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RELATIONSHIP AMONG URBANIZATION, ECONOMIC GROWTH, ENERGY INTENSITY, AND CO_2 EMISSION IN UPPER-MIDDLE INCOME

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Abstract

This study examines how urbanization affected CO_2 emissions in selected 24 upper-middle income countries between 1990 and 2014. It contributes to the literature by investigating the nonlinear impact of urbanization while accounting for dynamics of cross-sectional dependency within the sample. By taking advantage of the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) and the Environmental Kuznet Curve (EKC) hypothesis and balanced panel data technique ecological modernization theory has been empirically proved. The evidence showed that, except for a small part of the countries belonging to the sample (Mauritius, Guatemala, Indonesia, China, Azerbaijan, and North Macedonia), the urbanization levels they reached within the analyzed period have already tended to reduce carbon dioxide. Apart from this, economic growth, population, and technology elasticities of carbon emission are positive, that is, in harmony with the existing STIRPAT model literature. The evidence in this article provides a guide for policymakers and urban planners in upper-middle income countries for all steps to be taken to prevent climate change.

Keywords: Urbanization, CO_2 Emission, STIRPAT Model, EKC Hypothesis.

ÜST-ORTA GELİR SINIFI ÜLKELERİNDE KENTLEŞME, EKONOMİK BÜYÜME, ENERJİ YOĞUNLUĞU VE CO_2 EMİSYONU ARASINDAKİ İLİŞKİ

Özet

Bu çalışma, üst-orta gelir sınıfındaki 24 ülkede 1990 ile 2014 yılları arasında, kentleşmenin CO_2 emisyonlarını nasıl etkilediğini incelemektedir. Bu araştırma, hem örneklemdeki yatay kesit bağımlılığını hem de kentleşmenin doğrusal olmayan etkisini araştırarak, literatüre katkı sağlamayı amaçlamaktadır. Bu amaç çerçevesinde, STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) modeli ile EKC (Environmental Kuznet Curve) hipotezi doğrultusunda, dengeli panel veri tekniklerinden faydalanılarak, ekolojik modernizasyon teorisine ampirik kanıtlar sunulmuştur. Bulgular, Mauritius, Guatemala, Endonezya, Çin, Azerbaycan ve Kuzey Makedonya dışındaki ülkelerin, analiz edilen dönemde ulaştıkları kentleşme seviyelerinin, karbondioksiti azaltma eğiliminde olduğunu göstermektedir. Bununla birlikte, karbon emisyonunun ekonomik büyüme, nüfus ve teknoloji esneklikleri STIRPAT modeliyle uyumludur. Bir başka ifadeyle, bu değişkenlerin katsayıları pozitiftir. Bu makalede elde edilen bulguların, politika yapıcılara ve şehir planlayıcılara, iklim değişikliğini önleme konusunda yol gösterici olacağına inanılmaktadır.

Anahtar Kelimeler: Şehirleşme, CO_2 Emisyonu, STIRPAT Modeli, EKC Hipotezi.

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1. INTRODUCTION

Urbanization is a multifaceted socio-economic phenomenon that modifies the built environment, transforming rural areas into urban settlements and altering the spatial distribution of people living in rural to urban areas. The demographic and social structure of both urban and rural areas are altered as a result of changes in the predominant jobs, lifestyle, culture, and behavior (Montgomery et al., 2013). In countries where the rate of increase in urbanization is accelerating, considering factors such as job opportunities and industrialization, which are mutually causality brought by urbanization, urbanization leads to environmental pollution. In addition, even though the fastest urbanization (1.6% increase over the years) ever seen between 1990 and 2018 was seen in upper-middle income countries, it is predicted that this rate of increase will slow down (0.5% increase over the years) between 2030 and 2050 (United Nations, 2019). Considering all these, the effect of environmental pollution of urbanization has attracted the attention of researchers and it is interesting to examine how the decrease in the growth rate of upper-middle income group countries will affect carbon emissions in the future. Moreover, Cities were responsible for 62% of the global greenhouse gas increase and an estimated 67-72% between 2015 and 2020 (IPCC, 2023). Therefore, the link between urbanization and carbon emission has become an attractive problem that has to be solved by some researchers (Wang et. al., 2018; Zhang et. al., 2017).

Studies that have gained momentum in recent decades have shown that the relationship between urbanization and carbon emissions varies from country to country and region to region. Some of the research indicated that urbanization has an increasing effect on carbon emissions (Chen et. al., 2019; Liddle and Lung, 2010; Martínez-Zarzoso and Maruotti, 2011; McGee and York, 2018). In contrast, some research predicted the negative effect between urbanization and carbon emission (Liu et. al., 2023; Niu and Lekse, 2017; Shahbaz et. al., 2016). One of the reasons for the diversity of the results in the literature is related to the applied method and data. However, the most important reason is the heterogeneous structures of countries and regions (e.g., the differences in transportation networks and industrial sector structures).

The study aims to examine the impact of urbanization on carbon emissions in selected upper-middle income countries during the period 1990 and 2014. We employed panel data analysis techniques to test the validity of ecological modernization theory within this group of countries. One of our contributions to the literature is to employ the panel data estimator that considers the cross-sectional dependence among countries. The other important contribution of ours is to test the non-linear relationship between urbanization and carbon emissions in the country group where heterogeneity exists, excluding economic growth. Moreover, the results from the paper not only contribute to the existing literature but also policymakers will be attracted by them.

2. THEORETICAL FRAMEWORK

There are several obstacles to enhancing environmental quality and generating a sustainable energy supply as a result of the rapid expansion in urbanization, particularly in newly industrialized and emerging countries (Voumik and Sultana, 2022) For this reason, the relationship between urbanization and environmental degradation (especially carbon emissions) has been a subject of research (Li et. al., 2012; Rashid et. al., 2018; Churkina, 2016). However, the relationship reflects a network of relationships that are too complex to be explained by a single theory. Such government policies about climate change, energy structure of countries or cities, urban public infrastructure, consumption patterns of countries or cities, and transportation network features can influence environmental degradation in a different way. Three theories have been put forward to examine the relationship between urbanization and environmental degradation. Ecological modernization mostly explains the relationship between urbanization and carbon emissions with the development levels of countries. This theory evaluates the relationship from a more national-level perspective. Although the urban environmental transition and compact city theories make partially similar assumptions regarding ecological modernization they include evaluations at the city level (Poumanyvong and Kaneko, 2010).

According to the broadest definition, ecological modernization is the discourse that acknowledges the structural nature of the environmental problem while still assuming that current political, economic, and social institutions can incorporate environmental protection (Hajer, 1995). In this theory, urbanization is an important determinant of ecological modernization. It is claimed that urbanization will increase ecological degradation at countries' low levels of development. However, at the level of high development of countries, urbanization reduces ecological degradation with the emergence of agglomeration economies, advanced technologies, increasing efficiencies in the use of alternative resources, and increasing trend of service-based growth rather than industrial-based growth (Ehrhardt-Martinez, 1998; Ehrhardt-Martinez et. al., 2002; Poumanyvong and Kaneko, 2010).

Urban environmental Transition theory explains the evolution of environmental problems according to the development level of cities. The theory contends that environmental issues (so-called “Brown” agenda issues such as lack of safe water, inadequate waste management, and pollution control) in underdeveloped cities are frequently immediate, local, and immediately dangerous to health. In middle-income cities, the most urgent environmental issues (so-called “Gray” agenda issues such as air pollutants and chemical water pollutants) are often city-regional particularly large and industrialized ones, and frequently involve both ecological and health risks. The affluent city generally enjoys a healthy living environment, but economic activities such as the consumption patterns of affluent city residents being more resource intensive and lifestyles have a considerable negative impact on the environment and contribute significantly to long-term and global issues (so-called “Green” agenda issues such as non-point source pollution, CO_2 emission, and persistent chemicals) (Jacobi et.al., 2010; Marcotullio and Lee, 2003; Williams, 1997).

The compact city theory is a concept in urban planning and design that encourages mixed land use and a comparatively high residential density. The theory suggests that compact cities will reduce the distance traveled in transportation by using economies of scale in the infrastructure of cities, reduce car dependency, cause less electricity use, and lower carbon emissions (Dempsey and Jenks, 1978). However, the theory has drawn criticism due to the possibility of more serious social issues in densely populated residential areas, the concentration of pollution in living spaces, and the rising risk of congestion (Burton, 2000). Even if compact cities would reduce carbon emissions, without a plausible urban infrastructure it will increase environmental degradation (Burgess, 2002).

3. LITERATURE REVIEW

The degradation caused to nature by the constantly so-called developing human activity has been the subject of study for a long time. As a result of this development, the relationship between urbanization and environmental degradation, especially the relationship with carbon emissions, has become one of the issues that has been focused on a lot in the last 3 decades. It is possible to generally classify the studies examining this relationship between urbanization and carbon emissions as national, regional (or city), and domestic-level studies tested with the either STIRPAT or EKC hypotheses or the analyses that employed both STIRPAT and EKC hypothesis. Due to our topic being held at the national level, we will only compile studies at the national level under literature review. However, some regional studies will be included because the studies will be aforementioned also examine the relationships between urbanization and carbon emissions at the national level by working with the entire sample. In addition, there is no literature which the non-linear effects of urbanization on carbon emission where only the EKC hypothesis is investigated in the context of panel data analysis at the national level.

One of the first studies in this field, conducted by (York et. al., 2003) on 146 countries, showed a positive correlation between urbanization and carbon emission and energy footprint. However, they found that affluence and urbanization perpetually raise carbon emissions opposite to the ecological modernization theory. When the STIRPAT model is examined in the context of panel data analysis, (Cole and Neumayer, 2004) employed urbanization, household size, and age structure as control variables on carbon emission and found that urbanization affects carbon emissions positively. Using the STIRPAT model, (Poumanyvong and Kaneko, 2010) reached similar results. They applied the STIRPAT model to high-income, middle-income, and low-income countries, and in all income groups, urbanization was found to affect carbon emissions positively. Liddle and Lung (2010) examined the effect of urbanization on total carbon emissions and carbon emissions from transportation. They showed that the links between urbanization and both two dependent variables are positive but found only its effect on carbon emissions from transportation statistically significant. Nosheen et. al. (2020) reached similar findings on Asian Countries with other studies using dynamic panel data analysis. Surprisingly, Fan et. al. (2006) used the STIRPAT model by grouping the country sets as high-income, upper-middle income, lower-middle-income low-income worldwide, and China. They did not reach a positive link in any group except for low-income countries, while the results were statistically significant only in high-income countries.

Considering the literature in the context of the STIRPAT model based on the time series analysis, Alam et. al. (2007) found that urbanization and high population are positively related to carbon emissions in the long run, but have a negative relationship with economic development. Similarly, Li et. al. (2011) confirmed a positive relationship between urbanization and carbon emissions in China. However, the urbanization elasticity of carbon emission is quite higher than the study of Alam et. al. (2007). Contrary to the literature, Yakubu et. al. (2021) determined the relationship between urbanization and carbon emissions to be negative both in the long run and short run due to environmental policies working effectively despite increasing urbanization in Ghana, as they argued.

Considering the literature in the context of panel data analyses where both the EKC hypothesis and STIRPAT model are applied, Martínez-Zarzoso and Maruotti (2011) performed an analysis of less developed countries and divided countries into endogenously homogeneous groups. The results showed that a threshold level is found for two of the groups, over which the emission-urbanization elasticity is negative and additional increases in the rate of urbanization do not result in increased emissions. He et. al. (2017) divided China into 3 regions and the findings showed that inverted u-type relationship between urbanization and carbon emissions in all groups and the whole sample.

When we look at the time series analysis where both the EKC hypothesis and STIRPAT model are applied, Yeh and Liao (2017) identified an inverted u-shaped carbon urbanization relationship in the study where examined the relationship of other independent variables other than urbanization, which they thought affected carbon emissions in a non-linear way in Taiwan. However, Shahbaz et. al. (2016) found that the u-type relationship between urbanization and carbon emission in Malaysia was contrary to the theory but the coefficients were not statistically significant.

Considering panel data analysis where only EKC hypothesis is applied, Sun et. al. (2022) asserted that Mena countries is highly dependent on primary energy resources (oil, coal, and natural gas). In addition, the study found out that urbanization and economic growth positively related with carbon emission.

Haseeb et. al. (2018) found that urbanization is negatively related to carbon emissions and even increases carbon emissions as economic growth increases, meaning that economic development will not reduce environmental degradation in BRICS countries after a certain level.

Where only the EKC hypothesis is applied in the context of time series analysis, Ozataç et. al. (2017) alleged that trade openness, urbanization, and energy consumption all exhibited positive, statistically significant, and inelastic effects on carbon emission emissions. Moreover, the results revealed an inverted u-type relation between economic growth and carbon emission. Another piece of evidence from Turkey appeared in which the study conducted by Pata (2018) showed an inverted u-type relation between economic growth and carbon emission and a positive link between urbanization and carbon emission in accordance with Ozataç et. al. (2017). The results revealed by Dogan and Turkekul (2016) indicated that there is no inverted u-type relationship between economic growth and carbon emission in the USA but a positive link between urbanization and carbon emission exists.

4. DATA AND METHODOLOGY

This In the first subheading, a detailed explanation will be given about the sources and descriptive statistics of the data used in the article, while in the second subheading, the manipulations we applied to the macro data used in the article, the model definition, and the econometric tools and methods we used will be mentioned.

4.1. Data Source, Definitions and Descriptive Statistics

All variables employed in our analysis are taken from the World Bank's dataset known as World Development Indicators (World Bank, 2023). We analyze the relationships of carbon dioxide emissions with affluence, technology, urbanization, and population. The panel data, which consists of 24 upper-middle income countries (see in table A.3. Appendix A) as a cross-section and annual data starting from 1990 to 2014 as a time series, is used in the analysis.

We turned to account for the carbon dioxide emissions as the independent variable in our analysis. We used the total population to represent the population size in the STIRPAT model, and the GDP per capita variable to represent affluence. We exploit the share of industry and service sectors in GDP and energy intensity variables as proxy variables for technology. In addition to these 5 variables, we also add urbanization to show its pressures on carbon dioxide emission. The definitions and sources of all variables can seen in Table 1. The descriptive statistics of variables can be found in Table 2.

Table 1. Definitions of All Variables Used in The Analysis

Variables	Definitions	Units	Data Sources
Total carbon dioxide emissions (CO_2)	Carbon dioxide emissions stemming from the burning of fossil fuels and the manufacture of cement.	Kiloton	WDI
Energy Intensity (EI)	A kilogram of oil equivalent of energy use per constant PPP GDP	Energy use per 1000$ GDP (constant 2017 PPP)	WDI
Population (POP)	Midyear total population	Number	WDI
GDP per capita (GDP)	Gross domestic product divided by midyear population	US$ per capita (constant 2015 US$)	WDI

Share of service sector in GDP (SOS)	Share of service sector's value added in GDP	Percent	WDI
Share of service sector in GDP (SOI)	Share of service sector's value added in GDP	Percent	WDI
Urbanization (URB)	The share of urban population in the total population	Percent	WDI

Table 2. Descriptive Statistics of Variables

Variables	Obs.	Mean	Std. Dev.	Min	Max
CO_2 (100 kt)	600	3.801,09	11.898,06	11,64	100.000,00
EI (energy use/1000$)	600	137,05	94,88	51,59	607,72
POP (thousand)	600	93.200,00	253.000,00	983,00	1.370.000,00
GDP per capita ($)	600	5.353,33	2.484,02	905,03	14.200,27
SOS (%)	600	49,17	10,14	10,86	73,34
SOI (%)	600	34,48	11,33	16,21	84,80
URB (%)	600	62,88	13,46	26,44	91,38

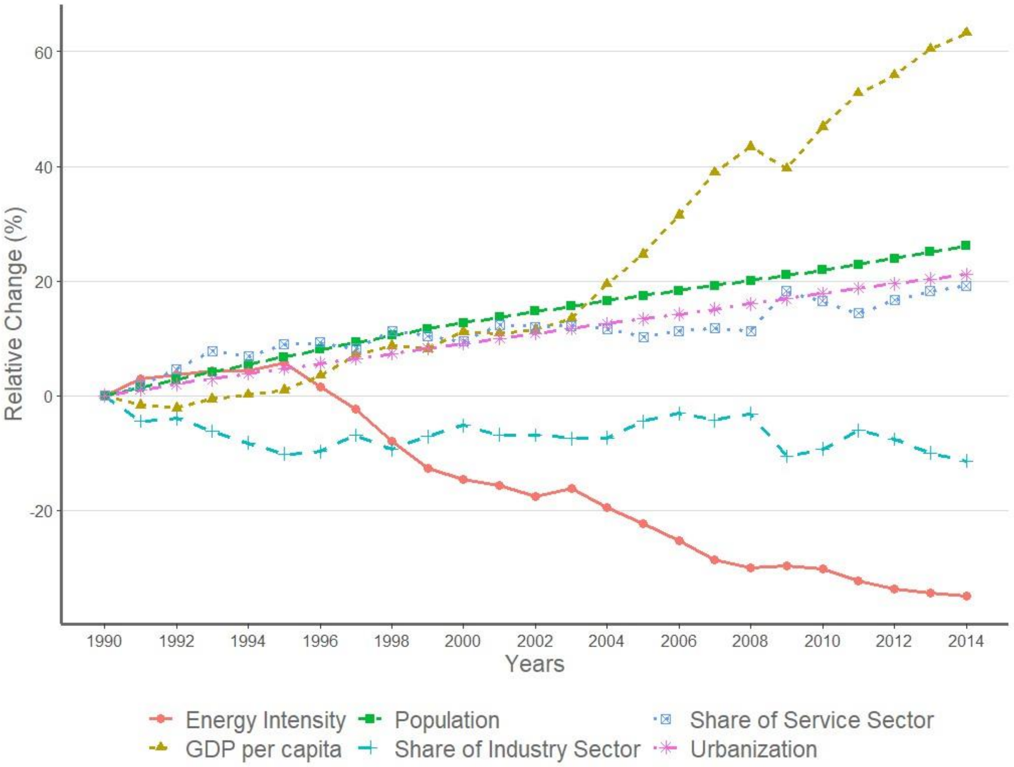
Figure 1 indicates the relative changes of independent variables in the country group during the period 1990-2014. It illustrates that GDP per capita, population, the share of service sector in GDP, and urbanization level increased 63,28%, 26,13%, 19,21%, and 21,13% from 1990 to 2014, respectively. However, energy intensity and the share of industry sector in GDP have declining trends which are 34,99% and 11,37%, respectively from 1990 to 2014 apart from the others.

From base year (1990) until 1995, energy intensity has a moderate increasing trend. Surprisingly, after 1995, it experienced a rapid decline. This is mainly due to the fact that there are several emerging markets in the income group studied. The rapid increase in income levels after the Mexican peso crisis in such countries caused a rapid decrease in the energy intensity variable (Hutchison and Noy, 2006; Han et. al., 2003; Aguiar, 2005).

Another interesting result in the figure is the rapid increase in GDP per capita after 2002. The main reasons for this were the shift of global production to Asia and that there was an acceleration in the growth rates of Latin and Central American countries as an indicator of post-crisis recovery after 2002. The large number of Asian, Latin, and Central American countries in the data set has caused a break in the relative change of GDP per capita after this year (Kharas, 2010; Coremberg, 2014).

Another critical fact is China's individual effects on the changes. When China is excluded from the data set, the relative change in GDP per capita, population, and energy intensity variables creates a significant difference compared to before, which is not surprising. The relative increase of GDP per capita and population are 57,48% and 33,33%, respectively, without China. The relative decrease in energy intensity is 30,14% without China. The relative changes of other variables remain the same with little difference.

Figure 1. The Relative Change of Independent Variable Based on The Analysis Period of 1990 and 2014



4.2. Methodology

Ehrlich and Holdren (1971) asserted a model called IPAT ($I = PAT$) to examine the effects of population, affluence, and technology on environmental impact. In the model, I states environmental impact (generally analyzed energy consumption and greenhouse gas emissions) which is determined by population size (P), per capita consumption (A), and technology (T). In the model affluence and technology are measured as per capita impact in general. Even if the model would be useful, it has some limitations. The most important of these limitations is that the model assumes that the effect of each force on the environment is proportional (Villanueva et. al., 2013).

Afterward, Dietz and Rosa (1994) revisited the IPAT model by taking into account the elasticities of the independent variables. They reformulated the model in a stochastic form called STIRPAT ($I = aP^bA^cT^de$) where a is a constant term, b, c, and d are the parameters of population, affluence, and technology variables respectively, and e is a disturbance term.

In this article, we added urbanization, thought to have a causality with greenhouse gas emissions, in addition to the variables in the STIRPAT model. By taking the natural logarithm of the model in exponential functional form, we both stabilized the variance of the variables in the model and put the function in linear form. For the panel data on CO_2 emissions, we can formulate the empirical models as follows:

$$lnCO_{2_{it}} = \beta_0 + \beta_1 ln(POP_{it}) + \beta_2 ln(GDP_{it}) + \beta_3 ln(SOS_{it}) + \beta_4 ln(SOI_{it}) + \beta_5 ln(EI_{it}) + \beta_6 ln(URB_{it}) + \delta_t + \theta_i + u_{it} \quad (1)$$

$$lnCO_{2_{it}} = \beta_0 + \beta_1 ln(POP_{it}) + \beta_2 ln(GDP_{it}) + \beta_3 ln(SOS_{it}) + \beta_4 ln(SOI_{it}) + \beta_5 ln(EI_{it}) + \beta_6 ln(URB_{it}) + \beta_6 ln(URB_{it})^2 + \delta_t + \theta_i + u_{it} \quad (2)$$

where POP and GDP state total population size and GDP per capita respectively. The shares of service and industry sectors in GDP were denoted by SOS and SOI respectively used as proxy variables so as to explain technology in STIRPAT model as (Shi, 2003) did. In addition to these two variables, technology was also proxied by energy intensity (EI) as used in (Chen et. al., 2019; Martínez-Zarzoso and Maruotti, 2011; Poumanyvong and Kaneko, 2010). In order to measure the effect of urbanization on carbon emission, the urbanization variable denoted as URB was added to the STIRPAT model. While δ is unobservable time-specific effects caused by technological progress, volatility in energy prices, and environmental changes, θ is unobservable country-specific effects resulting from resource endowments, locations, and political decision differentiations that can affect carbon emission (Baltagi and Baltagi, 2008). u shows the error term. While index i specified the country-level cross-sectional data, t specified years. The only difference between equation 1 and equation 2 is to be found the quadratic term of urbanization variable to test the EKC hypothesis in equation 2.

In this paper, we try to estimate the impact of urbanization on carbon emissions in upper-middle income countries. The country classification was made by (World Bank, 2022) classified as upper-middle income according to GNI per capita between $4,046 and $12,535. The purpose of focusing on this group of countries is that it is known that the urbanization rates of the countries have increased relatively more over the years compared to other income groups in the years subject to analysis (Ritchie and Roser, 2018). Moreover, as of 2021, the highest share of carbon emissions of upper-middle income countries in the world is 45.8%, compared to other country groups (high-income, lower-middle income, and low-income) upper-middle income countries is taking first place (Ritchie and Roser, 2023). Therefore, the article aimed to demonstrate the hypothesis that urbanization increases carbon emissions with the sample of selected upper-middle income countries.

Firstly we check whether the data are stationary or not. We applied the heterogeneity test developed by Pesaran and Yamagata (2008) to find out which unit root tests we could apply to the data. The test results show that our data are heterogeneous. Afterward, we applied 4 unit root tests to allow us to include the panel fixed effect. The first test was the LLC test proposed by Levin et. al. (2002). LLC test allows for heterogeneity in panel data by employing a test statistic that combines individual unit root tests, taking into account heterogeneous individual characteristics. The second test was IPS proposed by Im et. al. (2003). IPS test is robust to cross-sectional dependence and is created for heterogeneous panel data. To take into consideration the variation among cross-sectional units, it averages individual unit root statistics. The third test is ADF put forward by Maddala and Wu (1999). This test also considers heterogeneity by employing individual unit root tests and pooling the results while accounting for cross-sectional dependence. The fourth test is the PP test suggested for heterogeneous panel data by Choi (2001). According to the unit root test results, all data are stationary at level. All unit root tests can be seen in Table A.2. (Appendix).

After taking unit root test results, we conducted Pooled Ordinary Least Square (Pooled OLS), Fixed Effect (FE), and Random Effect (RE) estimators. Moreover, an F-test was used to choose whether the fixed-effect model and the pooled OLS model are appropriate. This F-test is done to compare the fixed-effect model's goodness-of-fit to the pooled OLS model. The test showed us that we have a country-specific effect rather than a time-specific effect which also proved the goodness of fixed effect model. Additionally, the Breusch-Pagan LM Test (Breusch and Pagan, 1980) was used to assess which model, the pooled OLS or the random effect model, is more appropriate. After seeing the test result, we deduced that our sample had a random individual effect. The Hausman specification test (Hausman, 1978) was then used to choose between fixed and random effect models as the final model. According to the test result, the fixed effect is more appropriate for our model.

To test heteroscedasticity, autocorrelation, and cross-sectional dependency in our model a range of diagnostic tests were applied. To detect whether the data has heteroscedastic we applied Modified Wald statistic for groupwise heteroskedasticity test in fixed effect model. The result revealed our models has heteroscedasticity. Furthermore, as for serial correlation in panel data, our data has autocorrelation problem. Finally, to check the cross-sectional dependence of our models, we employed a cross-sectional dependency test proposed for balanced panel data by Pesaran (2004). The test result shows that our sample has a cross-sectional dependence problem too for only model 1. Cross-sectional or "spatial" dependency is frequently disregarded, even though the majority of empirical research now produces standard error estimates that are heteroskedasticity and auto-correlation consistent (Hoechle, 2007). Thus, in the article, we used the Driscoll Kray estimator, which gives robust standard errors, paying attention to the problems of heteroscedasticity, serial correlation, and even cross-sectional dependence in panel data.

Since many of the utilized independent variables in this article can be highly correlated such as the population and GDP per capita theoretically, multicollinearity is another common issue. The correlation between independent variables can be seen in Table A.1 (Appendix). The share of service sectors and industry sectors in GDP have high correlations. However, multicollinearity is not a big issue, given that data is gathered from units in panel data models and there are a large number of observations (Tatoglu, 2012).

RESULTS

First of all, we demonstrated the Driscoll-Kray one-way fixed effect estimator results for model 1 and model 2. The results are reported in Table 3. While model 1 expressed our model considering only the STIRPAT model, we employed the Environmental Kuznet Curve (EKC) hypothesis to determine the existence of a non-linear relationship between the urbanization variables and carbon emissions in the upper-middle income countries. In these two models, all coefficients are statistically significant at least at a 5% level except for the share of industry in GDP (SOI) variable. We attribute the reason why the variable is not statistically significant to the high correlation between the service sector's share in GDP variable. In this article, we mainly pay regard to model 2 since it shows the quadratic relationship between Urbanization and Carbon dioxide emission. The fact that the non-quadratic urbanization variable is positive and the quadratic urbanization variable is negative indicates that there is an inverted U-shaped relationship between urbanization and carbon emissions and empirically confirms the EKC hypothesis and ecological modernization theory. Therefore, as urbanization increases, carbon emissions will begin to decrease after a certain level. Furthermore, coefficients of other variables have positive signs, as is expected, in compliance with economic common sense.

The elasticities of population, GDP per capita, energy intensity, the share of the service sector in GDP, and the share of industry sectors in GDP are 0.942, 0.918, 0.776, 0.162, -0.058, respectively, which indicate the effects of population, affluence, and technology variables on carbon emission according to STIRPAT model. We can see that they all are positively related to carbon emission except for the share of the industry sector in GDP in upper-middle income countries. 1% increases in population, GDP per capita, and energy intensity will each increase statistically significantly CO_2 emissions by 0.942%, 0.918%, and 0.776%, respectively, assuming all other factors remain constant. A 1% increase in the share of the service sector to the GDP increases carbon emission by 0.162%, which has a relatively lower impact on CO_2 emissions compared to other factors, assuming all other factors remain constant. The share of the industry sector in GDP is not statistically significant which means it empirically does not affect carbon emission and it both has a negative effect on carbon emission and is quite lower than others.

This pattern supports the claim made by the ecological modernization hypothesis, according to which there may be serious environmental problems as a result of modernization. Further modernization, however, can mitigate these issues. Urbanization, as a result of modernization, increases carbon emission to a certain level and decreases after this level in accordance with Martínez-Zarzoso and Maruotti's (2011) findings. Urbanization and CO_2 have an inverse U-shaped relation. Emissions rise until an inflection point, up until 58% urbanization for upper-middle income countries, and it will decrease after this urbanization level. With respect to analyze period and countries, Mauritius, Guatemala, Indonesia, China, Azerbaijan, and North Macedonia were under this level. However the other countries were above the level that decreases the carbon emissions. Since the square of urbanization is statistically significant, this finding supports the view suggested by Ehrhardt-Martinez et. al., (2002) and York et. al., (2003) that urbanization can be used as a proxy to indicate modernization. The inverted u-shaped relationship between urbanization and carbon emission shows that the increase in urbanization rates in upper middle-income countries does not create environmental problems, on the contrary, the high level of urbanization will already reduce carbon emissions, consistent with the common findings in the literature (Martínez-Zarzoso and Maruotti, 2011; He et. al., 2017; Yeh and Liao, 2017).

Table 3. Driscoll-Kray Estimation Results for Carbon Emission

Variables	Driscoll-Kray FE Estimator (Model 1)	Driscoll-Kray FE Estimator (Model 2)
Constant	-16,113***	-36,726***
	(-2,711)	(3,992)
lnPOP	0,732***	0,942***
	(-0,093)	(0,098)
lnGDP	0,947***	0,918***
	(-0,127)	(0,124)
lnSOS	0,305***	0,162**
	(-0,076)	(0,064)
lnSOI	0,085	-0,058
	(-0,08)	(0,073)
lnEI	0,808***	0,776***

	(-0,12)	(0,122)
lnURB	0,327**	9,826***
	(-0,133)	(0,792)
$lnURB^2$		-1,210***
		(0,110)
Country Dummies	Yes	Yes
Year Dummies	No	No
R2	0,78	0,80
Autocorrelation Test	F=10,41***	F=11,60***
Heteroscedasticity Test	12.475,03***	6.028,98***
Cross Sectional Dependence Test	Peseran test statistic=4,546***	Pesaran test Statistic=1,378
Observations	600	600

Notes: ln denotes the natural logarithm of the variables. POP, GDP, SOS, SOI, EI, and URB indicate population, GDP per capita, the share of service sector in GDP, the share of industry sector in GDP, energy intensity, and urbanization respectively. The number in parenthesis show driscoll-kray standart error. ***, **, and * denote significance at level 1%, 5%, and 10%, respectively.

Concluding to the results, population, GDP per capita, energy intensity, and the share of service sector in GDP have statistically significant positive correlation with carbon emission, as is expected. The share of the industry sector in GDP appears to have a negative correlation with carbon emissions, indeed it is not statistically significant.

CONCLUSION

In this work, we have conducted static panel data analysis on factors that influenced carbon emission in upper-middle income categories between 1990 and 2014 time period. We have conducted the EKC hypothesis and STIRPAT model on the selected group and tested the assertions of ecological modernization theory on urbanization as being an important determinant of carbon emission. We predicted two models one of which is the model we established to measure the non-linear effect of urbanization and the STIRPAT model. In model 1, while the technology variable is proxied by the share of the service sector and industry sector in GDP and energy intensity data in addition to population and affluence in the STIRPAT model, we also tested the effect of urbanization on carbon emissions. Furthermore, we added the quadratic term of urbanization variable to the model 1 as being in model 2.

The results show that the population and affluence elasticity of carbon emission is positive as expected and they have almost a unit effect on carbon emission. While the share of the service sector in GDP and energy intensity variable, as proxy variables of technology, confirm the hypothesis that technology has a positive effect on carbon emissions in the STIRPAT model, the industry sector's share in GDP does not represent technology. It cannot explain carbon emissions in upper-middle income countries as can be seen from its quite lower and and statistically insignificant elasticity.

We confirmed the ecological modernization theory in upper-middle income countries using the EKC hypothesis on urbanization. The finding showed that the urbanization elasticity of carbon emission is positive and revealed that there is an inverted u-type relation between urbanization and carbon emission. In addition, The findings demonstrated that, for the majority of the nations between 1990 and 2014, except Mauritius, Guatemala, Indonesia, China, Azerbaijan, and North Macedonia, further increases in the pace of urbanization do not result in higher emissions. Thus the results have significant policy implications. In addition to making recommendations for urban planners and policymakers, this article also contributed to the literature with its predictions taking into account cross-sectional dependence among the upper-middle income countries.

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APPENDIX

Appendix A.1. The Correlation Matrix of Dependent Variables

Variables	lnPOP	lnGDP	lnSOS	lnSOI	lnURB	lnEI
lnPOP	1					
LnGDP	-0.033	1				
lnSOS	0.0171	0.4749	1			
lnSOI	0.1224	-0.2323	-0.8164	1		
lnURB	0.0213	0.6186	0.1967	-0.0758	1	
lnEI	0.3096	-0.4719	-0.4633	0.3257	-0.0898	1

Appendix A.2. Unit Root Tests

Variables	Unit root tests at level				Unit root tests at first difference			
	LLC	PP	ADF	IPS	LLC	PP	ADF	IPS
$lnCO_2$	-4.15***	51.02	43.03	-3.03***	-5.35***	576.09***	36.65	-12.60***
lnPOP	-7.21***	144.01***	92.45***	-5.23***	-4.67***	246.15***	113.07***	-9.24***
LnGDP	-0.89	82.61***	53.56	8.32***	-2.96***	63.96*	33.63	-2.18**
lnSOS	-4.57***	135.37***	28.50	-4.91***	-12.83***	530.43***	32.68	-12.82***
lnSOI	-3.61***	80.97***	27.52	-4.08***	-9.31***	551.92***	31.89	-12.25***
lnURB	-5.97***	105.86***	65.29**	2.61***	-2.78***	125.75***	97.40***	-4.83***
lnEI	-1.37*	48.16	57.85	-3.55***	-5.84***	474.68***	66.52**	-12.01***

Notes: Individual effects and time trend included in all data. ***, ** and, * specify rejection of the null hypothesis of nonstationary at significance level 1%, 5%, and 10%, respectively.

Appendix A.3. Countries Used in The Analysis

Country List		
Argentina	Costa Rica	Malaysia
Azerbaijan	Dominican Republic	Mauritius
Belarus	Ecuador	Mexico
Botswana	El Salvador	North Macedonia
Brazil	Gabon	Paraguay
Bulgaria	Guatemala	Russian Federation
China	Indonesia	South Africa
Colombia	Iraq	Turkiye