}^{N}\sum_{t=2}^{T}\frac{1}{\hat{\alpha}_{(1)}}\tilde{y}_{it-1}\Delta\tilde{y}_{it} \quad (21)$$

Below equation can be written if it is the standard error of $\hat{\alpha}$.

$$SE(\hat{\alpha})=\left((\hat{S}^2_N)^{-1}\textstyle\sum_{i=1}^{N}\sum_{t=2}^{T}\tilde{y}^2_{it-1}\right)^{-\frac{1}{2}}\hat{S}^2_N\frac{1}{N}\sum_{i=1}^{N}\hat{S}^2_i \quad (22)$$

In the final stage, P_a and P_t statistics are computed as follows

$$P_t=\frac{(\hat{\alpha})}{SE(\hat{\alpha})}\text{ ve }P_a=T\hat{\alpha} \quad (23)$$

Denying null hypothesis for both group tests means that there is no cointegration relation in the whole panel. Related statistics can be used if the panel is homogeneous (Tatoğlu, 2017: 202). Table 3 shows Westerlund panel cointegration test results.

The null hypothesis, in the panel cointegration test in Table 2, was established based on the assumption of there is no cointegration relation. The lag length was specified by Akaike Information Criterion. The table shows Gt, Ga, Pt, and Pa test statistics, Z statistics, and probability value (P value). On the other hand, robust P value probability values are at the right side of the Table. Related values are obtained by computing bootstrap critical values in situations where there is a correlation between units; accordingly, the presence of the long-termed cointegration relation is tested within the frame of these values. For the results, H0 hypothesis is denied at a 90% confidence level based on Gt statistics. According to Ga and Pa, H0 hypothesis is denied at a 1% confidence level. So, the presence of the long-termed cointegration relation among variables is accepted.

Urbanization level (URBPOP) in the analysis is stationary at level; carbon dioxide emission (LCO2), energy consumption (LENER) and gross domestic product (LGDP) variables are stationary at their first difference. In this regard, the panel ARDL method that was developed by Pesaran, Shin, and Smith (1999) is used to analyze the long-termed relation between the variables. Below equation can be written if ARDL (p,q,q,q….q) is expressed as follows:

$$y_{it}=\sum_{j=1}^{p}\lambda_{ij}y_{i,t-j}+\sum_{j=0}^{q}\delta'_{ij}x_{i,t-j}+\mu_i+\varepsilon_{it} \qquad (24)$$

x_{it} in model is explanatory variables vector for (kx1) group; μ_i is the fixed effects and coefficient of lagged dependent value; λ_{ij} is scalar and δ'_{ij} is kx1 coefficient vector. Re-parameterized form of the equation as follows:

$$\Delta y_{it}=\emptyset_i y_{i,t-1}+\beta'_i x_{it}+\sum_{j=1}^{p-1}\lambda^*_{ij}\Delta y_{i,t-j}+\sum_{j=0}^{q-1}\delta^*_{ij}\Delta x_{i,t-j}+\mu_i+\varepsilon_{it} \qquad (25)$$

i=1,2,……N and t=1,2,……T while $\emptyset_i=-(1-\sum_{j=1}^{p}\lambda_{ij}),\beta_i=\sum_{j=0}^{q}\delta_{ij}$,

$\lambda^*_{ij}=-\sum_{m=j+1}^{p}\lambda_{im},j=1,2,\ldots\ldots p-1,\delta^*_{ij}=-(\sum_{m=j+1}^{q})\delta_{im},j=1,2,\ldots\ldots q-1,$

ε_{it} is the free distributed error term in time and unit dimension; y_i is the long-term coefficient; β_{ij} and δ_{ij} are long-term coefficients and $\emptyset_i$ gives the error correction coefficient expected to be negative. If the error correction coefficient is negative, there is a long-term relationship between dependent and independent variables. Pesaran et al. (1999) moved with reference to the two estimators in the panel ARDL method. The first of them is the mean group estimator (MG) while the second one is the pooled mean estimator (PMG). MG estimator depends on the averages of estimation of each cross section coefficient. On the other hand, the MG estimator allows some parameters to change by units; this is because it probably remains incapable in small samples. The long-term estimator is constant on the basis of units while short-term parameters, error correction parameter, and constant term vary from unit to unit. The long-term slope coefficient is constant in the PMG estimator while the short-term parameters and error variances vary by units (Özcan and Arı, 2015: 277). PMG estimator provides to be obtained more consistent results in the analysis of the long-termed relationship between series; this property of this estimator is its advantageous side. The validity of the test requires the time dimension T to be bigger than the unit size N (Shaari et al., 2020: 5). Hausman's (1978) test that is used in the determination of long-term homogeneity is utilized to decide between PMG and MG estimators. Hausman tests research whether there are statistical differences between PMG and MG estimators. For the Null hypothesis, there is not a statistically significant difference between PMG and MG estimators. Again, this assumption of the null hypothesis is accepted and the use of a PMG estimator is proper if the null hypothesis cannot be denied. The alternative hypothesis argues that there is a statistical difference between PMG and MG estimators. It is to the point to use the MG estimator in such a situation (Rafindadi and Yosuf, 2013:122–123). Table 4 shows PMG and MG test results that were obtained within the frame of panel ARDL analysis.

Table 3. Westerlund panel cointegration results

Statistic	Value	Z value	P value	Robust P value
Gt	–2.704	–1.414	0.079***	0.060***
Ga	–16.549	–2.244	0.012**	0.000*
Pt	–6.114	–0.645	0.259	0.190
Pa	–12.429	–2.143	0.016**	0.000*

*,**,***: Respectively show statistical significance at 1%, 5% and 10%.

Maximum lag for each variable for establishing panel ARDL model was specified as 3; Bayesian information criterion was utilized to determine the optimal lag length. However, H0 hypothesis could not be denied at the end of the Hausman test. In other words, long-term coefficients are homogeneous and they do not vary by country. This result reveals the reliability and effectiveness of the PMG estimator in line with the H0 hypothesis that shows the presence of long-term homogeneity of slope parameters. For PMG estimator results, energy consumption, urbanization level, and GDP are statistically significant at a 1% level on carbon dioxide emission. A single long-term error correction coefficient was estimated by the PMG estimator. Accordingly, the long-term error correction coefficient is significant and has a negative mark for the whole panel. There is a long-term relationship between independent variables and dependent variables. Approximately 31% of the imbalances that occur in one period will be corrected in the next period and the

Table 4. PMG and MG test statistics

Long term coefficients on panel basis	PMG	MG	Hausman
LENER	0.782*	−1.241	2.75 (0.432)
URBPOP	−0.011*	0.024	
LGDP	0.588*	1.500	
Error correction coefficient	−0.314*	−0.570*	
Short term coefficients			
ΔLENER	0.588*	0.285**	
ΔURBPOP	−0.009	0.051	
ΔLGDP	0.114	0.163	
C	−0.548	0.166	

Short term coefficients on country basis	PMG			
	ΔLENER	ΔURBPOP	ΔLGDP	Error correction coefficient
Brazil	1.101*	0.006	0.187	−0.099
China	0.851*	0.007	0.358***	−0.313*
Indonesia	1.187*	−0.083*	−0.432**	−0.155*
India	0.200	−0.084***	−0.079	−0.623*
Mexico	0.606*	0.006	0.246	−0.171
Thailand	0.093	−0.003	0.020	−0.669*
Turkey	0.622*	−0.008	−0.223	−0.338*
South Africa	0.040	0.085	0.838**	−0.143

*,**,***: Respectively show significance level at 1%, 5% and 10%. PMG: Pooled mean estimator; MG: Mean group estimator.

balance will be reached after about 3 periods. The 1% increase in energy consumption in the long term increases the carbon dioxide emission by 0.78%. Moreover, the 1% increase in the urbanization level has a very small but negative effect of 0.01% on carbon dioxide emissions. Finally, a 1% increase in GDP product increases the carbon dioxide emission by approximately 0.59%. Regarding short-term relationships, error correction coefficients, short-term coefficients, and constants vary from unit to unit. As is seen by these results, error correction coefficients are significant in Brazil, Mexico, and South Africa; error correction coefficients are significant and negative in other countries.

Conclusion and Evaluation

This study scrutinized the relationship between urbanization, energy consumption, and carbon dioxide emission through the panel ARDL method. It was decided to report the results of the Hausman test and PMG estimator in this study in which pooled average group (PMG) and average group (MG) estimators. Brazil, China, Indonesia, India, Mexico, Thailand, Turkey, and South Africa, which are the newly industrialized countries covering the period 1990–2018 were the country group of panel ARDL study. Analysis results show that the effects of urbanization, energy consumption, and GDP on carbon dioxide emission differ across the panel and on the basis of units. Many studies in the literature express that urbanization increases carbon dioxide emissions. However, this result is not valid for some countries. Considering that urbanization is closely related to industrialization and income, the industrialization rates of countries and accordingly their urbanization processes differ from each other. Countries that take slower action in the industrialization process also have low rates of income and urbanization. Low industrialization rate and low income, slows down the rate of rural-urban migration and urbanization spreads over time. Within the framework of empirical findings the low level of income in Indonesia and India a factor that minimizes the adverse effects of urbanization on carbon dioxide emissions. Low-income level reduces urban energy consumption, and environmental negativities arising from energy consumption are minimized. Except for India and Indonesia, no statistical results were obtained for the effect of urbanization level on CO2 emissions in other countries. In this context, the individual results obtained from the study show similarities with the results of the studies conducted by Behera and Dash (2017), Saidi and Mbarek (2017) and Ali et al (2016) in the literature and support the results. When the findings obtained from the analysis results are evaluated in terms of China, the rapid increase in national income due to industrialization over the last 20 years has had negative effects on CO2 emissions. In developing countries, the desire for faster economic growth and increased social welfare pushes the motives to protect and care for the environment to the background. The upward acceleration in the rate of industrialization, income growth and ultimately urbanization increases energy consumption in the context of both industrial and urban life. In this context, the results of the analysis reveal that energy consumption increases carbon dioxide emissions in Turkey, Indonesia and China. The results confirm the results of similar studies (Zhang et al, 2015; Yazdi and Shakouri, 2014; and Al Mulali et al, 2012) in the literature. Environmental problems are much more common in the initial stages of urbanization; public investments in areas such as infrastructure and public transportation that protect the environment and take care of awareness reduce environmental adversities in the later stages of urbanization over time. On the other hand, maintaining urbanization policies within certain planning plays an important role in reducing environmental negativities. In addition to all these, it is crucial to control the population, which is one of the important determinants of urbanization through national policies.

It is impossible for economic development to continue without energy that is one of the main determinants of growth. Economic growth-oriented energy consumption increases carbon dioxide emission. Achieving sustainable growth is closely related to reducing these emissions. Encouragement of investments to improve living conditions in both urban and rural areas plays an important role in reducing the environmental pollution. It is essential to consider regulations on reducing carbon dioxide emissions in the determination and enforcement of macroeconomic policies. On the other hand, the widespread use of smart city applications in areas such as transportation, infrastructure and superstructure, residences and workplaces will contribute to reducing carbon emissions. In this context, it is necessary to increase the proportional share of renewable energy, especially among the total energy resources, especially in cities. The proportional share of renewable energy among total energy sources needs to be increased. Diversifying energy in production to head for renewable energy creates a reducing effect on carbon dioxide emissions and thus environmental pollution can be prevented. R&D activities that reduce the investment costs should be focused on by increasing renewable energy investments.

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