Print ISSN: 2288-4637 / Online ISSN 2288-4645
doi:10.13106/jafeb.2021.vol8.no3.0079

Relationships between Urbanization, Economic Growth, Energy Consumption, and CO_2 Emissions: Empirical Evidence from Indonesia

Abdul BASHIR[1], Didik SUSETYO[2], Suhel SUHEL[3], Azwardi AZWARDI[4]

Received: November 20, 2020 Revised: January 25, 2021 Accepted: February 03, 2021

Abstract

This study aims to investigate the relationship between urbanization, economic growth, energy consumption, and CO_2 emissions in Indonesia. The data used in the study are time-series data for the period 1985–2017; the data utilized are sourced from World Development Indicators obtained on the World Bank database. The method uses a quantitative approach that applies the vector error correction model based on the Granger causality test. The empirical results reveal that, in the short run, there is evidence that urbanization and energy consumption can causes CO_2 emissions, and they also prove that urbanization can cause energy consumption. Also, other findings prove the existence of long-run relationships flowing from energy consumption, economic growth, and CO_2 emissions toward urbanization, as well as the existence of the relationship flowing from urbanization, economic growth, and CO_2 emissions towards energy consumption. The results of testing the relationship between economic growth and CO_2 emissions reveal that the environmental Kuznets curve hypothesis is proven in Indonesia. Thus, policies are needed to limit the impact of urbanization through high awareness-raising to maintain environmental quality and greater use of energy. Also, energy conservation policies are needed in all sectors, especially the electricity, industry, and transportation sectors.

Keywords: CO_2 Emissions, Economic Growth, Energy, Urbanization

JEL Classification Code: C32, O13, O44, P28, Q56

1. Introduction

The economic progress and technological development at this time have posed great challenges to every country in the world. Every country is massively improving competitiveness in both the economy and trade. Often developing countries ignore the environmental impact as a result of the increase of relatively large energy consumption. Excessive use of fossil fuels by industry and factories can cause high concentrations of carbon dioxide emissions. Environmental problems become very important when climate change occurs globally. As revealed by Ahuja and Tatsutani (2019) and Gielen et al. (2019), almost every country seeks to increase economic growth by relying on industrialization, while the use of technology in the industrial sector still uses fossil energy, which has a large impact on environmental degradation (Kurnia et al., 2020).

Economic development that occurs in an area can have implications for accelerating the flow of urbanization and increasing energy consumption. The link between urbanization, economic growth, and CO_2 emissions has proven to be very strong in several studies (Aguir Bargaoui, Liouane, & Nouri, 2014; Lin, Sun, Marinova, & Zhao, 2017; Lin, Zhao, & Marinova, 2009; Liu, Yan, & Zhou, 2016; Wang, Zhao, Zheng, & Hu, 2017; Zhou & Liu, 2016). Therefore, urbanization is believed to be able to encourage greater environmental degradation. Urban communities can change the environment through the consumption of energy, water, food and land. In turn, increasingly polluted urban environments affect the health and quality of life of urban populations.

[1]First Author and Corresponding Author. Lecturer, Department of Economics, Faculty of Economics, Universitas Sriwijaya, Indonesia [Postal Address: Jalan Inderalaya-Prabumulih, Rektorat Kampus Universitas Sriwijaya, KM. 32, Inderalaya, Ogal Ilir, Sumatera Selatan, 30662, Indonesia] Email: abd.bashir@unsri.ac.id
[2]Professor, Department of Economics, Faculty of Economics, Universitas Sriwijaya, Indonesia. Email: didiksusetyo@unsri.ac.id
[3]Lecturer, Department of Economics, Faculty of Economics, Universitas Sriwijaya, Indonesia. Email: suhel@fe.unsri.ac.id
[4]Associate Professor, Department of Economics, Faculty of Economics, Universitas Sriwijaya, Indonesia.
Email: azwardi_unsri@yahoo.com

Data released by the World Bank show that the rate of economic growth in Indonesia during 1985–2017 grew positively with an average growth of 5.07%; this is in line with urban population growth, which averaged 3.86 percent, energy consumption 5.26 percent, and CO_2 emissions 5.90 percent per year (Figure 1). The trend in energy consumption is expected to drive economic growth and increase CO_2 emissions in Indonesia. The extreme growth trend of 1998 was caused by the global economic crisis, ironically when the environment improved as a result of slowing economic activity impacting on lower energy consumption.

The CO_2 emissions produced by Indonesia are mostly caused by changes in land use and forest and peat fires; burning fossil fuels account for about 19 percent of total emissions. Indonesia is the largest contributor to forest-based emissions globally and most of its emissions come from land use, land-use change, and forestry. However, as Indonesia's population and wealth continue to grow substantially, the source of emissions will likely also changed, similar to other major emitters. According to estimates from the World Resources Institute, Indonesia's energy sector is likely to be the largest source of emissions in 2026–2027.

This study can be related to the environmental Kuznets curve (EKC) hypothesis. Several studies in the last two decades have examined the theoretical EKC hypothesis, such as that conducted by Stokey (1998) and Kijima et al. (2010) explaining the EKC hypothesis within the framework of optimal growth theory. This study assumes that pollution is the output produced from the process of production and capital accumulation. The research also explains how to improve social welfare and environmental regulations in reducing pollution emissions. A study conducted by Dinda (2005) uses the framework of an endogenous growth model to examine the types of environmental pollution; the model explains how to reduce environmental pollution through an optimal increase in commodity production assuming the economic conditions of the region continue and grow.

Besides, studies by Aguir Bargaoui et al. (2014), Sadorsky (2014), Heryadi and Hartono (2016), and Wang, Zhao, Zheng, and Hu, (2017) prove that urbanization, economic growth, and energy consumption have a significant effect on CO_2 emissions. On the other hand, a study conducted by Agung et al. (2012) and Zhou and Liu (2016) shows that urbanization does not affect energy consumption and CO_2 emissions. Sebri and Ben-salha (2014), Chang et al. (2017), Pao and Tsai (2010), and Zakarya et al. (2015) proved that there is a causal relationship between economic growth and energy consumption. Liu, Yan, and Zhou (2016) found that urbanization, economic growth, and CO_2 emissions could be integrated; other findings also prove that there is a two-way causality between urbanization, economic growth, and CO_2 emissions in China. Cowan et al. (2014) found evidence that economic growth and CO_2 emissions have a two-way causality. Also, we have carried out related studies showing that human capital, energy consumption, and economic growth cause CO_2 emissions. in the short-run (Bashir et al., 2019).

This study, based on modernization theory for developing countries, predicts environmental impacts by borrowing Kuznet's basic theory highlighting the relationship between

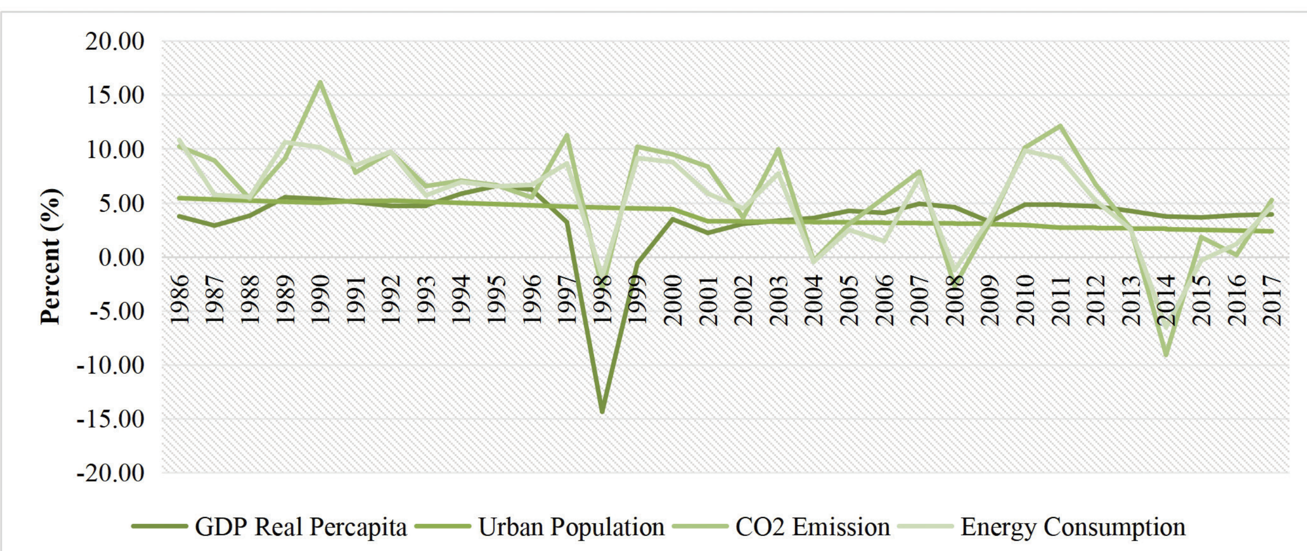

Figure 1: Trends of CO_2 Emissions, Energy, Urbanization, GDP Growth and in Indonesia
Source: World Development Indicator, 2018

affluence and environmental degradation (Goorha, 2010). This study is also based on the theory of urban environmental transition, which reveals that environmental aspects are related to development at the urban level (Marcotullio & Lee, 2003). This in turn leads to higher levels of environmental pollution. Likewise, ecological pressures damage the environment. The urban population is a major challenge in maintaining environmental quality because it can change the environment through various economic activities such as consumption and production in the urban regions.

This study is motivated by debates among economists about the current ecological pressures that damage the environment. The empirical evidence in Indonesia is still scarce, therefore the purpose of this study is to investigate the long- and short-run relationship between energy consumption, urbanization, economic growth, and CO_2 emissions in Indonesia. The contribution of this study is expected to be able to lead to green economic policies in the formulation of future environmental policies and adds to the research literature in the field of energy economics. In the next section, we will present and explain the research methods that will answer the study objectives. The third section presents the analysis and discussion of research findings. The final section presents conclusions and policy implications.

2. Literature Review

The link between urbanization, economic growth, and environmental degradation has been shown to be very strong in several studies (Lin, Zhao, & Marinova, 2009; Aguir Bargaoui et al., 2014; Zhou & Liu, 2016; Liu, Yan, & Zhou, 2016; Wang, Zhao, Zheng, & Hu, 2017). Evidence of the link between urbanization, economic growth, and the environment can be seen in study by Liu, Yan, and Zhou (2016) and Saidi and Mbarek (2017). The findings reveal that urbanization, economic growth, and technology have a long-term impact on increasing CO_2 emissions in the case of developing countries. Increased economic activity in urban areas, which also includes an increase in energy consumption, is a major factor. It can also increase economic needs in urban areas compared to rural areas (Ding et al., 2017). Then, more recent studies have been carried out in the last decade. Lin, Zhao, and Marinova (2009) test the existence of EKC in developed countries with the STIRPAT equation model approach. The results of this study prove that the population has the greatest potential environmental impacts, followed by the level of urbanization, level of industrialization, GDP per capita, and energy intensity. Therefore, the policy of having one child in China is to curb the country's rapid population growth, and is predicted to be effective at reducing the country's environmental impact.

Martínez-Zarzoso and Maruotti (2011) analyze the impact of urbanization on CO_2 emissions in developing countries from 1975 to 2003. The results of these studies prove that the relationship between urbanization and CO_2 emissions can form an inverted U curve. Other findings suggest that there is a positive elasticity of CO_2 emissions for urbanization, which means that low levels of urbanization can have a higher environmental impact in less developed areas. In addition, other countries show that there is elasticity of CO_2 emissions to urbanization, which means that increased urbanization does not contribute to higher CO_2 emissions.

Agung et al. (2012) investigate the effect of urbanization on energy consumption and CO_2 emissions in Indonesia using the STIRPAT model approach with panel data. The results of these studies prove that urbanization has a significant effect on fuel oil consumption and total energy consumption, but urbanization has no effect on electricity consumption and CO_2 emissions, while population has a significant effect on fuel oil consumption, electricity consumption and total energy consumption. Economic growth has a significant effect on fuel oil consumption, electricity consumption and CO_2 emissions in Indonesia. A study by Aguir Bargaoui et al. (2014) tries to assess the environmental impacts of economic and population growth, urbanization, energy intensity, and Kyoto protocol liability data on carbon dioxide emissions with the STIRPAT model approach. The results of the study found that economic growth, population growth, urbanization rates, and the Kyoto protocol have a significant effect on carbon dioxide emissions and that environmental impact is largely dominated by economic growth through per capita income.

Sadorsky (2014) uses a panel data regression model approach to investigate the effects of urbanization, per capita income, and energy efficiency on CO_2 emissions, which statistically proves that per capita income and energy intensity have a significant and positive effect on CO_2 emissions. Comparison of contemporary coefficient estimates shows that urbanization is relatively more sensitive to estimation techniques, whereas in most regression model specifications, it is statistically proven that the estimated coefficient of the urbanization variable has a positive, but insignificant sign for CO_2 emissions. Zhou and Liu (2016) focus on China, aiming to assess the extent to which demographic factors, income, and processes influence carbon dioxide emissions. Using the STIRPAT approach model, the results of this study found that income has become the dominant driving force for increasing CO_2 emissions in China, while demographic factors have no effect on increasing CO_2 emissions. On the other hand, the urbanization factor has actually increased energy consumption and CO_2 emissions, except in western China. It is very appropriate if the government makes policies to control the rate of urbanization and increase energy efficiency for environmental impact in China.

Liu, Yan, and Zhou (2016) investigated empirically the relationship between urbanization, economic growth, and carbon dioxide emissions at the national and regional levels with the panel cointegration approach and the vector error correction model (VECM). The results of this study found that urbanization, economic growth, and CO_2 emissions can be integrated; other findings also prove that urbanization contributes to economic growth, both of which increase CO_2 emissions in the eastern, central, and western regions of China. The impact of urbanization on CO_2 emissions in the western region is greater than in the eastern and central regions of China. Meanwhile, economic growth has a greater impact on CO_2 emissions in the eastern regions than in the central and western regions. Other findings point to evidence of a two-way causality between urbanization, economic growth, and long-term CO_2 emissions. At the regional level, there is also evidence of a two-way causality between urbanization and economic growth in eastern and central China. Further investigation revealed that there is a relationship between CO_2 emissions and economic growth in China, which is marked with an N-shaped curve, and concludes that it does not support the EKC hypothesis.

3. Research Methods and Materials

3.1. Data

This study focuses on investigating the relationship between energy consumption, urbanization, economic growth, and CO_2 emissions in the long and short run for the case of Indonesia. The data used are time series, the observation period is 1985–2017. Sources of data were obtained from the World Bank's official website on the World Development Indicators database.

3.2. Unit Root Test

To test whether there is a long-run relationship between variables in this study, the approach used is Johansen co-integration. Statistically, this approach forms the basis for dynamic model testing. However, the assumption that must be fulfilled is that all variables have stationary or do not contain a unit root at the level or first differences. The stationary test variable utilized unit root tests based on the criteria of the Augmented Dickey-Fuller test (Johansen, 1996, 1988). The unit root test equation by considering the ADF criteria as follows:

$$\Delta \ln y_t = \rho_i y_{t-1} + \sum_{j=1}^{\rho i} \delta_{i,j} \Delta \ln y_{t-j} + \varepsilon_t \tag{1}$$

where: y_t is a vector of the main endogenous variables in the study namely urbanization, energy consumption, economic growth, and CO_2 emissions.

3.3. Lag Order Selection Criteria

The next stage is to determine the appropriate lag length criteria in model testing. The determination of the optimal lag length is done to have efficient results in the system, because if the optimal lag that is entered is too short, it is feared that it cannot explain the overall dynamics of the model, and if the optimal lag that is too long it can produce inefficient estimates due to the reduced degree of freedom. The optimal sequence of the lag vector autoregressive model is determined based on the selection criteria by the Akaike's information criteria (AIC) and Schwarz information criterion (SC).

3.4. Johansen Cointegration Test

Furthermore, we utilized Johansen co-integration testing on the equations system. This test can be carried out after the statistical assumptions are met that all variables in the system do not contain a unit root; in this testing, there are two types of statistical tests, namely, (1) trace statistics, which are intended to test the null hypothesis of the co-integration relationship *r* to *k* alternative co-integration relations, where k is the number of endogenous variables, for $r = 0, 1, ..., k–1$; and (2) the maximum eigenvalues statistic, which is intended to test the null hypothesis of the co-integration relationship *r* with the $r + 1$ alternative. The Johansen co-integration test is stronger than the residual-based Engle-Granger test. Thus, if the equation in the system shows an indication of co-integration between variables, then the vector error

Table 1: Data and Source

Variable	Description	Unit	Source
URB	Urbanization	Urban population (total)	World Bank
EC	Energy Consumption	Kg of oil equivalent per capita	World Bank
GDP	GDP per capita	GDP real per capita, constant 2010	World Bank
CO_2	CO_2 emissions	Metric tons per capita	World Bank

correction model (VECM) test can be continued. The general form of the model is as follows:

$$y_t = A_0 + A_1 y_{t-1} + \dots + A_p y_{t-p} + \mu_t \qquad (2)$$

where: y_t is the dimensional-k vector of the variable to be tested; A_i for $i = 1, \dots, p$ is the slope matrix coefficient; A_0 is the coefficient of the intercept matrix; and μ_t is the dimensional-k residual vector.

3.5. Testing the EKC model

The last analysis is to investigate the validity of the EKC hypothesis. Several studies have been carried out using an econometric approach to test the validity of the EKC hypothesis using the income variable as a driving factor for environmental degradation, where GDP per capita is a proxy for income as an exogenous variable and per capita CO_2 emissions as a proxy for environmental degradation as an endogenous variable. Most of the literature uses a reduced-form model in which the income variable is a quadratic or cubic function. The general form of the model is presented as follows:

$$\ln CO_{2t} = \alpha_0 + \beta_1 \ln GDP_t + \beta_2 \ln GDP_{2t} + e_t \qquad (3)$$

where: CO_2 is CO_2 emissions from environmental degradation, GDP is income per capita, GDP^2 is income per capita squared, and e is an error term.

The equation (3) will provide information on the relationship pattern between CO_2 emissions and GDP per capita. That is, if $\beta_1 > 0$ ($\beta_1 < 0$, respectively) while $\beta_2 = 0$, then there is a monotonically increasing (decreasing) relationship between GDP per capita and CO_2 emissions. Conversely, if $\beta_1 < 0$, and $\beta_2 > 0$, then we observe an inverted U-shaped relationship or EKC pattern. In this case, the turning point of curve is given by $GDP^* = -\beta_1/2\beta_2$. Finally, if $\beta_1 = \beta_2 = 0$, this indicates that there is no relationships between GDP per capita and CO_2 emissions. Another case is not a concern in the EKC literature.

3.6. The VECM Granger Causality

Testing the direction of causality between urbanization, energy consumption, economic growth, and CO_2 emissions uses the vector error correction model; this tests the ability to identify the direction of causal links among variables. To determine the importance of the causal effect of one variable on the other variables, the model is based on the Granger causality test introduced by Granger (1969). This model was chosen because in previous studies it showed indications of co-integration evidence between variables. This test can answer the question of whether the variable x causes the variable y or y causes x. The variable x is mention to be Granger caused by y if y contributed in predicting the present value of x or its equivalent if the coefficient on lagged y is statistically significant. With the existence of a long-run relationship between the variables in the equation system, the lagging error correction term (ECT_{t-1}) is obtained from the long-run balance relationship and is included in the equation as additional independent variables in one time-series data with another time-series data. Then, the VECM equation is presented as follows:

$$\begin{aligned}\Delta \ln CO_{21} = \alpha_{1t} + \sum_{1=1}^{n=1} \beta_{1,1} \Delta \ln CO_{2t\text{-}1} + \\ \sum_{1=1}^{n=1} \gamma_{1,1} \Delta \ln EC_{t\text{-}1} + \sum_{1=1}^{n=1} \delta_{1i,1} \Delta \ln URB_{t\text{-}1} \\ + \sum_{1=1}^{n=1} \eta_{1i,1} \Delta \ln GDP_{t\text{-}1} + ECT_{t\text{-}1} + \varepsilon_{1it}\end{aligned} \qquad (4)$$

$$\begin{aligned}\Delta \ln EC_t = \alpha_{2t} + \sum_{1=1}^{n=1} \beta_{2,1} \Delta \ln CO_{2t\text{-}1} + \\ \sum_{1=1}^{n=1} \gamma_{2,1} \Delta \ln EC_{t\text{-}1} + \sum_{1=1}^{n=1} \delta_{2i,1} \Delta \ln URB_{t\text{-}1} \\ + \sum_{1=1}^{n=1} \eta_{2i,1} \Delta \ln GDP_{t\text{-}1} + ECT_{t\text{-}1} + \varepsilon_{2it}\end{aligned} \qquad (5)$$

$$\begin{aligned}\Delta \ln URB_t = \alpha_{3t} + \sum_{1=1}^{n=1} \beta_{3,1} \Delta \ln CO_{2t\text{-}1} + \\ \sum_{1=1}^{n=1} \gamma_{3,1} \Delta \ln EC_{t\text{-}1} + \sum_{1=1}^{n=1} \delta_{3i,1} \Delta \ln URB_{t\text{-}1} \\ + \sum_{1=1}^{n=1} \eta_{3i,1} \Delta \ln GDP_{t\text{-}1} + ECT_{t\text{-}1} + \varepsilon_{3it}\end{aligned} \qquad (6)$$

$$\begin{aligned}\Delta \ln GDP_t = \alpha_{4t} + \sum_{1=1}^{n=1} \beta_{4,1} \Delta \ln CO_{2t\text{-}1} + \\ \sum_{1=1}^{n=1} \gamma_{4,1} \Delta \ln EC_{t\text{-}1} + \sum_{1=1}^{n=1} \delta_{4i,1} \Delta \ln URB_{t\text{-}1} \\ + \sum_{1=1}^{n=1} \eta_{4i,1} \Delta \ln GDP_{t\text{-}1} + ECT_{t\text{-}1} + \varepsilon_{4it}\end{aligned} \qquad (7)$$

where: t is the period ($t = 1, \dots, t$) and *ln* shows the lag of each variable; $\Delta lnCO_2$ is CO_2 emissions per capita); ΔlnEC is energy consumption per capita; ΔlnGDP is GDP per capita, and ΔlnURB is the total of urban population; ECT_{t-1} is the lagging error correction term as long-run co-integration parameter coefficient; and ε_1, ε_2, ε_3, and ε_4 are assuming the error rate in the model (error-term).

4. Results and Discussion

The descriptive statistical results reported in Table 2 show that, based on the Jarque-Bera test, the variables in the study, namely, CO_2 emissions, urbanization, energy consumption, and economic growth are normally distributed. Furthermore, we also report the estimation results of the correlation matrix indicating that the correlation between CO_2 emissions, urbanization, energy consumption, and economic growth is positive.

Table 2: The Result of Descriptive Statistics and Correlation Matrix

Statistics & variable	ln CO_{2t}	ln URB_t	ln EC_t	ln GDP_t
Mean	5.543	3.703	4.552	7.773
Median	5.673	3.761	4.682	7.754
Maximum	6.261	4.007	5.181	8.326
Minimum	4.442	3.258	3.555	7.234
Std.Dev.	0.559	0.226	0.498	0.308
Skewness	–0.443	–0.452	–0.486	0.077
Kurtosis	1.999	1.950	2.030	2.125
JB-stat	2.457	2.641	2.594	1.084
Probability	0.292	0.266	0.273	0.581
ln CO_{2t}	1.000	–	–	–
ln URB_t	0.122	1.000	–	–
ln EC_t	0.270	0.109	1.000	–
ln GDP_t	0.159	0.064	0.141	1.000

Source: Author's calculation.

Table 3: The Unit Root Test Results

Variable	% Critical	*t*-statistic			
		Level	ADF test	1st difference	ADF test
ln CO_2	1% 5% 10%	–3.653 –2.957 –2.617	–0.165	–3.661 –2.960 –2.619	–4.660***
ln EC	1% 5% 10%	–3.653 –2.957 –2.617	–0.383	–3.661 –2.960 –2.619	–4.242***
ln URB	1% 5% 10%	–3.653 –2.957 –2.617	–1.898	–3.661 –2.960 –2.619	–5.728***
ln GDP	1% 5% 10%	–3.653 –2.957 –2.617	1.855	–3.661 –2.960 –2.619	–3.686***

***MacKinnon (1996) one-sided *p*-values.

Before discussing further the relationship between CO_2 emissions, energy consumption, urbanization, and economic growth in Indonesia, there are several steps that must be performed to estimate the VECM and Granger causality test. We first test for the existence of unit roots in each variable, the test used in this stage is the Augmented Dickey-Fuller test (ADF-test) criteria. The unit root tests whether the variables in the equation – CO_2 emissions, energy consumption, urbanization, and economic growth – contain the unit root or vice versa. The unit root test results can be seen in Table 2:

The unit root test results on the level indicate that the variable of the CO_2 emissions, energy consumption, urbanization, and economic growth contain unit root (no stationary); we have to re-estimate the first difference, the result indicating that all variables do not contain the unit root (stationary), as indicated by the ADF test which is greater than *t*-statistic at the level of 1 percent, 5 percent, and 10 percent.

The optimal lag length criterion is important in causality modelling (Bahmani-Oskooee & Brooks, 2003). The results of the optimum lag criteria are presented in Table 3 with various lag length criteria; the results show that the lag length criteria offered are relatively varied, from these results our decision is to follow Akaike's information criteria (AIC) to select the appropriate lag length because AIC has superior power properties for the data.

The sample is small compared to other lag length criteria, as suggested by Lütkepohl (2013). AIC can also provide efficient and consistent results compared to final prediction error (FPE), Schwarz information criterion (SC), and Hannan-Quinn information criterion (HQ). We find that, according to AIC, the optimal lag is lag 2 in the time series data for the period 1985–2017.

The results of the Johansen cointegration test reported in Table 5 show that the variables of urbanization, energy consumption, economic growth, and CO_2 emissions in Indonesia are cointegrated from two tests through Trace and Max-Eigen statistics. The Trace statistical test indicated that predicted data have three equations cointegration at a significance level of 5 percent; this can be seen from the Trace statistical value, which is greater than the critical value or the null hypothesis (H_0) is rejected. Meanwhile, the Max-Eigen statistics also show that there are two equations that are cointegrated at the 5 percent significance level. In the period 1985–2017, the four variables of urbanization, energy consumption, economic growth, and CO_2 emissions in Indonesia are estimated to have a long-run balance relationship. The existence of EKC can be analogized if CO_2 emissions increase in line with economic growth at a certain point and reach a certain income, then CO_2 emissions can be reduced in line with the increase in income, which is indicated by an inverted U curve (Shahbaz & Lean, 2012).

4.1. Empirical Results of Environmental Kuznets Curve

The estimation results shown in Table 6 indicate that the residual distribution as determined by the JB-statistic is normal. Furthermore, the autoregressive conditional heteroscedasticity (ARCH) model is used to deal with heteroscedasticity in errors in the equation. Statistical

Table 4: Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
1	166.127	274.930	3.64e-10	–11.181	–10.992	–11.122
2	309.234	236.867*	2.59e-14*	–19.947*	–19.004*	–19.651*
3	318.693	13.047	4.36e-14	–19.496	–17.798	–18.964
4	330.895	13.463	6.85e-14	–19.234	–16.782	–18.466
5	353.972	19.098	6.35e-14	–19.722	–16.516	–18.718

*indicates lag order selected by the criterion.

Table 5: Johansen Co-Integration Test Result

Trace-Statistic				
Hypothesized	**Eigenvalue**	**Trace Statistic**	**Critical Value (0.05)**	**Prob.****
$r = 0$*	0.8084	100.319	63.876	0.000
$r \leq 1$*	0.5991	52.386	42.915	0.004
$r \leq 2$*	0.3880	25.872	25.872	0.050
$r \leq 3$	0.3303	11.629	12.517	0.070
Maximum Eigenvalue Statistic				
Hypothesized	**Eigenvalue**	**Max-Eigen Statistic**	**Critical Value (0.05)**	**Prob.****
$r = 0$*	0.8084	47.932	32.118	0.000
$r \leq 1$*	0.5991	26.513	25.823	0.040
$r \leq 2$	0.3880	14.243	19.387	0.238
$r \leq 3$	0.3303	11.629	12.517	0.070

*Rejection of the H_0 at the 0.05 level and **MacKinnon-Haug-Michelis (1999) *p*-values.

Table 6: The Empirical Result of EKC Model

Dependent Variable = ln CO_{2t}			
Model	**Coefficient**	***t*-statistic**	**Prob.**
Intercept	–7.343*** (1.383)	–5.309	0.000
ln GDP	1.859*** (0.356)	5.226	0.000
ln GDP^2	–0.082*** (0.028)	–4.739	0.000
Summary: R^2 = 0.9509; Adj-R^2 = 0.9476; *F*-stat = 290.602 (0.000)			
Diagnostic test	*F*-stat (Prob)		
X^2 NORMAL	2.602 (0.272)		
X^2 ARCH	4.363 (0.112)		
X^2 SERIAL	3.588 (0.166)		

Note: Level of significance at ***1%, **5%, and *10% respectively.
Source: Authors calculation.

autocorrelation determined by serial correlation (LM-test) was not found. The estimation results we get where the long-run coefficients of equation (3) show that the elasticity of GDP per capita to CO_2 emissions is statistically significant at the 1 percent level, the magnitude of the ranged impact is 1,859, this indicates that 1 percent increase in GDP per capita means an increase on CO_2 emissions by 1,859 percent. The elasticity of GDP per capita squared shows a negative sign and significantly affects CO_2 emissions.

The elasticity of per capita emissions with respect to GDP per capita in the long run can be defined as $-\beta_1/2\beta_2$= –1.859/2.–0.082. The results show that the EKC turning point occurs at the income level 11.335 (in logarithms). Similar to the findings of Ang (2007); Pao and Tsai (2010)energy consumption and output for a panel of BRIC countries over the period 1971–2005, except for Russia (1990–2005 and Arouri et al. (2012), these results support the EKC hypothesis that emission levels first increase with income, stabilize, and then decrease. The elasticity of GDP per capita to CO_2 emissions indicates a high response of CO_2 emissions to changes in

GDP per capita in the long-run. Thus, these results support the existence of EKC in Indonesia. These findings are in line with studies conducted Sebri and Ben-salha (2014), Chang et al. (2017), Pao and Tsai (2010), and Zakarya et al. (2015).

4.2. Empirical Results of Granger Causality

The results of the VECM Granger causality estimation are presented in Table 7, showing that short-run causality can be detected by the combined significance of the LR-test for the explanatory variable lagging in the equations. In the short run, there is evidence that urbanization and energy consumption lead to CO_2 emissions unidirectional, unless economic growth is not proven at a significant level of 5 percent. This implies that urban populations are believed to be able to change the environmental quality through life patterns such as production and consumption that produce various kinds of waste, which in turn, can cause deteriorating environmental quality (Adebayo et al., 2020). Likewise, the excessive use of fossil energy, especially in the industrial, electricity, and transportation sectors, which are still relatively large in Indonesia, results in greater CO_2 emissions. This finding is in line with the study by Anwar, Younis, and Ullah (2020), Çetin and Ecevit (2015), Salim, Rafiq, and Shafiei (2017), and Vu and Huang (2020). The economic growth has no relationship to CO_2 emissions in the short run; this implies that not all economic growth causes environmental damage. There is some evidence that explains that with increasing welfare, individuals have greater awareness and ability to protect the environment (Akram, 2012; Al-Mulali et al., 2015; Chang, 2015; Pao & Tsai, 2010; Sadorsky, 2014). Likewise, the model estimation results show that energy consumption in the short-run is proven to be due to urbanization at a significance level of 5 percent. This provides evidence that the lifestyle of the urban population can directly increase energy consumption through production and consumption activities in Indonesia. This finding is in line with the study by Wang, Wu, Zeng, and Wu (2016), Salim et al. (2017), and Long (2020).

Other results show that there is no evidence of a relationship between CO_2 emissions, energy consumption and economic growth, and urbanization; this implies that the driving factors for urbanization are more likely due to expectations of a better life such as getting jobs and better urban facilities and infrastructure. This findings is in line with the study by Marcotullio et al. (2014). Unidirectional causality was found ranging from urbanization to energy consumption, unless for economic growth and CO_2 emissions, this indicates that the more activity of urban population leads to greater energy consumption. Furthermore, CO_2 emissions, urbanization, and energy consumption do not have a relationship in the short run with economic growth; this implies that in the short run these factors cannot fully predict changes in economic growth. Economic growth in Indonesia is more due to foreign direct investment, open trade, and government spending. These findings are in line with the study by Hossain (2012).

The VECM Granger causality results show evidence of cointegration in the equations of CO_2 emissions, energy consumption, and economic growth, except the urbanization equation is not proven to have cointegration. The empirical results indicated by the coefficient of one period lagged the error correction term (ECT_{t-1}) have negative sign for the equations of CO_2 emission, energy consumption, and economic growth which are statistically significant in VECM equations, except in the urbanization equation. The long-run causality results show that there is a feedback effect from urbanization to CO_2 emissions. The relationship from energy consumption to CO_2 emissions is unidirectional. Likewise, unidirectional causality was found ranging from urbanization to energy consumption.

Table 7: The Results of Testing the Long-Run Equilibrium Relationship

Dependent variable	Causality test				
	Short-run				Long-run ECT_{t-1}
	Δ (ln CO_2)	Δ (ln URB)	Δ (ln EC)	Δ (ln GDP)	
Δ (ln CO_2)	–	6.014^{***} (0.007)	1.931^{**} (0.016)	0.275 (0.761)	-0.019^{***} [–4.102]
Δ (ln URB)	0.092 (0.912)	–	0.183 (0.833)	1.962 (0.160)	0.367 [0.948]
Δ (ln EC)	0.348 (0.709)	6.153^{***} (0.006)	–	0.375 (0.690)	-0.265^{***} [–3.153]
Δ (ln GDP)	1.341 (0.279)	0.634 (0.538)	0.954 (0.398)	–	-0.367^{***} [–4.200]

Note: Probability value in ( ); level of significance at ***1%, **5%, and *10% respectively.
Source: Authors calculation.

The ECT_{t-1} coefficient proves that there is an adjustment mechanism that affects the long run. The amount of adjustment for the ECT_{t-1} parameter from the short run to the long run in the CO_2 emission model is –0.0193; this shows the validity of the long-run equilibrium relationship between the variables of urbanization, energy consumption, and economic growth on CO_2 emissions. Inequality due to shocks in the previous period is in line with the long-run equilibrium in the CO_2 emission equation of –0.0193 percent in the current period. In other words, there is a long-run causality starting from the direction of urbanization, energy consumption, and economic growth towards CO_2 emission, where in the long run, if the policy of urbanization, energy consumption, and economic growth is better, then it can lead to reduced CO_2 emissions. These findings are in line with the study by Shaojian Wang et al. (2016) and Odugbesan and Rjoub (2020).

The coefficient of ECT_{t-1} adjustment from short to long run in the energy consumption equation is –0.2651, this shows evidence of the validity of the long-run equilibrium relationship between CO_2 emissions, urbanization, and economic growth on energy consumption. Inequality due to shocks in the previous period reintegrates into long-run equilibrium in the energy consumption equation of –0.2651 percent in the current period. In other words, there is long-run causality ranging from CO_2 emissions, urbanization, and economic growth to energy consumption. This is clear evidence of energy consumption, which is relatively difficult to move unless there are significant changes in CO_2 emission concentrations, urbanization, and economic growth. Energy consumption control in Indonesia is running well in the long run. CO_2 emissions in Indonesia are mostly caused by peatland fires due to unprofessional land use practices; this results in loss of forest and land functions (Agus et al., 2013). Nevertheless, energy consumption control is also important because the highest use of fossil energy in Indonesia is proven to come from electricity generation for 58 percent, the rest from the industry, transportation, and household sectors; it can be suppressed through energy conservation policies. This finding is in line with the study by Saidi and Hammami (2015).

In the long run, the evidence for the validity of the long-run equilibrium relationship between CO_2 emissions, urbanization, and energy consumption to economic growth is seen in the ECT_{t-1} adjustment coefficient from short to long run in the economic growth equation, which is –0.3671. Inequality due to shocks in the previous period reintegrates into the long-run equilibrium in the economic growth equation of –0.2651 percent in the current period. Long-run relationships ranging from CO_2 emissions, urbanization, and energy consumption to economic growth can be easily driven if there are significant changes in the concentration of CO_2 emissions, urbanization and energy consumption. The increase in economic growth in Indonesia is progressing well in the long run. Nevertheless, policies to promote economic growth need to be carried out in an integrated manner with other policies, so that the control of CO_2 emissions and energy consumption can be carried out properly. These findings are in line with the study by Odugbesan and Rjoub (2020). and Shaojian Wang et al. (2016).

5. Conclusions

This paper systematically discusses the relationship between urbanization, economic growth, energy consumption, and CO_2 emissions in Indonesia. Based on the results of this study, interesting findings indicate that in the short run urbanization and energy consumption can cause CO_2 emissions. It is estimated that the contribution of urbanization in the next 10 years to CO_2 emissions is quite high, namely, 53.20 percent, while energy consumption for CO_2 emissions is 48.45 percent. In addition, we also find evidence that urbanization can lead to energy consumption in the short run, which suggests that urbanization in the short run is uncontrollable due to weak policies to control urbanization. Urban residents are believed to be able to change the quality of the environment through life patterns such as production and consumption that produce various types of waste, which in turn can cause environmental damage. Thus, the excessive use of fossil energy, especially in the industry, electricity and transportation sectors, is still relatively large in Indonesia. In the short run there is no relationship between economic growth and CO_2 emissions. There is some evidence that explains that, with increased well-being, individuals have greater awareness and ability to protect the environment. Although CO_2 emissions, energy consumption, and economic growth do not affect urbanization, this suggests that the driving factors for urbanization are more due to expectations of a better life such as getting jobs and better city facilities and infrastructure. Likewise, there is no evidence of a lasting relationship from CO_2 emissions, urbanization, and energy consumption to economic growth in the short-run, implying that in the short-run these factors cannot fully predict changes in economic growth, due to economic growth in Indonesia, caused by foreign direct. investment, trade openness, and government spending.

The result of Granger causality shows evidence of cointegration in the equations of CO_2 emissions, energy consumption, and economic growth, except that the urbanization equation is not shown to have cointegration. The empirical results shown by the coefficient of one period lagging the error correction term (ECT_{t-1}) are negative for the equations of CO_2 emissions, energy consumption, and economic growth, which are statistically significant in the VECM equation. The concentration of CO_2 emissions can increase if increased urbanization, energy consumption and economic growth cannot be properly controlled in the long term. Other findings also show that energy consumption is caused by urbanization, economic growth, and CO_2 emissions in the long-run, this implies that the aggregate activity of urban residents through consumption and production can lead to energy consumption in Indonesia.

The highest use of fossil energy in Indonesia is proven to come from power plants for 58 percent, the rest from the industry, transportation and household sectors. Likewise, the ECT_{t-1} coefficient of economic growth equation shows evidence of the validity of the long-run equilibrium relationship between CO_2 emissions, urbanization, and energy consumption on economic growth seen in the ECT_{t-1} adjustment coefficient from the short run to the long run in the economic growth equation. Economic growth can easily be boosted if there are significant changes in CO_2 emission concentrations, urbanization and energy consumption. The increase in economic growth in Indonesia is progressing well in the long term. However, policies to promote economic growth need to be integrated with other policies, so that CO_2 emission control and energy consumption can be carried out properly. Other findings also show that if the EKC hypothesis is proven for the case of Indonesia, where CO_2 emissions increase with economic growth at a certain point and reach a certain income, then CO_2 emissions can be reduced as income increases as indicated by the inverted U curve. Increasing welfare in the future is expected to improve environmental quality through high awareness by encouraging better economic activities and prioritizing environmental aspects.

The study also provides information to policymakers on the relationship between urbanization, economic growth, energy consumption, and CO_2 emissions in Indonesia. Urbanization does not only increase CO_2 emissions and energy consumption in the short run. Therefore, policies are needed to limit the impact of urbanization through high awareness-raising to maintain environmental quality and greater use of energy. Also, energy conservation policies are needed in all sectors, especially the electricity, industry, and transportation sectors, as well as encourage and optimize the use of alternative fuels.

References

Adebayo, T. S., Awosusi, A. A., & Adeshola, I. (2020). Determinants of CO_2 emissions in emerging markets: An empirical evidence from mint economies. *International Journal of Renewable Energy Development*, *9*(3), 411–422. https://doi.org/10.14710/ijred.2020.31321

Aguir Bargaoui, S., Liouane, N., & Nouri, F. Z. (2014). Environmental Impact Determinants: An Empirical Analysis based on the STIRPAT Model. *Procedia - Social and Behavioral Sciences*, *109*, 449–458. https://doi.org/10.1016/j.sbspro.2013.12.489

Agung, P., Hartono, D., & Awirya, A. A. (2017). Pengaruh Urbanisasi terhadap Konsumsi energi dan emisi CO_2: Analisis Provinsi di Indonesia. *Jurnal Ekonomi Kuantitatif Terapan*, *10*(2), 9–17.

Agus, F., Gunarso, P., Sahardjo, B. H., Harris, N., Noordwijk, M. Van, & Killeen, T. J. (2013). Historical CO_2 Emissions From Land Use and Land Use Change From the Oil Palm Industry in Indonesia, Malaysia and Papua New Guinea. In: *Reports from the Technical Panels of RSPOs 2nd Greenhouse Gas Working Group*.

Ahuja, D., & Tatsutani, M. (2019). Sustainable energy for developing countries. *Surveys and Perspectives Integrating Environment and Society*, *2*(1), 1–17.

Akram, N. (2012). Is Climate Change Hindering Economic Growth of Asian Economies? *Asia-Pacific Development Journal*, *19*(2), 1–18. http://www.unescap.org/pdd/publications/index_apdj.asp%5Cnhttp://search.ebscohost.com/login.aspx?direct=true&db=ecn&AN=1368183&site=ehost-live

Al-Mulali, U., Saboori, B., & Ozturk, I. (2015). Investigating the environmental Kuznets curve hypothesis in Vietnam. *Energy Policy*, *76*, 123–131. https://doi.org/10.1016/j.enpol.2014.11.019

Ang, J. B. (2007). CO_2 emissions, energy consumption, and output in France. *Energy Policy*, *35*, 4772–4778. https://doi.org/10.1016/j.enpol.2007.03.032

Anwar, A., Younis, M., & Ullah, I. (2020). Impact of Urbanization and Economic Growth on CO_2 Emission: A Case of Far East Asian Countries. *International Journal of Environmental Research and Public Health*, *17*(2531), 1–8. https://doi.org/10.3390/ijerph17072531

Arouri, M. E. H., Ben Youssef, A., M'henni, H., & Rault, C. (2012). Energy consumption, economic growth and CO_2 emissions in Middle East and North African countries. *Energy Policy*, *45*, 342–349. https://doi.org/10.1016/j.enpol.2012.02.042

Bahmani-Oskooee, M., & Brooks, T. J. (2003). A new criteria for selecting the optimum lags in Johansen's cointegration technique. *Applied Economics*, *35*(8), 875–880. https://doi.org/10.1080/00036840210129419

Çetin, A. P. M., & Ecevit, A. P. E. (2015). Urbanization, Energy Consumption and CO_2 Emissions in Sub-Saharan Countries: A Panel Cointegration and Causality Analysis. *Journal of Economics and Development Studies*, *3*(2), 66–76. https://doi.org/10.15640/jeds.v3n2a7

Chang, M. C. (2015). Room for improvement in low carbon economies of G7 and BRICS countries based on the analysis of energy efficiency and environmental Kuznets curves. *Journal of Cleaner Production*, *99*, 140–151. https://doi.org/10.1016/j.jclepro.2015.03.002

Chang, T., Deale, D., Gupta, R., Hefer, R., Inglesi-, R., & Simo-kengne, B. (2017). The causal relationship between coal consumption and economic growth in the BRICS countries: Evidence from panel-Granger causality tests. *Energy Sources, Part B: Economics, Planning, and Policy*, *12*(2), 138–146. https://doi.org/10.1080/15567249.2014.912696

Cowan, W. N., Chang, T., Inglesi-lotz, R., & Gupta, R. (2014). The nexus of electricity consumption, economic growth and CO_2 emissions in the BRICS countries. *Energy Policy*, *66*(2014), 359–368. https://doi.org/10.1016/j.enpol.2013.10.081

Ding, Q., Cai, W., Wang, C., & Sanwal, M. (2017). The relationships between household consumption activities and energy consumption in china: An input-output analysis from the lifestyle perspective. *Applied Energy*, *207*(2017), 520–532. https://doi.org/10.1016/J.APENERGY.2017.06.003

Gielen, D., Boshell, F., Saygin, D., Bazilian, M. D., Wagner, N., & Gorini, R. (2019). The role of renewable energy in the global energy transformation. *Energy Strategy Reviews*, *24*(2019), 38–50. https://doi.org/10.1016/j.esr.2019.01.006

Goorha, P. (2010). Modernization Theory. In *Oxford Research Encyclopedia* (Issue July 2018, pp. 1–24). Oxford University Press, USA. https://doi.org/10.1093/acrefore/9780190846626.013.266

Granger, C. W. J. (1969). Investigating Causal Relations by Econometric Models and Cross-spectral Methods. *Econometrica*, *37*(3), 424–438. https://doi.org/10.2307/1912791. JSTOR 1912791

Heryadi, M. D., & Hartono, D. (2016). Energy efficiency, utilization of renewable energies, and carbon dioxide emission: Case study of G20 countries. *International Energy Journal*, *16*(4), 143–152.

Hossain, S. (2012). An Econometric Analysis for CO_2 Emissions, Energy Consumption, Economic Growth, Foreign Trade and Urbanization of Japan. *Low Carbon Economy*, *3*(November), 92–105.

Johansen, S. (1988). Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control*, *12*(2–3), 231–254. https://doi.org/10.1016/0165-1889(88)90041-3

Johansen, S. (1996). *Likelihood-based inference in cointegrated vector autoregressive models*. Oxford University Press.

Kurnia, P., Darlis, E., & Putra, A. A. (2020). Carbon Emission Disclosure, Good Corporate Governance, Financial Performance, and Firm Value. *Journal of Asian Finance, Economics and Business*, *7*(12), 223–231. https://doi.org/10.13106/jafeb.2020.vol7.no12.223

Lin, S., Sun, J., Marinova, D., & Zhao, D. (2017). Effects of population and land urbanization on China's environmental impact: Empirical analysis based on the extended STIRPAT model. *Sustainability (Switzerland)*, *9*(5), 1–21. https://doi.org/10.3390/su9050825

Lin, S., Zhao, D., & Marinova, D. (2009). Analysis of the environmental impact of China based on STIRPAT model. *Environmental Impact Assessment Review*, *29*(6), 341–347. https://doi.org/10.1016/J.EIAR.2009.01.009

Liu, Y., Yan, B., & Zhou, Y. (2016). Urbanization, economic growth, and carbon dioxide emissions in China: A panel cointegration and causality analysis. *Journal of Geographical Sciences*, *26*(2), 131–152. https://doi.org/10.1007/s11442-016-1259-2

Long, N. T. (2020). Do Foreign Direct Investment, Energy Consumption and Urbanization Enhance Economic Growth in Six ASEAN Countries? *Journal of Asian Finance, Economics and Business*, *7*(12), 33–42. https://doi.org/10.13106/jafeb.2020.vol7.no12.033

Lütkepohl, H. (2013). *Introduction to Multiple Time Series Analysis* (2nd ed.). Springer-Verlag Berlin Heideberg.

Marcotullio, P. J., Hughes, S., Sarzynski, A., Pincetl, S., Sanchez Peña, L., Romero-Lankao, P., Runfola, D., & Seto, K. C. (2014). Urbanization and the carbon cycle: Contributions from social science. *Earth's Future*, *2*(10), 496–514. https://doi.org/10.1002/2014EF000257

Marcotullio, P. J., & Lee, Y. S. F. (2003). Urban environmental transitions and urban transportation systems: A comparison of the North American and Asian experiences. *International Development Planning Review*, *25*(4), 325–354. https://doi.org/10.3828/idpr.25.4.2

Martínez-Zarzoso, I., & Maruotti, A. (2011). The impact of urbanization on CO_2 emissions: Evidence from developing countries. *Ecological Economics*, *70*(2011), 1344–1353. https://doi.org/10.1016/j.ecolecon.2011.02.009

Odugbesan, J. A., & Rjoub, H. (2020). Relationship Among Economic Growth, Energy Consumption, CO_2 Emission, and Urbanization: Evidence From MINT Countries. *SAGE Open*, *10*(2), 1–15. https://doi.org/10.1177/2158244020914648

Pao, H. T., & Tsai, C. M. (2010). CO_2 emissions, energy consumption and economic growth in BRIC countries. *Energy Policy*, *38*(12), 7850–7860. https://doi.org/10.1016/j.enpol.2010.08.045

Sadorsky, P. (2014). The effect of urbanization on CO2 emissions in emerging economies. *Energy Economics*, *41*, 147–153. https://doi.org/10.1016/j.eneco.2013.11.007

Saidi, K., & Hammami, S. (2015). The impact of CO_2 emissions and economic growth on energy consumption in 58 countries. *Energy Reports*, *1*, 62–70. https://doi.org/10.1016/j.egyr.2015.01.003

Saidi, K., & Mbarek, M. Ben. (2017). The impact of income, trade, urbanization, and financial development on CO_2 emissions in 19 emerging economies. *Environmental Science and Pollution Research*, *24*(14), 12748–12757. https://doi.org/10.1007/s11356-016-6303-3

Salim, R., Rafiq, S., & Shafiei, S. (2017). Urbanization, Energy Consumption, and Pollutant Emission in Asian Developing Economies: an Empirical Analysis. *Asian Development Bank Institute Working Paper Series*, *718*. https://doi.org/10.1017/S0020818300006032

Sebri, M., & Ben-salha, O. (2014). On the causal dynamics between economic growth, renewable energy consumption, CO_2 emissions and trade openness: Fresh evidence from BRICS countries. *Renewable and Sustainable Energy Reviews*, *39*, 14–23. https://doi.org/10.1016/j.rser.2014.07.033

Shahbaz, M., & Lean, H. H. (2012). Does financial development increase energy consumption? The role of industrialization and urbanization in Tunisia. *Energy Policy*, *40*(1), 473–479. https://doi.org/10.1016/j.enpol.2011.10.050

Vu, T. V., & Huang, D. C. (2020). Economic Development, Globalization, Political Risk and CO_2 Emission: The Case of Vietnam. *Journal of Asian Finance, Economics and Business*, *7*(12), 21–31. https://doi.org/10.13106/jafeb.2020.vol7.no12.021

Wang, Q., Wu, S., Zeng, Y., & Wu, B. (2016). Exploring the relationship between urbanization, energy consumption, and CO_2 emissions in different provinces of China. *Renewable and Sustainable Energy Reviews*, *54*, 1563–1579. https://doi.org/10.1016/j.rser.2015.10.090

Wang, S., Zhao, T., Zheng, H., & Hu, J. (2017). The STIRPAT analysis on carbon emission in Chinese cities: An asymmetric laplace distribution mixture model. *Sustainability (Switzerland)*, *9*(2017), 1–13. https://doi.org/10.3390/su9122237

Wang, Shaojian, Li, Q., Fang, C., & Zhou, C. (2016). The relationship between economic growth, energy consumption, and CO_2 emissions: Empirical evidence from China. *Science of The Total Environment*, *542*, 360–371. https://doi.org/10.1016/J.SCITOTENV.2015.10.027

Zakarya, G. Y., Mostefa, B., Abbes, S. M., & Seghir, G. M. (2015). Factors Affecting CO_2 Emissions in the BRICS Countries: A Panel Data Analysis. *Procedia Economics and Finance*, *26*, 114–125. https://doi.org/10.1016/S2212-5671(15)00890-4

Zheng, H., Hu, J., Guan, R., & Wang, S. (2016). Examining Determinants of CO_2 Emissions in 73 Cities in China. *Sustainability*, *8*(12), 1–17. https://doi.org/10.3390/su8121296

Zhou, Y., & Liu, Y. (2016). Does population have a larger impact on carbon dioxide emissions than income? Evidence from a cross-regional panel analysis in China. *Applied Energy*, *180*, 800–809. https://doi.org/10.1016/j.apenergy.2016.08.035