The effects of urbanization and renewable energy on CO2 emissions: A panel data

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Abstract: As the largest developing country in the world, with rapid economic growth, Europe has experienced fast-paced urbanization development over the past three decades. A better understanding of the relationship between urbanization, economic growth and energy consumption is important for Europe's future sustainable development. This paper empirically investigates the long-run relationships and causal relationships between urbanization, renewable energy consumption, economic growth and CO2 emissions in EU countries. DOLS and FMOLS approaches are used for the period 1992–2014 into consideration.

Granger causality results show that there is a unidirectional relationship from CO2 emissions to urbanization, and there is no causality between renewable energy consumption and CO2 emissions. The results have important implications for EU policymakers on the path towards a sustainable society. Theories of ecological modernization and urban environmental transition recognize that urbanization can have negative impacts on the natural environment with the net effect being hard in EU countries.

Key-Words: Urbanization, Renewable Energy Consumption, Granger Causality Test, EU countries.

1 Introduction

Climate change and global warming have attracted considerable worldwide attention. Many studies have focused on the relationships between growth and CO2 emissions, growth and energy over last two decades. It has been observed that higher economic growth causes environmental degradation and threatens the sustainability of the environment because economic growth is closely linked to energy consumption [1]. Higher economic growth requires a higher level of energy consumption and is responsible for higher levels of CO2 emissions. This notion attracted the world's attention in the 1990s because of the potential threats to the ecosystem. Rapid urbanization has been shown to promote economic development and improve people's living standards; on the other hand, it can also contribute to the increase in energy consumption and consequently generate energy crises [2], [3]. As a scarce natural resource, fossil fuels have begun to set more limits to urbanization process and economic growth, especially in the context of fossil energy crisis [3].

While urbanization in developed countries continues to increase, developing countries are expected to experience the greatest increase in urbanization. For example, the United Nations Population Division [4] predicts that in the year 2020, urbanization in the less developed regions of the world will increase from 50%. Furthermore, it is expected that urbanization in the less developed regions of the world will more than triple, from 18% in 1950 to 67% in 2050. The Changes in urbanization can affect economic growth, energy consumption and CO2 emissions. If urbanization has a significant impact on CO2 emissions, then this will have implications for sustainable development and climate change policies.

The EU countries have witnessed fast-paced urbanization development over the past three decades. This rapid growth of the EU's urbanization and the economy has, however, been achieved by huge consumption of energy resources. Under the background of a new round of urbanization and economic development, the issue of energy consumption will become increasingly important, and could probably become the bottleneck of urbanization and economic development. Thus, considering the challenges of curbing fossil energy consumption while maintaining development, it is necessary to investigate the relationship between urbanization, economic growth and energy consumption for developing energy conservation and emission reduction policy [5].

While urbanization is found to have a positive and statistically significant impact on CO2 emissions, it may affect forecasting models and climate change policy. Energy and environmental policies that omit the impact of urbanization on CO2 emissions will likely lead to inaccurate outcomes making sustainable development goals more difficult to achieve. If urbanization is found to have a negative and statistically significant impact on CO2 emissions then this will make sustainable development goals easier to achieve.

In general, the approach EKC examines CO2 emissions as a dependent variable in a function that considers economic growth and the role of economic growth as repressors (independent variables). According to this feature, the EKC specific hypothesis states that when economic growth increases, emissions and increase to a level of economic growth threshold are reached, then the CO2 emissions begin to decline.

The increased concerns about climate change have made renewable energy an important topic of research. Several researchers have used different methods to examine the relationships between renewable energy consumption, economic growth of individual and groups of countries and to analyze the environmental effects of energy policies. Previous studies have analyzed carbon emission savings, using renewable energy usage as an individual source or in combination with traditional sources of energy (e.g., hybrid plants) in connection with lifecycle analysis methods. It is shown that after a certain period, economic growth leads to the promotion of environmental quality. In addition, in order to further determine the direction of the causal relationship between urbanization, renewable energy consumption and CO2 emissions that occurs in EU's development process, recent research that contains time series data is needed. Moreover, studies are limited in regarding urbanization as a shift factor when estimating interactive relationships between variables.

The purpose of this paper is to investigate the impact of urbanization on CO2 emissions for a panel of EU countries. Empirical models are estimated using heterogeneous panel regression techniques. The long-run relationship is studied using the DOLS, FMOLS technique and Granger causality tests. The paper is organized as follows. Section 2 briefly reviews the relevant literature. Section 3 presents the theoretical framework, specifies the model and the empirical analysis. Section 4 discusses the main results and Section 5 is conclusions.

2. Literature

Although urbanization is often discussed in the context of economic modernization, it is a demographic indicator that increases urban density and transforms the organization of human behaviour, which affects energy use patterns [6]. The existing literature points to three theories (ecological modernization, urban environmental transition and compact city theories) that are useful for explaining how urbanization can impact the natural environment.

The theory of ecological modernization details how urbanization is a process of social transformation which is an important indicator of modernization. As societies evolve from low to middle stages of development, environmental problems may increase because in these stages of development, economic growth takes priority over environmental sustainability. As societies continue to evolve to higher stages of development, environmental damages become more important and societies seek ways to make their societies more environmentally sustainable. The damaging impact of economic growth on the environment may be reduced by technological innovation, urbanization, and a shift from a manufacturing- based economy to a service-based economy [7], [8].

The traditional EKC hypothesis argued the existence of an inversely U-shaped curve relationship between environmental quality and per capita income [9]. Some empirical studies suggested an EKC hypothesis between demographic factors and environmental quality, providing evidence to support of the existence of an inverted U-shaped relationship between urbanization and CO2 emissions. The empirical relationship between urbanization and CO2 emissions has been studied by a number of authors. In one of the earliest studies, Parikh and Shukla [10] used a data set of 83 developed and developing countries for the year 1986 to investigate the impact of urbanization on energy use and toxic emissions. They found that urbanization has a positive and significant impact on CO2 emissions, CH4 emissions, and CFC emissions. In particular, they find CO2 emissions elasticity of urbanization of 0.036.

In a panel data context, Shi [11] found a relationship between population changes and carbon dioxide emissions in 93 countries over the period from 1975 to 1996. He found that the impact of population on emissions varies with the levels of affluence and has been more pronounced in lower-income countries than in higher-income countries. Similarity, using panel data, York et al. [12] used a cross section of 137 countries to test a relationship between urbanization and CO2 emissions. They showed evidence that increases in urbanization lead to increases in CO2 emissions. Cole and Neumayer [13] used a panel of 86 countries to empirically examine the relationship between urbanization, other demographic factors and environmental quality. Their findings showed that urbanization has a positive effect on the increase of carbon emissions. For European Union member countries, Martinez-Zarzoso et al. [14] studied the effect of population growth on carbon emissions covering the period 1975-1999. Their findings indicated that population growth is positively linked to the increase of carbon emissions, and that environmental impacts are smaller in relatively developed member countries.

In another study, Poumanyvong and Kaneko [6] used a Stochastic Impacts on Population, Affluence and Technology (STIRPAT) model to investigate the impact of urbanization on CO2 emissions in 99 countries over the period 1975 to 2005. A variety of panel regression techniques are used, but the empirical approaches are all static in nature. They found that urbanization has a positive and significant impact on CO2 emissions for each income group but its impact is greatest for the middle income group of countries. Liddle and Lung [15], used a panel data set of 17 developed countries followed over 10, 5 year periods, find a positive but insignificant impact of urbanization on CO2 emissions when aggregate carbon dioxide emissions are used as the dependent variable. Urbanization has a positive and statistically significant impact on CO2 emissions when CO2 from transport is used as the dependent variable.

Based on a panel data of 69 countries, Sharma [16] presented evidence that the effect of urbanization on the increase of carbon emissions is negative for all the three panels of high-, middle- and low-income countries. Martinez-Zarzoso and Maruotti [14] studied the effect of urbanization, with concern for heterogeneity in the development stage across countries. Their findings strongly supported the presence of an inverted U-shaped curve nexus between urbanization and CO2 emissions. Zhu et al. [17] applied a semiparametric panel model to examine the urbanization and CO2 emissions nexus within the STIRPAT framework, revealing the inverted U-shaped curve nexus between variables for a panel of 20 emerging countries, with only a certain level of urbanization.

Accordingly, the studies incorporate urbanization and energy consumption variables into models to explore potential Granger causality from urbanization to carbon emissions. Hossain [18] performed a multivariate causality framework to investigate the dynamic relationship for emerging industrialized countries, find a positive causal relationship from urbanization to CO2 emissions. For seven regions across the world, Al-mulali et al. [19] explored the long-run bidirectional link between the variables and discovering a positive relationship in 84% of countries under study. They used the panel model to study the nexus between variables for the Middle East and North Africa (MENA) countries, finding evidence of long- and short-run bidirectional causalities between the urbanization and CO2 emissions variables. Also, based on the dynamic ordinary least squares test, the significance and magnitude of elasticities of urbanization for CO2 emissions were seen to vary between countries, because of their income levels and development stages.

Energy performs a key to sustainable development. There are a number of studies that have been tried to find the direction of causality between renewable energy, income, and environmental degradation, but the results are mixed and the specific country.

Recently, the causal relationship between an environmental indicator economic growth, renewable energy consumption and CO2 emissions started to be investigated in the literature of energy economics. In addition, there are a few studies that have examined the causal relationship between CO2 emissions as a dependent variable, renewable and /or non-renewable energy consumption and output. However, limited research has been conducted on the nexus between renewable energy sources, economic growth and CO2 emissions.

Using a sample of Group of 7 (G7) countries, Sadorsky [20] investigated the relationship between renewable energy consumption, income, oil prices and CO2 emissions during period from 1980-2005. The results showed that an increase in real per capita GDP emissions contributes CO2emissions in the long-run. In a panel data analysis, Marrero [21] conducted for 24 EU countries using renewable energy consumption and GHG emissions, since it was expected that greater use of renewables in final energy consumption would eventually lower GHG emissions in the world. For OECD countries, Shafiei and Salim [22] showed that renewable energy consumption decreases CO2 emissions, while non-renewable energy consumption increases these CO2 emissions.

3. Data, Model and Econometric Methodology

3.1 Data

The dataset is a panel of EU countries followed over the years 1992–2014. The list of countries includes: Belgium, Czech Republic, Germany, Finland, France, Italy, Netherlands, Poland, Portugal, Romania, Spain, Sweden, and United Kingdom. The sample was restricted to all countries for which data are available during this period.

In the empirical analysis, CO2 is the CO2 emissions (metric tons of carbon dioxide emissions), GDP is the natural log of real per capita GDP (GDP per capita, in constant 2005 US dollars), renewable energy consumption (REN) is proxy electricity production from renewable sources, excluding hydroelectric (metric tons of oil equivalent), and Urbanization level represents the share of urban population to total population (measured by the fraction of the population living in urban areas). Following (Poumanyvong and Kaneko [6], and Martinez-Zarzoso and Maruotti [14] the technology variable measured using energy intensity. Intensity is the natural log of total energy use per dollar of GDP (energy use in kg of oil equivalent relative to GDP, constant 2005 US dollars). All variables are obtained from the WDI [23].

3.2 Model

Following other authors, a Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model is used to investigate the relationship between urbanization and CO2 emissions ([6], [14]). The STIRPAT model is based on the Influence, Population, Affluence, and Technology (IPAT) model developed by Ehrlich and Holdren [24]. The IPAT model relates environmental impact to population, affluence (consumption per capita), and technology.

$$I = P \times A \times T \quad (1)$$

The IPAT model has been criticized as 1) being primarily a mathematical equation or an accounting identity which is not suitable for hypothesis testing, and 2) assuming a rigid proportionality between the variables. In response, Dietz and Rosa [25] proposed a stochastic version of IPAT.

$$\mathbf{I_{it}} = \boldsymbol{\alpha_i P_{it}^{\beta} A_{it}^{\gamma} T_{it}^{\delta} e_{it}} \qquad (2)$$

Product (GDP), REN shows renewable energy consumption, URB is the urban population and EI is energy intensity.

Since the model is specified in natural logarithms, the coefficients of the explanatory variables can be directly interpreted as elasticities. The time effects, ıt can be considered as a proxy for all the variables that are common across countries but which vary over time. Within the context of decomposition analysis, these effects are sometimes interpreted as the effects of emissions-specific technical progress over time [26].

3.3. Econometric Methodology

Cross-Section Dependence (CD) Test Cross-Section Correlations of the Residuals in ADF (p) egressions. Two second-generation panel unit root tests are employed to determine the degree of integration in the respective variables. The Pesaran [27] panel unit root test does not require the estimation of factor loading to eliminate cross-sectional dependence.

Specifically, the usual ADF regression is augmented to include the lagged cross-sectional mean and its first difference to capture the cross-sectional dependence that arises through a single-factor model. The null hypothesis is a unit root for the Pesaran [27] test. The bootstrap panel unit root tests by Smith et al. [28] utilize a sieve sampling scheme to account for both the time series and cross-sectional dependence in the data through bootstrap blocks. All four tests by Pesaran are constructed with a unit root under the null hypothesis and heterogeneous autoregressive roots under the alternative hypothesis.

The unit root tests that assume cross-sectional independence can have low power if estimated on data that have cross-sectional dependence. Given the unit root test results, we investigate the presence of cointegration within a heterogeneous panel context using Padroni’s methodological approach [29] .The mixture of I(0) and I(1) variables indicates that standard panel regression techniques won't be applicable in this case. Consequently, modelling is carried out using recently developed techniques for heterogeneous panels that are robust to cointegration and cross-sectional dependence ([30], [31]). Levin et al. [32] proposed a panel unit root test based on ADF test. Given that each variable contains a panel unit root. To obtain the long-run estimates, the panel DOLS and FMOLS are used. Since OLS estimate is inconsistent in time series data cointegration, polarization could be reduced by the magnitude of the cross section. Resolution methods are either using fully modified OLS or dynamic OLS as the estimation method. FMOLS is a nonparametric estimation is able to handle the problem of serial correlation. The estimation DOLS and FMOLS methods were mostly developed by Pedroni [33].

4. Empirical results

Table 1 presents descriptive statistics of the variables used in the analysis, for each country.

Table 1 Descriptive statistics of the variables for the selected EU countries

		Mean.	Median	Min.	Max.	St. Deviation
Belgium	CO2	10.39475	10.64264	8.849400	11.62383	0.933547
	GDP	34820.31	35384.22	28862.24	38557.27	3287.754
	REN	7790.059	7986.524	6850.664	8683.671	531.3738
	URB	97.25222	97.29200	96.54200	97.81800	0.388434
	EI	0.178870	0.178000	0.147000	0.206000	0.017754
ch Republic	CO2	11.59074	11.89684	13.43793	10.30516	0.857473
	GDP	12305.21	11942.00	15170.15	9094.607	2214.498
	REN	5941.078	6074.849	6528.530	5032.404	469.1348
	URB	73.85422	73.74000	75.03000	73.01900	0.619565
	EI	0.219174	0.226000	0.293000	0.164000	0.040420
Germany	CO2	9.887596	9.976400	8.804000	11.06330	0.707168
	GDP	34571.16	34298.97	29884.96	39717.70	3099.177
	REN	6841.106	6900.780	6244.960	7270.153	379.0267
	URB	73.64309	73.36000	73.06000	75.09400	0.631916
	EI	0.132087	0.130000	0.106000	0.150000	0.015225
Finland	CO2	11.01303	10.72952	9.415520	13.26110	1.040886
	GDP	35236.89	36714.34	25590.25	42415.08	5515.465
	REN	15327.08	15687.19	12514.10	17212.95	1305.511
	URB	82.43196	82.63800	80.12800	84.08600	1.180884
	EI	0.231652	0.230000	0.196000	0.283000	0.027331
France	CO2	5.861071	5.976830	5.185040	6.344930	0.390967
	GDP	33234.23	33898.63	28482.49	36073.52	2644.934
	REN	7206.321	7335.523	6453.001	7735.787	397.3285
	URB	76.69891	76.63200	74.40100	79.28900	1.557454
	EI	0.145652	0.148000	0.124000	0.165000	0.012481
Italy	CO2	7.490765	7.573030	6.702560	8.216490	0.532400
	GDP	30150.09	30363.99	26823.96	32830.74	1803.962
	REN	5235.665	5397.741	4303.645	5833.450	492.7939
	URB	67.62304	67.50100	66.74200	68.82100	0.656092
	EI	0.106870	0.109000	0.093000	0.112000	0.005075
Netherlands	CO2	10.54740	10.54069	11.27785	10.06449	0.327560
	GDP	39550.75	40138.98	45148.95	31799.66	4316.240
	REN	6556.845	6751.122	7226.070	5441.655	561.8667
	URB	80.26796	80.34100	89.91000	70.22300	6.378362
	EI	0.141043	0.138000	0.167000	0.120000	0.014095

		Mean.	Median	Min.	Max.	St. Deviation
Poland	CO2	8.367714	8.335790	7.711750	9.246720	0.471688
	GDP	7726.962	7319.109	4508.505	11304.62	2153.435
	REN	3416.377	3324.471	2961.396	3899.177	322.9733
	URB	61.31809	61.44900	60.56800	61.78700	0.384182
	EI	0.205174	0.189000	0.129000	0.332000	0.063806
Portugal	CO2	5.385032	5.243740	4.690090	6.412900	0.614412
	GDP	17769.74	18365.50	14750.05	19489.27	1542.619
	REN	4124.197	4375.732	2803.202	4959.094	771.1264
	URB	56.18591	56.28700	49.13000	62.90800	4.255917
	EI	0.109087	0.110000	0.096000	0.117000	0.006403
Romania	CO2	4.594643	4.447220	3.918410	5.603080	0.529275
	GDP	4445.918	4039.181	3087.518	6195.836	1150.454
	REN	2342.953	2328.794	1935.561	2639.033	212.4776
	URB	53.55735	53.56700	52.78000	54.39300	0.483271
	EI	0.214739	0.222000	0.128000	0.325000	0.062089
Spain	CO2	6.677613	6.368310	5.594720	8.097060	0.871618
	GDP	24226.27	25296.68	19447.84	27661.04	2683.608
	REN	5160.259	5573.401	3654.483	6111.219	845.5738
	URB	77.10000	76.77800	75.61000	79.35500	1.222886
	EI	0.113261	0.119000	0.093000	0.122000	0.009026
Sweden	CO2	5.754420	5.747030	4.704370	6.434230	0.400844
	GDP	39719.84	40488.75	30367.84	46061.43	5578.341
	REN	15158.48	15410.70	14030.16	16020.98	563.5155
	URB	84.37709	84.19600	83.36100	85.66500	0.645098
	EI	0.184043	0.183000	0.141000	0.233000	0.030666
United Kingdom	CO2	8.631500	8.987430	7.085730	9.659400	0.867973
	GDP	36473.36	38393.25	28386.41	41567.28	4316.915
	REN	5823.457	5831.958	5380.264	6270.984	308.8981
	URB	79.73909	79.33900	78.17200	82.34500	1.409316
	EI	0.120565	0.118000	0.082000	0.166000	0.025605

WDI (World Development Indicators) online database

The CO_2 emissions are in Czech Republic is the highest and Romania has the lowest CO_2 emissions for the period 1992-2014. Additionally, Finland has the highest and Romania has the lowest renewable energy consumption. Belgium is the highest urbanization and the lowest urbanization is in Romania for the EU countries.

4.1 Cross-Sectional Test

The CD tests indicate that the series exhibits cross-sectional dependence. Our empirical study starts with examining the existence of cross-sectional dependency across the countries in concern. To investigate the existence of cross-sectional dependence, we carried out four different tests (CDBP, CDLM, CD and LM_{adj}) and illustrate the results in Table 2.

Table 2 Cross–sectional dependence

Test	Statistic	Prob
CD_{BP}	193.3368**	0.0000
CD_{LM}	8.193500**	0.0000
CD	7.898046**	0.0000
LM_{adj}	-3.242048**	0.0012

** indicates significance at the 0.5 level.

The results reported uniformly reject the null hypothesis of cross-section independence, demonstrating the cross-sectional dependence in the data given the statistical significance of the CD statistics. The residuals are tested for cross-sectional dependence. It is important to test for stationarity in the residuals because residual stationarity is an important part of a good fitting econometric model. Applying the CD test to the regression residuals provides strong evidence of cross-section dependence in each specification.

It is clear that the null of no cross-sectional dependency across the countries was strongly rejected at the conventional significance levels, implying that the DOLS, FMOLS methods are more appropriate than a country - by -country OLS estimation.

4.2 Panel Unit Root Tests

Table 3 shows the results of Unit root tests Levin, Lin &Chu [32] and Im, Peseran & Shin [34] for panel model.

Table 3 Panel unit root tests

	LnCO2	Ln GDP	Ln GDP^2	Ln REN	Ln URB	Ln EI
Level						
Levin, Lin& Chu t*	0.1741	3.96871**	3.65260**	-3.95315**	-17.6690**	1.08647
Im, Pesaran and Shin W-stat	1.05504	0.33433	0.50060	-0.72906	-3.75434	5.79935
ADF - Fisher	18.9256	18.2429	16.9767	31.5420	151.809	3.08837

Chi-square						
PP - Fisher Chi-square	26.3535	16.8503	16.3071	33.5079	373.276	3.26950
Level 1						
Levin, Lin& Chu t*	6.13480**	96385**	.09829**	3.88406**	3.20396	7.46366**
Im, Pesaran and Shin W-stat	7.98585**	78311**	.83148**	5.76555**	0.05299	8.53291**
ADF - Fisher Chi-square	12.632*	1.1166**	.7301**	4.3128**	29.3540	120.388**
PP - Fisher Chi-square	73.866**	35.678**	33.115**	84.733**	114.327**	278.183**

Critical value is at the 5% level, significance denoted by (**).

All variables are not static at significant at 5% according to the test results. They are static when first differences are taken, I (1). Thus, from all tests, we can conclude that each of the variables contain a unit root panel. These tests clearly indicate that five of the series are first difference stationary.

4.3. Panel Long-Run Estimates

To estimate panel data, the DOLS, FMOLS methods is used successively. Table 4 shows the results of EU countries.

Table 4 Panel long-run equation DOLS, FMOLS

	DOLS			FMOLS		
Dependent Variable: CO2	Coefficient	t-Statistic	Prob.*	Coefficient	t-Statistic	Prob.*
Ln GDP	1.87**	6.270744	[0.0000]	1.85**	126.8039	[0.0000]
$LnGDP^2$	-0.04**	-3.189449	[0.0016]	-0.09**	-3.888660	[0.0001]
Ln REN	-0.12***	-1.639027	[0.1023]	-0.18**	-9.009444	[0.0000]
Ln URB	-0.09	-0.585457	[0.5587]	-0.08**	-32.12807	[0.0000]
Ln EI	1.15**	17.24939	[0.0000]	1.12**	131.8817	[0.0000]
R-squared	0.984265			0.837884		

Note: **, *** show significant at 5% and 10% level.

All the coefficients are statistically significant at the 0.05 and 0.1 level of significance, except urbanization in DOLS method. The renewable energy coefficients (REN), and urbanization (URB) have a negative impact and energy intensity (EI) has a positive impact on CO2 emissions. The estimated regression of CO2 emission functions appears to fit the data well with more than 98 percent of the variation in CO2 emissions explained by the DOLS (R-squared 0.984265) and more than 83 percent of the variation in CO2 emissions explained by the FMOLS (R-squared 0.837884).

The signs of the coefficients per capita GDP and its squared form indicate the shape of a Kuznets Curve. The statistical significance of the square of per capita real income rules out the suggestion that output increases monotonically with the level of CO2 emissions. Hence, the results seem to provide support for the EKC hypothesis that the level of environmental pollution initially increases with income until it reaches its stabilization point then decreases. In other words, our results show that the inverted- U shape is applicable for EU countries.

Our estimated coefficient shows that pollution decreases with renewable energy consumption. Under DOLS estimates, a 1% increase in renewable energy consumption decreases CO2 emissions by 0.12%, while a 1% increase in renewable energy consumption decreases CO2 emissions by 0.18% in FMOLS estimates. Consequently, the results showed that carbon emission is reduced through power generated by renewable energy sources. There is an extensive literature regarding the potential of carbon saving using renewable energy technologies from 1992 to 2014 in the EU countries.

The result shows an increase in rate of CO2 emissions in relation to the variables of energy patents and environmental tax. In addition, considering that we estimated our both model from 1992 to 2014, and the financial crisis occurred within this period, the EU countries have to reduce expenditures for renewable energy, and coal-fuelled power plants restarted operations due to the lower unit cost compared with imported crude oil and natural gas.

As expected, the increase of energy intensity results in greater increases pollution for both methods in EU-13 counties. According to Nordhaus [35], it is expected that energy conservation and energy efficiency induced innovation would lead to a reduction in carbon intensity per unit of output, but the cumulative effect might be larger in the long term. Time trend showed a decreasing rate of per capita CO2 emissions. It indicated that its growth rate is reduced over time. The amount of CO2 emissions is increasing; because the amount of production and consumption is increasing. However, the rate is decreasing because of the effects of technological change, productivity, and energy use efficiency. This finding is consistent with Popp [36], who investigated the gradual process of the diffusion and adoption of new technologies. It is also consistent with the implications of energy efficiency technologies for climate policy, as discussed by Jaffe et al. [37].The long-run population elasticities are -0.09 and -0.08, respectively. Since urbanization is found to have negatively statistically significant impact on CO2 emissions, the energy and environmental polices formulated without considering the effects of urbanization on CO2 emissions will probably meet their stated objectives. The results are consistent with Sharma [16] which is constructed based on the income levels of 69 countries show that urbanization has a negative impact on CO2 emissions in all three groups (high income, middle income, and low income panels). The approach directs cross-sectional dependency across countries in the causality test; therefore, they can result in misleading conclusions about the nature of causality between variables. We find strong evidence for the existence of cross-section dependence among transition countries. The bootstrap panel Granger causality results are reported in Tables 5**.**

Table 5 panel granger causality test

	DLn CO2→ DLn URB	DLn URB→ DLnCO2	DL CO2→ DLn REN	DLn REN → DLn URB
Panel	0.21583 [0.8060]	4.78063** [0.0091]	2.12112 [0.1217]	0.54909 [0.5781]
Belgium	4.39723** [0.0301]	2.06985 [0.1587]	5.08120** [0.0196]	3.41412*** [0.0582]
Czech Republic	1.00630 [0.4212]	1.56502 [0.2453]	2.70185*** [0.0887]	1.44079 [0.2762]
Germany	1.46485 [0.2605]	10.4976** [0.0012]	2.79776** [0.0058]	2.92246*** [0.0828]
Finland	4.94542** [0.0213]	0.05751 [0.9443]	0.50156 [0.6148]	0.26276 [0.7722]
France	3.57811** [0.0439]	2.34525 [0.1204]	3.05531*** [0.0663]	1.29714 [0.3171]
Italy	2.43712 [0.1191]	0.92645 [0.4162]	1.67341 [0.2188]	0.68573 [0.5179]
Netherlands	4.32598** [0.0315]	2.27842 [0.1347]	2.84209** [0.0879]	0.23430 [0.7938]
Poland	0.37043 [0.6962]	1.89431 [0.1827]	0.14719 [0.8643]	1.16044 [0.3384]
Portugal	3.93493** [0.0408]	0.38597 [0.6860]	3.5513*** [0.0529]	1.93805 [0.1763]
Romania	0.35847 [0.7042]	0.66300 [0.5289]	0.57869 [0.5719]	1.95376 [0.1741]
Spain	2.12203 [0.1523]	1.74008 [0.2071]	1.02036 [0.3828]	0.83438 [0.4522]
Sweden	0.99042 [0.3931]	1.98112 [0.1703]	0.17434 [0.8416]	6.46268** [0.0088]
United Kingdom	5.04330** [0.0200]	0.13315 [0.8763]	0.70913 [0.5069]	1.80676 [0.1961]

Note: **, ***The statistical significance at the 5%, 10 % levels.
Denote x → y means x Granger causes y
Source: Author's Estimation using Eviews 9

The Results show panel Granger causality between urbanization, economic growth and CO2 emissions at the 5% and 10% significant level. There is a unidirectional causality from urbanization to CO2 emissions at the 5%, significant level for Belgium, Finland, France, Netherlands, Portugal and United Kingdom. A reverse relationship from CO2 emissions to urbanization is found for Germany. However, we find that neutral relationships exist for Czech Republic, France, Italy, Poland, Romania, Spain and Sweden. Also, there is a unidirectional causality from CO2 emissions to urbanization for EU countries. Signs of coefficients for all the countries are positive.

The panel Granger causality tests shows that the relationship between renewable energy consumption and CO2 emissions at the 5% and 10% significant level. There is a unidirectional causality from renewable energy consumption to CO2 emissions for Czech Republic, France, Netherlands and Portugal. A reverse relationship from CO2 emissions to renewable energy consumption is found for Sweden and a feedback hypothesis is not found for Belgium and Germany. However, we find that neutral relationships exist for Finland, Italy, Poland, Romania, Spain and United Kingdom. There is no causality between renewable energy consumption and CO2 emissions for EU countries.

Their results also revealed that countries with greater urban populations had much more significant bidirectional long-run relationships compared to countries with smaller urban populations. Using a panel data of countries at different income levels, Fan et al. [38] found different behaviour patterns can greatly influence environmental change. In other words, the impact of urbanization on CO2 emissions varies at different levels of development.

5. Conclusions

In this paper an analysis of the determinants of carbon dioxide emissions in EU countries during the period 1992 to 2014 has been conducted. In model, population is introduced as a predictor, together with per capita GDP, renewable energy consumption and the level of environmentally damaging technology, proxied with energy intensity. We have added urbanization as a predictor and used two estimation methods for estimating panel data framework. This paper uses a STIRPAT model to explore the impact that urbanization has on carbon dioxide emissions in EU counties. It is expected that urbanization will continue rising in EU economies and understanding how urbanization affects CO2 emissions is an important and timely topic to study. The results show in EU countries, the elasticity, emission-urbanization, is negative. This result has a very important policy implication: once urbanization reaches a certain level, the effect on emissions turn out to be negative, contributing to reduced environmental damage.

The findings show that there is statistical evidence in favor of the existence of an EKC (inverted-U) for per capita CO2 emissions in EU countries. The regulations in EU countries have not actually improved efforts to reduce their CO2 emissions. Accordingly, we conclude that policies to reduce fossil energy use and /or carbon emissions must go beyond promoting economic growth. This means that economic development itself cannot be expected to control CO2 emissions and /or environmental pollution. One of the implications of these results is that omitting the urbanization variable will have little impact on emissions reduction strategies or sustainable development policies. The theories of ecological modernization and urban environmental transition recognize that urbanization can have both positive and negative impacts on the natural environment with the net effect is difficult hard to determine a priori. Higher urbanization is associated with higher economic activity. The higher economic activity generates higher wealth and wealthier residents often demand more energy intensive products (automobiles, air conditioning, etc.) which can increase CO2 emissions. Wealthier residents are also likely to care more about the environment. Increased urbanization also helps to facilitate economies of scale for public infrastructure and these economies of scale lead to lower environmental damages.

This implies that much improvement in energy efficiency and / or a change in the energy mix towards cleaner energy technologies (renewable energies) could be very important in achieving the environmental objectives. Since the contributions limited in terms of energy resources and CO2 emissions are very low compared to conventional energy sources in the chain of renewable energy, the deployment of renewable energy instead of fossil fuels could contribute to efforts climate mitigation.

Some alternative measures include optimizing industrial structures, energy restructuring, improving energy efficiency and developing low-carbon technology are necessary for EU decision makers to address energy security and sustainable economic growth and urbanization development.

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