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ORIGINAL PAPER

The causal trend of energy intensity and urbanization in emerging countries

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Abstract
Due to economic activities intensification associated with the developing countries, the relationship between population density and energy density in urban areas becomes an important issue in the energy studies. In this study, the relationship between energy intensity and urbanization is examined in 23 developing countries (Argentina, Brazil, Chile, China, India, Indonesia, Jordan, Malaysia, Mexico, Nigeria, Pakistan, Peru, Philippines, Hungary, Poland, Romania, Russia, South Africa, Thailand, Tunisia, Turkey, Ukraine, and Uruguay) over the period 1990–2015. The cointegration and causality relationships between variables are examined using Westerlund (2007) cointegration and Dumitrescu and Hurlin (2012) Granger causality tests. The cointegration test results revealed that there is no long-term relationship between variables. However, the Granger causality test results showed that there is a bidirectional causality relationship between energy density and urbanization, energy density and economic growth, economic growth and energy density in the short-term. Thus, the result posit a policy direction that could guide the governments of the respective economies especially on achieving a sustainable environment to avoid feasible consequence of trade-off between energy and population growth.

Keywords Energy · Urbanization · Economic growth · Developing economies · Sustainable development · Developing economies

1 Introduction

With the inreasing rate of population growth associated with the developing countries, the relationship between population density and energy density in urban areas becomes an important issue in the field of energy. Urbanization is an important indicator of development along with industrialization and modernization because devel-

Extended author information available on the last page of the article opment and modernization process acount for s social, economic and demographic transformations. Poumanyvong et al. (2012) emphasized that urbanization increases population and economic activities in urban areas that expands residential areas, and changes land use and land cover. In recent years, the share of cities in respect to the GDP has been increasing every year (Bilgili et al. 2017). Considering the increased economic activities associated with urban areas, urbanization process has an arguably remarkable association with energy use which isoften measured by energy intensity (Elliott et al. 2017). Energy intensification is a general measure of how much energy is used to produce a unit of economic output in a country or region. Energy intensity can give a general idea about the energy performance of an economy vis-a-vis energy efficiency (Liu & Xie, 2013; Hemmati, 2006; Pehlivanoglu et al. 2021).

Increase in economic activities in urban areas is associated with increase especially in energy demand (Zhou et al., 2011; Shahbaz et al., 2012; Koyuncu et al. 2021; Onifade et al. 2021). Precisely, previous studies have revealed several channels through which urbanization can affect energy use (Jones 1991; Madlener & Altar, 2011; Parikh and Shukla 1995). First, urbanization can affect energy use through its impact on production. Urbanization is associated with the concentration of economic activities in cities and metropolitan areas, which leads to economies of scale in production (Schneider and Enste 2000). Second, urbanization increases the amount of motor vehicles entering and leaving urban areas, affecting mobility and transportation, and thus this increase in traffic increases energy demand. Third, increasing urbanization increases the demand for infrastructure such as transportation (Umar et al. 2021). For example, as the infrastructure becomes denser in growing cities, the demand for energy-intensive products and materials increases (Sadorsky 2013). The fourth channel through which urbanization affects energy intensity is the change in the lifestyle and consumption patterns of newly urbanized societies, that tend to be more dependent on certain energy-intensive products such as air conditioners, refrigerators, and specialty items (Jones 1989). With urbanization, the sustainability of energy resources may be endangered. Most of the world's energy consumption is provided by fossil energy sources and these energy resources are likely to be depleted in the near future. Therefore, efficient use of these resources comes to the fore.

Given the above motivation and the perception of the aspects of urbanization, the research question of this study is derived from the objective of establishing the nature of relationship between urban population and energy intensification. While studies have been conducted to examine the impact of urbanization on energy use and environmental aspects, less is known about how urbanization affects energy intensity especially in the developing countries. In this study, the panel of 23 leading developing countries (Argentina, Brazil, Chile, China, India, Indonesia, Jordan, Malaysia, Mexico, Nigeria, Pakistan, Peru, Philippines, Hungary, Poland, Romania, Russia, South Africa, Thailand, Tunisia, Turkey, Ukraine, Uruguay) is considerted to examine the relationship between energy density and urbanization. Given this aforementioned objective, the impact of economic expansion on energy intensity is further investigated by conducting both cointegration and Granger causality estimations. Thus, the study contribute a novel insight to the existing literature on energy intensity and urban population expansion with the case of the emerging economies.

By providing an outlay of the other sections of the study, there is a clear presentation of the study insight. Thus, the other sections comprises of the related studies in Sect. 2, data and methodology outline in Sect. 3, discussion of the findings in Sect. 4, and the concluding remark in Sect. 5.

2 Related studies

Studies have been carried out to investigate the relationship between energy use and urbanization since the 1990s. For example, Jones (1991) investigate the direct mechanism by which urbanization affects energy use for cross-sectional data and found the long-term urbanization and energy use elasticity of 0.35. Similarly, Parikh and Shukla (1995) predicted the relationship between urbanization and increased resource consumption for some developing and developed countries between 1965 and 1987. The study emphasized that the elasticity of energy density compared to urbanization is 0.47. In the same study, while analysing the effects of urbanization on energy consumption for the panel of 78 developed and developing, Parikh and Shukla (1995) found that urbanization has positive effects on energy consumption.

Additionally, Ewing and Rong (2008) examined urbanization and residential energy use in the United States of America over the 1940–2000 while Sadorsky (2014) found a negative relationship between energy use and urbanization over the 1971–2008 for the panel of 18 developing countries. Mishra et al. (2009) examined the impact of urbanization on per capita energy use in a sample of Pacific Island economies. The findings revealed that urbanization has a negative effect on energy use in New Caledonia, but revealed a positive effect in Fiji, French Polynesia, Samoa and Tonga. Poumanyvong and Kaneko (2010) examined the effects of income, urbanization, industrialization and population on energy use in the panel of 99 countries for the period 1975–2005 and concluded that urbanization reduced energy use in low-income groups while increasing energy use in middle and high-income groups.

Furthermore, Al-Mulali et al. (2013) utilized the casse of the Middle East and North African countries for the period 1980–2009, Wang et al. (2014) considered the case of China for the period 1995–2011 and Angola for the period 1971–2009, and Solarin and Shahbaz (2013) determined that there is a bidirectional causality relationship between urbanization and energy. In addition, Liu and Xie (2013) analyzed the nonlinear relationships between energy intensity and urbanization by dealing with the period 1978–2010 at both national and macro-regional levels in China. As a result of the analysis, it has been determined that there is a nonlinear bi-directional causality relationship between energy density and urbanization in China. Meanwhile, Sadorsky (2013) analyzed the impact of income, urbanization and industrialization on energy intensity with mean group (MG) and common correlated mean group (CCMEG) estimators for the panel of 76 developing countries. Given the result of the analysis, it is revealed that increase in income decreases the energy intensity in the long term. Additionally, the result found that industrialization and urbanization positively affect the energy density in the long term. In the case of Rafiq et al. (2016), the investigation established the impact of urbanization and commercial openness on energy intensity in 22 emerging economies. Specifically, the result revealed that population density and economic well-being increased energy density.

Moreover, Elliot et al. (2017) discussed the direct and indirect effects of urbanization on energy use intensity in China for the period 1995–2012. In the study, and by using dataset for 30 provinces, it was determined that the effect of urbanization on energy density was positive. Similarly, Bilgili et al. (2017) examined the effects of urbanization on energy intensity for 10 Asian countries (Bangladesh, China, India, Indonesia, Malaysia, Nepal, Philippines, South Korea, Thailand and Vietnam) by using annual dataset between 1990 and 2014. According to the results, urbanization has a negative effect on the energy density in the short and long term. Additionally, the results of the study revealed that there is a bidirectional causality between urbanization and energy density.

3 Data and method

3.1 Data

The following model was created to examine the impact of developments on energy intensity and renewable energy consumption on economic growth.

$$EI_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 URB_{it} + \varepsilon_{it} \quad (1)$$

Energy intensity (EI), economic growth (GDP) and urbanization (URB) variables are respectively measured as the energy use GDP growth rate per unit (PPP $ per kg oil equivalent), real GDP growth per capita (unit as %), and city population / total population. An annual data for all variables were taken from the World Bank database over the period of period 1990–2015 such that the panel and country-specific descriptive statistics of the dataset are also provided.

3.2 Methodology

Examining whether there is cross-sectional dependence and heterogeneity in the data set is very important in determining the unit root and cointegration tests to be used. For this reason, cross-sectional dependency was examined by Breusch and Pagan (1980) LM test and Pesaran (2004) LM CD tests. The Swamy test developed by Pesaran and Yamagata (2008) was used to determine whether the slope coefficients were homogeneous.

The existence of a cointegration relationship between energy intensity, economic growth and urbanization was analyzed by Westerlund's (2007) cointegration test. The Westerlund (2007) cointegration test is a test that takes into account both cross-sectional dependency and heterogeneity. In addition, the causality relationships between variables were examined using the Dumitrescu and Hurlin (2012) causality test. İn general, the step-by-step procedure of the aforementioned estimation approaches are not provided in this text because of space limitation.

4 Findings

Given the descriptive statistics in Table 1, reveals positive skewness only for energy intensity while GDP and urbanization are negatively skewed in the panel examination. However, for country-specific observation, there is a spread of both positive and negative skewness of the indicators across the countries. For instance, positive skweness is only observed in Uruguay (for EI and GDP), Ukraine (for Urb), Turkey (for GDP), Thailand (for Urb), South Africa (for GDP), for Russia (for Urb), Romania (for GDP), Poland (for EI), Hungary (for EI and Urb), Philippines (for GDP and Urb), Peru (for EI and GDP), Pakistan (for GDP), Nigeria (for GDP and Urb), Jordan (for Urb), Indonesia (for GDP), India (for EI, GDP, and Urb), Chile (for EI), Brazil (for EI and GDP), and Argentina (for EI). It is also noted that Chile has the highest change in urbanization followed by Indonesia, Nigeria, and Malaysia while the highest deviation in GDP is also observed in Chile followed by India, Poland, Romania, China, and joinly by Russia and Ukraine. For energy intensity, the highest change over the investigation period happened in Romania and followed by Poland, Chile, Ukraine, Nigeria, Russia, and India.

Here, Table 2 contains the results of the tests performed to determine whether there is cross-sectional dependency in the model. Accordingly, the H_0 hypothesis, which states that there is no cross-sectional dependency, is rejected at the 1% significance level. This situation implies that a shock occurring in a developing country may affect other developing countries as well.

In Table 3, the results of the Swamy test used to determine whether the slope coefficients are homogeneous or not are presented. In addition, Table 3 show that the H_0 hypothesis, which states that the slope coefficients are homogeneous, is rejected at the 1% significance level. Therefore, the slope coefficients were determined to be country specific (heterogeneous) using Pesaran (2006, 2008). Because the variables include cross-sectional dependency and heterogeneity, the levels at which the variables are stationary were tested with the Pesaran (2007) Panel unit root (CADF) test.

In Table 4, CADF unit root results are reported. Accordingly, it was determined that the series were not stationary at the level, and when the first differences of the series were taken, they became stationary.

In addition, Table 5 shows the results of Westerlund (2007) ECM cointegration test. Accordingly, Ho hypothesis, which states that there is no cointegration relationship between variables, could not be rejected because the result is evenly divided between evidence of cointegration in G_a and P_t and no cointegration evidence in G_t and P_a. In other words, it was determined that the variables are not cointegrated.

The H_0 hypothesis of the Westerlund (2007) test states that there is no cointegration. The test is estimated using the constant in the model. 400 replications were applied for testing. However, a short-term causality relationships between variables whose cointegration relationship could not be determined were examined by Dumitruscu and Hurlin (2012) panel causality test and the results are reported in Table 6.

The test results revealed that there is a bidirectional causality relationship between energy density and urbanization, energy density and economic growth, and economic growth and urbanization in the short run. By implication, for instance, the present information about energy intensity can be predicted by using the historical infor-

Table 1 Descriptive Statistics (natural logarithmic)

	Variables	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis
Panel	EI	1.72	1.60	3.28	0.87	0.47	0.97	3.68
	GDP	8.40	8.63	9.60	6.36	0.81	-0.60	2.34
	URB	4.07	4.17	4.55	3.24	0.35	-0.70	2.41
Argentina	EI	1.51	1.51	1.69	1.41	0.07	0.75	3.18
	GDP	9.06	9.04	9.29	8.74	0.16	-0.08	1.95
	URB	4.49	4.50	4.52	4.47	0.02	-0.22	1.86
Brazil	EI	1.36	1.36	1.42	1.33	0.02	0.47	2.88
	GDP	9.16	9.10	9.39	8.96	0.14	0.41	1.76
	URB	4.40	4.41	4.45	4.30	0.04	-0.62	2.18
Chile	EI	2.38	2.31	3.05	1.90	0.30	0.64	2.68
	GDP	7.72	7.68	8.78	6.59	0.68	-0.01	1.80
	URB	3.66	3.67	4.02	3.27	0.23	-0.07	1.73
China	EI	1.46	1.46	1.58	1.33	0.07	-0.16	2.71
	GDP	9.22	9.21	9.60	8.69	0.27	-0.30	2.07
	URB	4.45	4.46	4.47	4.42	0.02	-0.79	2.15
India	EI	1.86	1.87	2.15	1.55	0.19	0.00	1.64
	GDP	6.85	6.80	7.47	6.36	0.35	0.18	1.79
	URB	3.35	3.35	3.49	3.24	0.08	0.21	1.79
Indonesia	EI	1.52	1.54	1.67	1.26	0.12	-0.70	2.48
	GDP	7.82	7.78	8.25	7.44	0.23	0.34	2.09
	URB	3.75	3.78	3.98	3.42	0.17	-0.47	2.02
Jordan	EI	1.65	1.68	1.83	1.44	0.11	-0.38	1.93
	GDP	8.02	8.02	8.23	7.77	0.14	-0.04	1.63
	URB	4.39	4.36	4.50	4.29	0.06	0.57	2.16
Malaysia	EI	1.67	1.69	1.75	1.54	0.06	-0.54	2.17
	GDP	8.91	8.89	9.30	8.42	0.24	-0.27	2.31
	URB	4.14	4.16	4.31	3.91	0.12	-0.42	1.95
Mexico	EI	1.46	1.47	1.58	1.32	0.07	-0.22	2.62
	GDP	9.10	9.11	9.21	8.95	0.08	-0.48	2.06
	URB	4.32	4.32	4.37	4.27	0.03	-0.10	1.87
Nigeria	EI	2.11	2.28	2.35	1.73	0.24	-0.36	1.37
	GDP	7.47	7.41	7.85	7.21	0.23	0.38	1.61
	URB	3.62	3.61	3.87	3.39	0.15	0.12	1.71
Pakistan	EI	1.64	1.68	1.73	1.49	0.07	-0.82	2.35
	GDP	6.79	6.73	6.99	6.61	0.12	0.23	1.55
	URB	3.51	3.51	3.58	3.42	0.05	-0.17	1.89
Peru	EI	1.05	1.02	1.27	0.87	0.11	0.25	2.07
	GDP	8.24	8.13	8.72	7.86	0.28	0.42	1.87
	URB	4.30	4.30	4.35	4.23	0.04	-0.33	1.77
Philippines	EI	1.42	1.51	1.64	1.11	0.21	-0.37	1.43
	GDP	7.49	7.42	7.87	7.28	0.18	0.64	2.16
	URB	3.83	3.83	3.85	3.81	0.01	0.18	1.93
Hungary	EI	1.71	1.69	2.00	1.43	0.19	0.08	1.58
	GDP	9.33	9.37	9.59	9.05	0.19	-0.19	1.39
	URB	4.20	4.19	4.26	4.17	0.03	0.70	1.96

mation of urbanization and vice versa. This is expected considering that increase

Table 1 (continued)

	Variables	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis
Poland	EI	1.91	1.86	2.47	1.42	0.33	0.31	1.83
	GDP	9.12	9.10	9.59	8.61	0.32	-0.09	1.72
	URB	4.12	4.12	4.12	4.10	0.01	-0.89	2.71
Romania	EI	1.78	1.82	2.31	1.25	0.34	-0.05	1.67
	GDP	8.74	8.65	9.18	8.38	0.28	0.24	1.43
	URB	3.98	3.98	3.99	3.97	0.01	-0.26	1.80
Russia	EI	2.39	2.43	2.67	2.12	0.21	-0.06	1.33
	GDP	9.03	9.06	9.37	8.61	0.26	-0.17	1.54
	URB	4.30	4.30	4.30	4.30	0.00	1.19	3.21
South Africa	EI	2.32	2.34	2.43	2.16	0.08	-0.52	2.16
	GDP	8.77	8.73	8.93	8.62	0.12	0.18	1.36
	URB	4.06	4.06	4.17	3.95	0.07	-0.02	1.78
Thailand	EI	1.64	1.67	1.73	1.50	0.07	-0.86	2.27
	GDP	8.29	8.26	8.66	7.83	0.24	-0.11	1.99
	URB	3.58	3.54	3.86	3.38	0.17	0.36	1.54
Tunisia	EI	1.40	1.42	1.49	1.27	0.06	-0.25	1.81
	GDP	8.07	8.06	8.37	7.71	0.23	-0.13	1.56
	URB	4.16	4.17	4.22	4.06	0.05	-0.51	2.27
Turkey	EI	1.29	1.31	1.35	1.08	0.07	-2.20	7.30
	GDP	9.11	9.02	9.54	8.81	0.22	0.42	1.96
	URB	4.19	4.19	4.30	4.08	0.07	-0.04	1.77
Ukraine	EI	2.92	2.99	3.28	2.47	0.26	-0.16	1.65
	GDP	7.85	7.94	8.29	7.43	0.26	-0.37	1.81
	URB	4.21	4.21	4.23	4.20	0.01	0.46	1.63
Uruguay	EI	1.09	1.09	1.22	0.98	0.06	0.27	2.47
	GDP	9.16	9.11	9.54	8.84	0.21	0.50	2.11
	URB	4.53	4.53	4.55	4.49	0.02	-0.31	1.82

Table 2 Cross-section Dependency Results

Cross-section Dependency Tests	Model	P - value
Breusch-Pagan LM	2987.899*	0.000
Pesaran scaled LM	121.5811*	0.000
Bias-corrected scaled LM	121.1211*	0.000
Pesaran CD	35.98721*	0.000

Note: * is the statistical significant at 1% level

Table 3 HomogeneityTest

Homogeneity test	Value	p-value
$\tilde{\Delta}$	8.41*	0.000
$\tilde{\Delta}_{adj}$	8.99*	0.000

Note: * is the statistical significant at 1% level

in urban population accounts for expansion of socioeconomic activites which are potentially propelled by energy use. Also, this explains the justification for observing a statistically significant bidirectional Granger causality between GDP and energy intensification. Obviously, this result align with the studies of Liu and Xie (2013),

Table 4 CADF Panel Unit Root Test

Variables Variables Variables	t-bar	Z[t-bar]	Prob-ability Value
LEI	-2.281	0.150	0.560
LGDP	-2.300	0.050	0.520
LURB	-1.540	3.972	0.999
DLEI	-3.306	-5.135	0.000*
DLGDP	-2.656	-1.786	0.037**
DLURB	-2.913	-3.110	0.001*

Note: * and ** are the statistical significant at 1% and 5% level respectively. Whereas, the GDP, EI, and URB are the Gross Domestic Product, Energy Intensity, and urbanization respectively

Table 5 Results of Westerlund ECM Panel Cointegration Test

Model $EI_{it}=f(GDP_{it}, URB_{it})$				
Statistics	Value	Z-value	p-value	Robust p-values
G_a	-2.536*	-3.873	0.000	0.140
G_t	-4.592	2.472	0.993	0.780
P_t	-8.275***	-1.495	0.067	0.740
P_a	-4.241	0.022	0.509	0.720

Note: * and *** are the statistical significant at 1% and 10% level respectively. Whereas, the GDP, EI, and URB are the Gross Domestic Product, Energy Intensity, and urbanization respectively

Table 6 Dumitrescu and Hurlin (2012) Panel Causality Test

Null hypothesis	W-Stat	Zbar-Stat	p-value
DLGDP is not the cause of DLEI	6.844	8.786	0.000*
DLEI is not the cause of DLGDP	3.929	3.229	0.001*
DLURB is not the cause of DLEI	4.754	4.802	0.002*
DLEI is not the cause of DLURB	5.701	6.607	0.004*
DLURB is not the cause of DLGDP	7.398	9.843	0.000*
DLGDP is not the cause of DLURB	8.393	11.73	0.000*

Note: * is the statistical significant at 1% level. Whereas, the GDP, EI, and URB are the Gross Domestic Product, Energy Intensity, and urbanization respectively

Al-Mulali et al. (2013), Solarin and Shahbaz (2013), Wang et al. (2014), Bilgili et al. (2017). In essence, the pre-historical information of either of the variables are useful at explaining the present dynamics of the other variables.

5 Conclusion and policy perspective

According to the 2012 United Nations Environment Program, urban areas, which currently occupy about 3% of the world's surface area, consume about 75% of natural resources. Therefore, growing urban environments potentially lead to the issues of rising cost, population density, and infrastructure concentration, thus suggesting a challenge to achieving efficiency of energy resources utilization. The ability of both developed and developing countries to reduce the intensity of energy use will play an important role in determining the sustainable growth capacity of the world in the future. One of the factors that is thought to be important in shaping energy density is urbanization.

In this study, the relationships between urbanization and energy intensity were examined using the data of 23 developing countries for the period 1990–2015. As a result of the cointegration test, it is revealed that the variables are not cointegrated. This may be partly due to the upward trend in the adoption of clean technologies in these increasingly urbanized developing economies. Then, the causality relationship between the variables was investigated and the evidence revealed that there was a bidirectional causality relationship between energy intensification and urbanization, energy density and economic growth and urbanization in the short term. Causality test results reveal that the increase in urbanization rate provides a two-way interaction with energy intensity. Likewise, economic growth is also found to Granger cause energy demand and energy density. Thus, suggesting that policies aimed at accelerating urbanization and economic growth will also affect energy density.

5.1 Policy recommendation

It is an important issue to understand how urbanization affects energy intensity especially as urban population expentedly continues to increase in developing countries. Reducing energy intensity is one way to partially reduce the impacts of climate change, oil and energy security issues. Moreover, urbanization increases economic activity with a higher consumption and production, but urbanization also leads to economies of scale and can provide opportunities for increased energy efficiency. Therefore, sustainable urbanization policies, which mainly consider energy efficiency, are very important to successfully manage the pace of urbanization process in the developing economies.

As a result, decision makers in developing countries need to implement policies that are geared for promoting energy efficiency in urbanization and growth processes. An example of such policies could be to provide subsidy to clean energy/technology end users or tax cut on clean energy and energy efficient technology producers and importation of related technology components in order to enhance affordability and accessibility. If well implemented, the policy should reduce the energy utilization arising from the urbanization process and economic activities. Specifically, such mechanisms should force urban production to embrace innovative apporaches and guide producers to use more environmentally friendly technologies and as well increasingly promote the re-use of material resources.

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