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Article

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On the Relations among CO_2 Emissions, Gross Domestic Product, Energy Consumption, Electricity Use, Urbanization, and Income Inequality for a Sample of 134 Countries

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ABSTRACT

This paper is aimed at examining the relations among CO_2 emissions, gross domestic product (GDP) growth, energy consumption, electricity use, urbanization, and income inequality for a sample of 134 countries by using principal components analysis, Granger causality, vector error correction models, and panel vector autoregression models. Data was obtained from the World Bank with annual observations from 1990 to 2014. The chosen countries are those with 10 years or more of concurrent data of the variables under study. The main empirical findings suggest a Kuznets curve between CO_2 emissions per capita and GDP per capita. In addition, CO_2 emissions have a long-term relationship with economic growth, energy use, electricity use, urbanization, and inequality. Finally, in the short run, CO_2 emissions depend on economic growth, urbanization, and income inequality.

Keywords: CO_2 Emissions, Energy, Economic Growth, Urbanization, Gini Index
JEL Classifications: F64, O13, O18, 044

1. INTRODUCTION

Global warming has become a prominent environmental challenge in recent decades. For that reason, the relationship between carbon dioxide (CO_2) emissions and economic growth is one of the relevant issues in environmental and energy economics; being CO_2 the main responsible gas for global warming. The increasing volume of CO_2 emissions released to the earth atmosphere as byproduct of different economic activities (electricity generations, manufacturing, general transportation, among others) produces a concentration of greenhouse gases (GHG), which induce global warming and alter the planet weather cycle stability. At the same time energy generation is an essential input for industrialization and a significant factor to improve living standards. Such ambivalence presents an ethical dilemma to governments and industry (Antonakakis et al., 2017). It is understandable that the study of the interaction between economic growth, energy consumption, and CO_2 emissions has attracted the attention of a large number of researchers which has been extensively documented; see, for instance, Ang (2007), Huang et al. (2008), Bartleet and Gounder (2010), Ghosh (2010), Chang (2010), Ozturk and Acaravci (2010), Acaravci and Ozturk (2010), Niu et al. (2011), Alam et al. (2011), Niu et al. (2011), Saboori (2012), Yang and Zhao (2014), Dritsaki and Dritsaki (2014), Saidi and Hammami (2015), Mahmoodi (2017), Fan and Hossai (2018), Cai et al. (2018), Mikayilov et al. (2018), Gorus and Aydin (2019), and Salazar-Núñez et al. (2020), among others.

In Beckerman's (1992) seminal contribution on the pollution effects of CO_2 production and their association with economic growth it was questioned the need for rigorous policies to control the risk of global warming. Author's position was that CO_2 production cannot be considered the most urgent economic problem, and that it only distracts the attention from other far more serious challenges as the fact that developing countries cannot restrain or postpone the pace of their economic development in order to improve the living conditions of their sometimes very large populations (*e.g*., India, China, and Malaysia, among others). Also, the author sustains that there is enough evidence that economic growth limits the deterioration of the environment and concludes that "the best and probably the only way to attain a decent environment in most countries is to become rich." This concern has been one of the most frequently discussed features of the relationship between economic growth and CO_2 emissions, and is frequently referred to as the Environmental Kuznets Curve (EKC) hypothesis, which postulates that environmental quality deteriorates during the early stages of economic development, but afterward improves during the more advanced stages (Kuznets, 1955). In this regard, Dinda (2004) describes this phenomenon by saying that "environmental pressure increases faster than income at early stages of development and slows down relative to GDP growth at higher income levels". The EKC is usually represented as an inverted U-shaped curve; the first segment of the curve represents the early phases of economic development when industrialization is beginning and societies engage in relatively simple and frequently high-pollution production processes, so CO_2 emissions increase more rapidly than production levels, subsequently, as economic growth continues, CO_2 emissions growth gradually slows down because production becomes increasingly efficient and, eventually, both reach similar growth rates (at the maximum point of the inverted U-curve). Subsequently, as economic growth continues, societies have more resources to invest in slowing down the growth of CO_2 emissions (Kaika and Zervas, 2013). The EKC is empirically observed and documented by many studies; see, for example: Dinda (2004), Aldy (2005), Pao and Tsai (2010). Gao and Zhang (2014), Heidari et al. (2015), and Demir (2019). There is also a generalized agreement with respect to the most obvious factors that explain the EKC. Some authors refer to the inclination of higher income populations to take care of environmental quality. However, the evidence that supports the EKC has been questioned and there is no common acceptance regarding the income threshold at which environmental degradation stops and conditions begin to improve. Dinda (2004) extensively discusses the results, research methodology and policy implications of different studies that have found empirical evidence on the EKC. The author concludes that it is not possible to rely too much on the EKC, nor policy responses of different governments because environmental decay is a complex problem and "different stages of damage have some definite relations with economic growth". This means that there is no individual policy that may be completely successful in reducing environmental pollution as economy grows, and makes clear that: (1) there is a need for models that objectively incorporate the interaction between the economy and the environment; (2) identifying which factors play an influential role on the EKC has a high priority in research because good government policies may only be designed and implemented once the drivers of the EKC are correctly recognized; and, (3) structural instead of reduced models are required to better understand the nature of the relations among variables. The possibility that both, technological change and structural change interact in the determination of the EKC makes the decomposition analysis a useful approach to improve the understanding on the EKC.

A different perspective on the subject refers to the relationship between economic growth and energy consumption, which is mainly a variation on the issue since energy generation is until today highly related to the burning of fossil fuels (oil and charcoal). Measuring that relationship is once more equivalent to addressing the connection between economic growth and CO_2 emissions. Following the seminal Kraft and Kraft's (1978) work about causality between energy consumption and gross national product (GNP) in the United States concludes that GNP growth leads energy consumption. Many authors have supported Kraft and Kraft's conclusions, but others have questioned them; see, for example: Huang et al. (2008); Apergis and Payne (2009), Narayan and Popp (2012), Bella et al. (2014), and Omri (2014). There is a lack of consistency in the results reported since some works conclude there is no association between the two variables (the "Neutrality Hypothesis"). Some others authors report a causal relationship from economic growth to energy consumption, and still others argue that causality goes from energy consumption towards economic growth. A critical analysis of the literature concludes that the diversity of results has to do most likely with the different econometric techniques used (Huang et al., 2008). A possible argument to explain the lack of consistency among earlier studies (produced during the 1980s and 1990s) is that Ordinary Least Squares (OLS) was profusely used without considering the presence of unit roots in the time series resulting in spurious regressions. As progress in econometrics allowed the use of more robust techniques, the relationship was revisited with Cointegration Analysis, Vector Error Correction Models (VECM) and Granger Causality analysis; however, conflicting results were still observed.

While early studies focused on a bivariate analysis, more recent ones circumvent the problem by increasing the number of variables considered in the models and so overcoming the criticism of possible omitted variables (Zhang and Cheng, 2009). Despite everything, results still are not fully consistent with the theory and have motivated further elaboration. More recent research on the relationship between energy and economic growth[1], and economic growth and CO_2 emissions has opted for combining both effects and has opened a better opportunity of empirical validation. The new approach is an ongoing effort in which the present research is inscribed innovating in the econometric techniques used and using a large and comprehensive database for empirically testing the theorical assumptions.

Based on all the above analysis, this paper focuses on the relationships among CO_2 emissions, gross domestic product (GDP) growth, energy consumption, urbanization, and income inequality for a sample 134 countries by using principal components, granger causality, VEC models, and panel vector autoregression (PVAR) models. Data is obtained from the World Bank with annual observations from 1990 to 2014.

This paper is organized as follows: section 2 deals with a brief literature review of significant papers; section 3 presents the nature of data and the main descriptive statistics; section 4 carries out

1 For a literature survey on energy-growth nexus see Ozturk (2010).

the econometric modeling through principal components analysis, Granger causality, VEC, and PVAR; section 5 finds evidence on the Kuznets curve; section 6 discusses the general empirical findings; finally, section 7 presents conclusions.

2. REVIEW OF LITERATURE

Several detailed and comprehensive literature review papers have explored the relative abundance of studies interested on finding evidence on the energy consumption and economic growth nexus. Five of the most thoroughly comprehensive published reviews (Ozturk, 2010; Payne, 2010; Omri, 2014; and, Tiba and Omri, 2017) are briefly reviewed to delineate the current frontiers of the field, and to frame the present work as part of the ongoing research on that nexus.

Most empirical research on this subject can be grouped as part of the following four testable hypothesis (Ozturk, 2010; Payne, 2010): (i) the "feedback hypothesis" that suggests there is a bidirectional causality relation between energy consumption and economic growth (see, for example, Squalli, 2007); (ii) the "growth hypothesis" that theorizes a causal relationship from electricity consumption to economic growth, with important implications because energy consumption attains the status of a factor of production that combines with labor and capital to impulse economic growth, but it also represents a risk whenever energy supply is subject to the influence of environmental factors (see for example, Ozturk, 2010), while the policy implications are that energy conservation-oriented policies may slow down economic growth (Payne, 2010); (iii) the "conservation hypothesis" that emphasizes energy conservation measures (e.g., reduction in greenhouse emissions, CO_2) and measures to improve efficiency (Payne, 2010), according to which causality takes place from economic growth to electricity consumption, i.e., as the economy grows an augmented consumption of energy is expected, but it may happen that the economy is so severely constrained that even in the presence of relatively abundant electricity supply the economy cannot grow, and that conservation policies to reduce electricity consumption have little or no effect; (iv) the "neutrality hypothesis" proposes there is no causality relation between economic growth and energy consumption implying that electricity conservation policies will not have any consequences on economic growth.

The work of Ozturk (2010) surveys a collection of studies published between 1978 and 2009 that are focused on the causal relationship between energy consumption (mainly electric energy) and economic growth, and aims to extract some lessons for future studies as well as to provide support for policymakers responsible for the design of energy production and consumption, as well as environment conservation policies. Specifically, Ozturk reviews 38 country-specific studies focused on the energy consumption-economic growth nexus; 26 cross-country studies on the energy consumption-economic growth nexus; six studies on the energy consumption-economic growth causality; 25 country-specific studies on the electricity consumption-economic growth nexus; and, eight cross-country studies focused on the electricity consumption-economic growth nexus. To organize the analysis, Ozturk adopts the four testable hypotheses on causality between energy consumption and economic growth and reports summary tables with the highlights of the studies under review (authors, period of analysis, country or region, methodology, and the nature of the causality relationship). From this comprehensive revision, the author concludes that: (i) it is difficult to say that any given type of causal relationship between energy consumption and economic growth prevails; (ii) almost all possible causality results are observed (unidirectional, bidirectional, and non-existing); (iii) in most studies a bivariate model is used to test for causality, and only few multivariate models are discussed; (iv) among multivariate models, besides energy consumption and some measure of economic growth, real gross fixed capital formation, labor force and carbon dioxide emissions are included. A general conclusion is that the studies reviewed show conflicting outcomes and that there is no consensus neither on the existence nor on the direction of causality. However, the evidence discussed on the electricity consumption and economic growth nexus among most country-specific researches indicates the presence of causality from electricity consumption to economic growth and, based on that evidence the paper concludes that electricity acts as a limiting factor to economic growth.

Payne's (2010) literature review paper postulates that understanding the causality between electricity consumption and economic growth is a fundamental prerequisite for policymakers on the elaboration of energy conservation policies. To better understand the nature of that relationship, Payne reviews several studies, among them, 36 studies refer to the electricity consumption and economic growth nexus across many different geographies that use multiple econometric techniques (v.g., the Engle-Granger cointegration analysis, the Vector Auto Regression (VAR) model, the Johansen-Juselius' test, the Auto Regressive Distributed Lags (ARDL) bounds test, the VEC model, the Toda-Yamamoto causality analysis, the Zivot-Andrews unit-root test with structural breaks, among others). Given the wide variable selection, diversity of econometric techniques, and different sample periods, it is not surprising that the reported empirical tests offer mixed results in terms of the four hypotheses related to the causal relationship between electricity consumption and economic growth (growth, conservation, neutrality, and feedback). The main conclusions of this author suggest the following: (i) improve the quality of the estimations by overcoming the omitted variable bias that is widely present in the studies reviewed by "framing the relationship between electricity consumption and economic growth nexus within a production model" and include additional control variables; (ii) integrate the electricity consumption-growth causality literature with the growth-emissions causality literature; (iii) adopt the utilization of data on electricity consumption per capita or real income per capita to homogenize the information used in panel error correction models; (iv) examine the electricity consumption-growth nexus for the transition economies of Eastern Europe and the Commonwealth of Independent States; (v) incorporate the possibility of structural breaks in unit root tests and cointegration tests; and (vi) examine the sign and magnitude of the coefficients associated with causality tests.

A second paper by the same author, Payne (2010), also presents a comprehensive literature review, but this time on the causal relationship between energy consumption and economic growth. Payne analyzes 101 studies on countries from all over the world that use an assorted list of econometric techniques whose results on the causality issue are mixed. The organization of the paper is, once again, based on the previously introduced four testable hypotheses whose results are summarized and reported as a percentage of the total number of studies reviewed as follows: "29.2 percent support the neutrality hypothesis; 28.2 percent the feedback hypothesis; 23.1 percent the growth hypothesis; and 19.5 percent the conservation hypothesis." When the sample is segmented according to the World Bank's income classification (high income 36 countries, upper middle income 22 countries, lower middle income 31 countries, and low-income income 22 countries), then there is some variation in the results, but no consensus becomes evident under any of the four hypotheses. Even though results are not consistent across different regions, the few panel data-based studies included in Payne's (2010) support the "growth hypothesis", i.e., an increase in energy consumption causes an increase in economic activity. There are some valuable recommendations that round-up Payne's (2010) survey: (i) combine the energy consumption-economic growth studies with those interested on the economic growth-CO_2 emissions under the environmental Kuznets cycle perspective; (ii) disaggregate the measures of energy consumption to measure the differentiated effect of economic growth on energy consumption; (iii) group countries in samples according to their consumption patterns/level of development to identify resemblances and differences; and (iv) examine the causal relationship estimated through coefficients signs and their magnitude to provide solid grounds for policy decisions.

Omri (2014) revises the literature on the relationship between economic growth and energy consumption using four different measures of energy: aggregate energy consumption, electricity consumption, nuclear energy consumption, and renewable energy consumption. This work also follows the four-testable causality hypothesis mentioned before between energy consumption and economic growth. A valuable contribution consists on summarizing the literature review findings in a statistical presentation by reporting the percentage of published studies reviewed that support each of the four hypotheses proposed relative to the complete sample. The report is as follows: "(i) for the energy consumption-growth nexus, 29% supported the growth hypothesis, 27% the feedback hypothesis, 23% the conservation hypothesis, and 21% the neutrality hypothesis; (ii) for the electricity consumption-growth nexus, 40% supported the growth hypothesis, 33% the feedback hypothesis, and 27% conservation hypothesis; (iii) for the nuclear consumption-growth nexus, 60% supported the neutrality hypothesis, and 40% the growth hypothesis; and (iv) for the renewable consumption-growth nexus, 40% supported the neutrality hypothesis, 40% the conservation hypothesis, and 20% the growth hypothesis." These results corroborate the already mentioned lack of consensus regarding the nature of the relationship studied, and suggest there is a need to develop new and more refined methodological approaches and better, more comprehensive, and higher-frequency databases whose analysis may contribute to improve the quality of the empirical results in order to understand and provide consistent support for the policy decision making processes.

Several of the above discussed review papers coincide on the need to build bridges among the consumption-growth relationship and the environment-growth sustained by the EKC proponents. In general, the review papers highlight the lack of consensus in a large number of studies on the nature of the causal relation between energy consumption and economic growth. Tiba and Omri's (2017) work aims to survey the existing literature on the energy-environment-growth nexus for a number of specific country studies and some more cross-country studies that were published between 1978 and 2014. These authors claim their study is the first one that simultaneously analyzes the three-dimensional linkages among energy consumption, economic growth and the environment, each of which have very significant implications for research and policy making. The collection of empirical works is classified according to the following criteria: (i) 100 country-specific studies on the energy consumption-economic growth nexus; (ii) 80 cross-country energy studies on the consumption-economic growth nexus; (iii) 51 country-specific studies on the existence of the Environmental Kuznets Curve (EKC) hypothesis; (iv) 63 cross-country studies on the existence of the Environmental Kuznets Curve (EKC) hypothesis; (v) 33 empirical specific-country investigations on energy-environment–growth nexus; (vi) 28 empirical specific-country studies on energy-environment–growth nexus. Tiba and Omri's (2017) literature survey is an example of the new direction in research on this subject but and a starting point of the review is the unanimous consensus among the sample authors on the economic relevance of the interaction among those three dimensions. Their conclusion of the reviewed studies does not allow a consensus verdict about the existence of clearly identifiable causality relationships. As in most previous studies, the most common problems are: the diversity of databases, the included variables, the different time span, and the diversity of econometric techniques. However, one of the most valuable conclusions of this review has to do with a critique on the reduced form used in empirical models, which assumes there is no feedback from the environment on economic growth, i.e., economic growth impacts directly the environment, but it is well known that the environment degradation may have direct consequences on economic growth *via* adverse consequences upon production factors, or indirectly through higher emissions reduction costs. Indeed, economic growth and environment are more likely jointly determined and, for that reason, it is not proper to estimate a single equation, but a simultaneous equation model may be more adequate.

3. DATABASE NATURE AND DESCRIPTIVE STATISTICS

This section, first presents the nature and description of the data. Subsequently, a principal components factor analysis and a Granger's causality tests are carried out. Finally, it reports the main results from the models; a VEC model, including a series of impulse-response functions, and a VAR model.

The country data included in this investigation was retrieved from the World Bank Data Bank (WBDB)[2], with annual observations

2 https://databank.worldbank.org/home.aspx

for the period 1990-2014. The variables are: carbon dioxide emissions per capita in metric tons (CO_2CAP); annual gross domestic product per capita (GDPCAP); energy use per capita (ENECAP); electricity use per capita (ELECAP); proportion of the urban population with respect to the total population in each country (URBPOP); and the Gini Index (GINII). The sample includes all the countries in the WBDB with 10 years or more of concurrent data; a total of 134 countries comply with that requirement. Table 1, Part A, presents the summary statistics of the variables in levels. A wide dispersion of values is observed for all six variables (CO_2CAP, GDPCAP, ENECAP, ELECAP, GINII and URBANPOP), reflecting the global diversity of the sample. Table 1, Part B, presents a summary the descriptive statistics of the 1-year difference of the natural log of CO_2CAP, GDPCAP, and ENECAP, as well as the first and second differences for URBPOP, and the first difference for GINII.

It is observed that CO_2 emissions per capita, GDP per capita, energy used per capita, and electricity used per capita increase throughout the period of study. The proportion of the urban population with respect to the total population also increased, but at a decreasing rate. The income inequality, as measured by the GINI index, marginally increased (with a mean value for the first difference of the original variable of 0.060). All variables show strong kurtosis. Also, D1LnGDPCAP, D1LnENECAP, and D2URBANPOP have a sizeable negative skewness, and on the contrary, D1LN CO_2CAP and D1URBANPOP have a considerable positive skewness.

A graphical representation of the medians of the main variables (along with the 25% and 75% quantiles) is presented in Figure 1. The median of CO_2 emissions per capita slightly increases from 1990 to 2014 and, subsequently, presents an abrupt increment in 1992. The median for GDP per capita steadily rises throughout the period. Both the median of energy consumption per capita and electricity consumption per capita begin the 1990s with a downward trend that reverts in 1992 for the first median, and in 1994 for the second one. The proportion of urban population follows a steadily increasing tendency throughout the period. Finally, the median Gini index decreased throughout the period, except for 2002 when there was a short-term bounce, and continued going down after that.

Most of the cross-correlations of the independent variables with respect to the first difference of the logarithm of CO_2CAP are large and highly statistically significant. Besides, their correlation is substantial. The Pearson pairwise cross-correlations between DLn CO_2CAP, DLnGDPCAP, DLnENECAP, DLnELECAP, and DURBPOP are all statistically different from zero (Table 2). In the case of D2URBPOP, its correlation with DENECAP (0.0387) and DURBPOP (0.4399) is statistically different from zero. However, DGINII does not have any statistically significant correlations with other variables, even though its correlation with DLn CO_2CAP is 0.0339.

4. PRINCIPAL COMPONENTS, GRANGER CAUSALITY, VEC, AND PVAR

4.1. Stationarity Test

The left panel of Table 3 reports Dickey-Fuller unit-root tests for the variables in levels, except for URBPOP where first differences were considered. The tests do not reject the null hypothesis that they have a unit root according to the inverse-normal statistic (Choi, 2001). The tests are performed after subtracting the cross-sectional averages of the series to mitigate the cross-sectional dependence (Levin, Lin, and Chu, 2002). Similar tests conducted on the first differences (in the case of URBPOP, the second difference were taken) are reported on the right-hand side panel of Table 3. They reject the null for the presence of unit root in all cases.

4.2. Principal Components Analysis

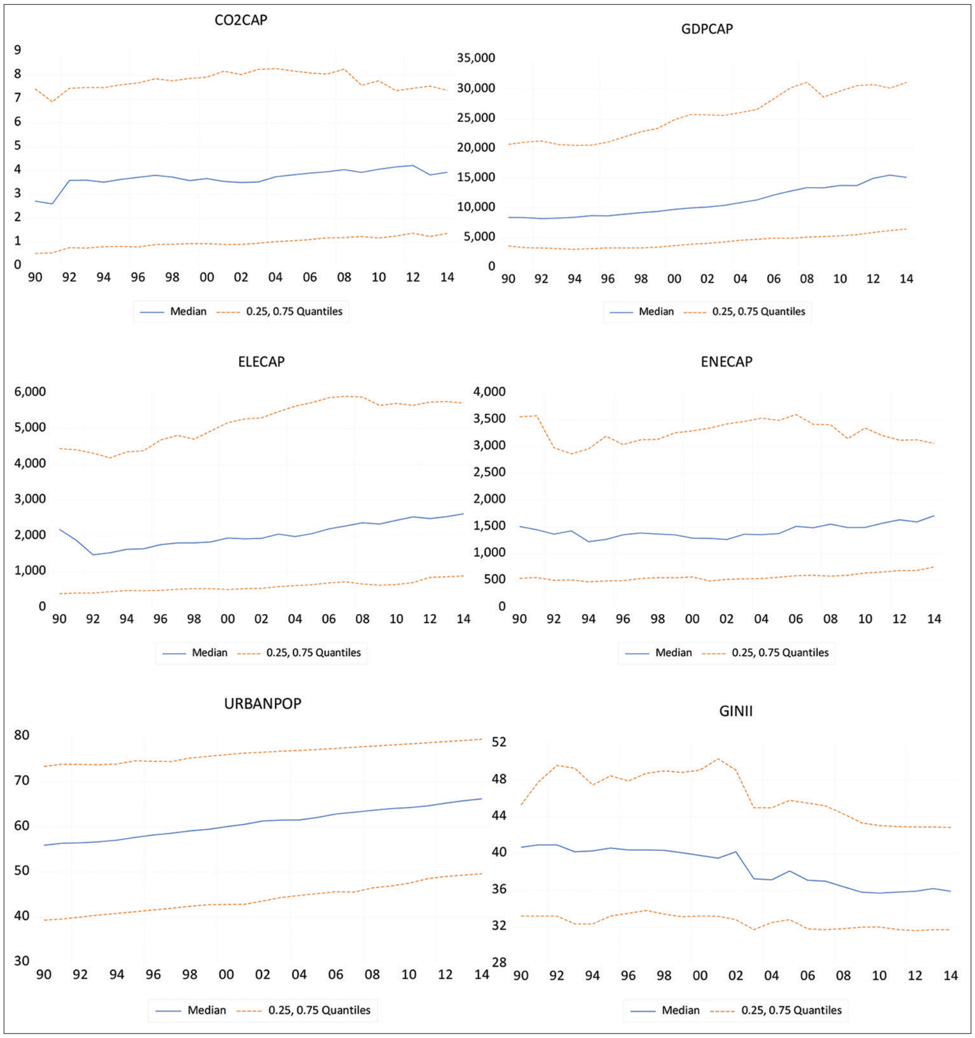
Principal Components Factor Analysis (PCFA) is a useful technique that may be applied to examine the relationships among several variables and is also useful to determine a smaller set of factors or components that can summarize all the information. The results of a PCFA on the sample database of this study are reported in Table 4. First, these results indicate that the first component explains as much as 34.49% of the variance, which is mainly associated to changes in economic growth, energy consumption,

Table 1: Descriptive statistics of the variables under study

Variable	Obs.	Mean	Std. Dev.	Skewness	Kurtosis	Minimum	Maximum
A. Data in Levels							
CO_2CAP	3281	5.68	7.22	3.39	21.17	0.02	70
GDPCAP	3284	17,783.36	19,346.35	2.08	8.44	361.09	124,025
ENECAP	3310	2,444.17	2,823.39	2.61	12.25	113.09	22,120
ELECAP	3316	3,788.05	5,103.08	3.45	23.5	13.51	54,799
GINII	2276	39.54	9.36	0.56	2.57	22.8	65
URBPOP	3350	59.74	21.47	(0.21)	2.24	-	100
B. Growth and Differences							
Dln CO_2CAP	3255	0.008	0.143	2.597	100.01	(1.579)	3.235
DlnGDPCAP	3150	0.02	0.062	(3.30)	73.77	(1.050)	0.797
DlnENECAP	3284	0.005	0.078	(2.76)	39.15	(1.188)	0.458
DlnELECAP	3290	0.023	0.081	0.11	18.59	(0.639)	0.792
D1URBPOP	3350	0.317	0.249	16.42	1,478.12	(35.771)	50.393
D2URBPOP	3216	(0.018)	1.264	(19.60)	1,174.51	(50.030)	35.771
DGINII	2195	(0.060)	1.756	(0.25)	27.25	(15.400)	17.400

Source: Authors' own elaboration

Figure 1: Dynamics of the main variables



Source: Authors' own elaboration

Table 2: Pearson pairwise cross-correlations

	Dln CO_2CAP	DlnGDPCAP	DlnENECAP	DlnELECAP	DURBPOP	D2URBPOP	DGINII
Dln CO_2CAP	1.0000**						
DlnGDPCAP	0.2441**	1.0000**					
DlnENECAP	0.5086**	0.3886**	1.0000**				
DlnELECAP	0.2717**	0.3450**	0.3873**	1.0000**			
DURBPOP	0.8555*	0.0499**	0.1270**	0.1257**	1.0000**		
D2URBPOP	−0.0176	0.03219	0.0387*	0.0154	0.4399**	1.0000**	
DGINI	0.0339	−0.0084	0.0093	0.0069	0.0197	−0.0155	1.0000**

** and *indicate statistically significant coefficients at the 1% and 5% levels, respectively. Source: Authors' own elaboration

Table 3: Augmented Dickey Fuller stationarity test

Variable	Z statistic	p-value	Variable	Z Statistic	p-value
Ln CO_2CAP	4.9707	1.0000	DLn CO_2CAP	−3.1119	0.0009
LnENECAP	6.5074	1.0000	DLnENECAP	−4.2200	0.0000
LnELECAP	9.9350	1.0000	DLnELECAP	−2.8342	0.0023
URBPOP	7.1201	1.0000	D2URBPOP	−1.9425	0.0260
DURBPOP	3.0008	0.9987	DGINII	3.0241	0.0012
GINII	2.5417	0.9945			

Source: Authors' own elaboration

CO_2 emissions, and electric consumption. Secondly, going from the second to the fifth components these explain 17.17%, 16.43%, 13.15%, and 11.58% of the variance, respectively. The second component reflects the increasing proportion of urban population to total population associated with reductions in inequality and CO_2 emissions, increases in GDP and decreases in energy

Table 4: Principal component analysis: Unrotated model

Component	1	2	3	4	5	6
Eigenvalue	2.0692	1.0304	0.9860	0.7887	0.6945	0.4311
Explained Proportion	0.3449	0.1717	0.1643	0.1315	0.1158	0.0719
Eigenvector						
Dln CO_2CAP	0.5243	−0.1086	−0.0237	−0.5575	0.0154	0.6338
DlnGDPCAP	0.4481	0.1951	0.0569	0.4161	−0.7631	0.0494
DlnENECAP	0.5679	−0.0706	−0.0664	−0.3028	0.0966	−0.7531
DlnELECAP	0.4478	0.0164	−0.0236	0.6248	0.6169	0.1661
D2URBPOP	0.0231	0.7788	0.5808	−0.1702	0.162	−0.0176
DGINII	0.027	−0.5816	0.8086	0.0701	−0.0363	−0.0293

Source: Authors' own elaboration

use. The third component's factor loads again reveals the role of increasing urban population, this time in combination with increasing inequality. The fourth component is associated with energy efficiency because, according to its factor loads, GDP growth appears positively related with electric generation and negatively related with energy consumption and CO_2 emissions. Finally, the fifth component suggests that the use of electricity is costly in terms of GDP growth.

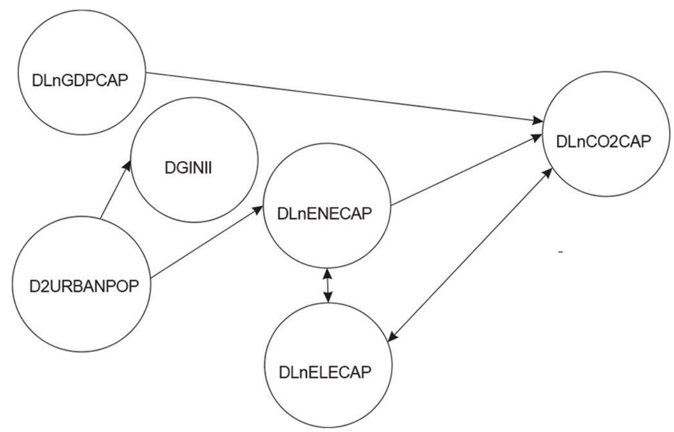
4.3. Granger Causality

Granger's causality captures the correlation between lagged values of one variable with current values of another variable, which do not necessarily reflect a causal relationship. Figure 2 represents the statistically significant Granger causality relations found among the variables of interest. As it can be seen, DLnGDPCAP, DLnENECAP, and DLnELECAP Granger cause DLn CO_2CAP, and there is a bidirectional Granger causality relationship between DLnENECAP and DLnELECAP. Moreover, D2URBANPOP Granger causes DLnENECAP and GINII. The results are in line with those found by Nnaji et al. (2013) that report that the relationship between CO_2 emissions and electricity supply is weak. The authors conclude that it is possible to have economic growth without increasing CO_2 emissions. An argument consistent with the discussion in Sezgin (2013), centered on ecological modernization and energy efficiency. The same conclusion follows for Algeria according to Eddrief-Cherfi and Kourbali's (2012) work that report empirical evidence that energy conservation policies do not affect growth. On the contrary, Aali-Bujari et al. (2017), using Granger causality tests, find that real gross domestic product per capita growth is positively affected by the growth rate of energy use. Salazar-Núñez et al. (2020) analyze the short-run and long-run relation of CO_2 emissions per capita, energy consumption per capita, and gross domestic product per capita in a large sample of countries divided by income level into four groups; depending on the group, the study variables have different Granger causality relationships.

4.4. VEC Modeling

A VEC model simultaneously reveals long-term and short-term relationships, and cointegration equations capture the long-term relationships. Johansen's trace and maximum eigenvalue cointegration tests reject the null that there are at most five cointegration vectors at a five percent significance level, with a trace statistic and a maximum eigenvalue statistic of 6.2463; in contrast with the MacKinnon et al. (1999) 5% critical value of 3.8415. Therefore, in the following stage of estimations

Figure 2: Granger statistically significant causality relations at the 5% level



Source: Authors' own elaboration

the VEC system includes five cointegration equations, which is the possible maximum number for a system containing six variables (see Table 5, below). The specification includes as many as five lags, which is the number of lags that minimizes the Akaike Information Criteria (AIC). Ln CO_2CAP(-1) is included as the independent variable in each cointegration equation, and, as seen in Table 5, its coefficient is statistically significant in all cases.

4.5. Cointegration Analysis

The following discussion gives attention to the short- and long-term dynamics of CO_2CAP, GDPCAP, ENECAP, and ELECAP. The long-term dynamics of CO_2CAP statistically depend on the cointegration of Ln CO_2CAP with LnGDPCAP, LnENECAP, and GINII. In the equation for DLn CO_2CAP, the coefficients of C1, C2, and C5 cointegration equations are statistically significant. These equations correspond to LnGDPCAP(−1), LnENECAP(−1), and GINII(−1) as the dependent variables and Ln CO_2CAP(−1) as the independent variable.

The short-run dynamics of CO_2CAP statistically depend on lagged differences of Ln CO_2CAP, LnGDPCAP, LnELECAP, DURBANPOP, and GINII. The coefficients of DLnGDPCAP(−1), DLnELECAP(−1), D2URBANPOP(−3), DLnELECAP(−5), DGINII(−1), DLn CO_2CAP(−1) and DLn CO_2CAP(−2) are significant at a 5% or 10% level. The first three have a positive effect, and the fourth one has a negative effect on CO_2CAP.

Table 5: VEC with all variables

Cointegrating Equation:	C1	C2	C3	C4	C5
Coefficient (−1)	LnGDPCAP(−1)	LnENECAP(−1)	LnELECAP(−1)	DURBPOP(−1)	GINII(−1)
LN CO_2CAP(−1)	0.5909**	2.2922**	0.3096**	−0.3921**	9.4809**
C	8.6342	5.2231	6.9781	0.6777	32.2864

Error Correction:	DLn CO_2CAP	DLnGDPCAP)	DLnENECAP	DLnELECAP	D2URBPOP	DGINII
C1	0.013*	0.0168**	0.004	-0.0086*	0.0056	0.006
C2	−0.008**	-0.0017	0.0036*	0.0034	0.0056*	-0.1733**
C3	−0.0032	-0.0022	0.0046	0.0209**	-0.0038	0.0959
C4	−0.0076	-0.0021	-0.0006	-0.008	0.0431**	-0.1992
C5	−0.0005*	0	−0.0005**	−0.0001	0.0001	0.0245**
DLn CO_2CAP(−1)	−0.1354**	0.0055	−0.0042	0	−0.0052	−0.5298
DLn CO_2CAP(−2)	−0.1099**	0.0031	−0.0072	0.0618**	−0.042	−0.3629
DLn CO_2CAP(−3)	0.0004	−0.0039	0.0037	0.0223	0.0389	−0.8817
DLn CO_2CAP(−4)	0.0208	−0.0081	0.0066	0.0104	−0.0303	1.2329*
DLn CO_2CAP(−5)	−0.0092	−0.0013	0.0208	0.0342	−0.0089	−0.6664
DLnGDPCAP(−1)	0.1782*	0.3653**	0.2058**	0.1327**	0.0059	−1.2899
DLnGDPCAP(−2)	0.0055	−0.0063	−0.0397	−0.0415	0.0109	−0.0843
DLnGDPCAP(−3)	−0.0011	0.0927**	0.0788	0.011	0.0546	−1.4413
DLnGDPCAP(−4)	0.1295	0.0692*	0.014	−0.0214	−0.044	−0.8946
DLnGDPCAP(−5)	0.076	−0.0084	−0.0283	0.0544	0.0069	0.0725
DLnENECAP(−1)	0.0598	−0.0006	−0.1204**	0.0736*	0.0802	2.1345*
DLnENECAP(−2)	0.0972	0.0018	−0.033	0.001	0.0183	0.3226
DLnENECAP(−3)	0.0543	−0.0133	0.0127	0.0071	−0.0272	2.3848*
DLnENECAP(−4)	0.0693	−0.016	0.0597	0.0578	−0.0105	−1.8964
DLnENECAP(−5)	0.0379	−0.0099	0.0241	−0.0563	−0.0464	−0.1487
DLnELECAP(−1)	0.1272**	−0.0052	0.0637**	−0.0921**	−0.0076	−1.9451**
DLnELECAP(−2)	−0.0035	−0.0008	0.0576*	0.0272	0.0148	−1.0081
DLnELECAP(−3)	0.0082	−0.0023	0.0056	0.1131**	0.0114	0.34
DLnELECAP(−4)	−0.0422	−0.0084	−0.0044	0.0231	0.0038	0.9631
DLnELECAP(−5)	−0.0925**	−0.0096	−0.0023	0.0566*	0.0532	0.5482
D2URBANPOP(−1)	−0.0112	−0.0012	0.0146	0.0014	0.2801**	−0.5962
D2URBANPOP(−2)	−0.0303	−0.0069	−0.0059	0.0306	−0.0691**	−0.1488
D2URBANPOP(−3)	0.0574*	0.0234*	0.0175	−0.0113	0.0267	1.0389*
D2URBANPOP(−4)	−0.0099	−0.0029	0.0011	0.0021	0.015	−0.3868
D2URBANPOP(−5)	−0.0127	−0.0047	0.0093	−0.0115	−0.0517**	0.1767
DGINII(−1)	−0.0026*	−0.0005	−0.0013	−0.0014	0	−0.0811**
DGINII(−2)	−0.001	0.0002	−0.0004	−0.0007	0.0013	−0.0588*
DGINII(−3)	−0.001	−0.0002	−0.0007	−0.001	0.0012	0.0124
DGINII(−4)	−0.002	−0.001*	−0.0016*	−0.0014	0.0008	−0.0222
DGINII(−5)	0.0013	−0.0004	0.0008	0.0009	0.001	0.0094
C	0.0038	0.0147**	0.001	0.0155**	−0.0015	0.0343
Adjusted R−squared	0.0987	0.2652	0.0766	0.1469	0.1322	0.0586
AIC (Error Correction)	−1.9926	−3.9374	−2.9375	−2.7562	−2.2837	3.8138
AIC (Residual Covariance)	−10.7576					

** and *, identify statistically significant coefficients at the 1% and 5% levels, respectively. Source: Authors' own elaboration

The long-term dynamics of GDPCAP statistically depend on the cointegration of Ln CO_2CAP with LnGDPCAP because in the DLnGDPCAP equation the C1 cointegration equation coefficient is statistically significant at the 1% level. The short-term dynamics of GDPCAP statistically depend on DLnGDPCAP(−1), DLnGDPCAP(−3), DLnGDPCAP(−4), D2URBANPOP(−3), and DGINII(−4) as revealed by their significant coefficients at 5% or better. The sign of the significant coefficients is positive for all, except the last one.

Since in the DLnENECAP equation, the C2 and C5 cointegration equations coefficients are statistically significant at the five and one percent levels, respectively, the long-term dynamics of ENECAP statistically depends on the cointegration of Ln CO_2CAP with LnENECAP and GINII. The short-term dynamics of ENECAP depend on the coefficients of DLnGDPCAP(−1), DLnENECAP(−1), DLnELECAP(−1), DLnELECAP(−2) and DGINII(−4), which are statistically significant at a minimum 5% level. The first, third and fourth show a positive sign coefficient and the other two have a negative sign.

In the case of ELECAP the long-term dynamics depend on the cointegration of Ln CO_2CAP with LnGDPCAP and LnELECAP because in the DLnELECAP equation the C1 coefficient is significant at a 5% level and the C3 cointegration equation coefficient is statistically significant at a 1% level. The short-term dynamics of ELECAP depend on the following statistically significant (at least at a five percent level) coefficients: DLnGDPCAP(−1), DLnENECAP(−1), DLnELECAP(−1), DLnELECAP(−3), DLnELECAP(−5), and DLn CO_2CAP(−2). All of the coefficients have a positive sign, with the exception of its own first lag indicating a possible mean reversion process.

4.6. Impulse-response Functions

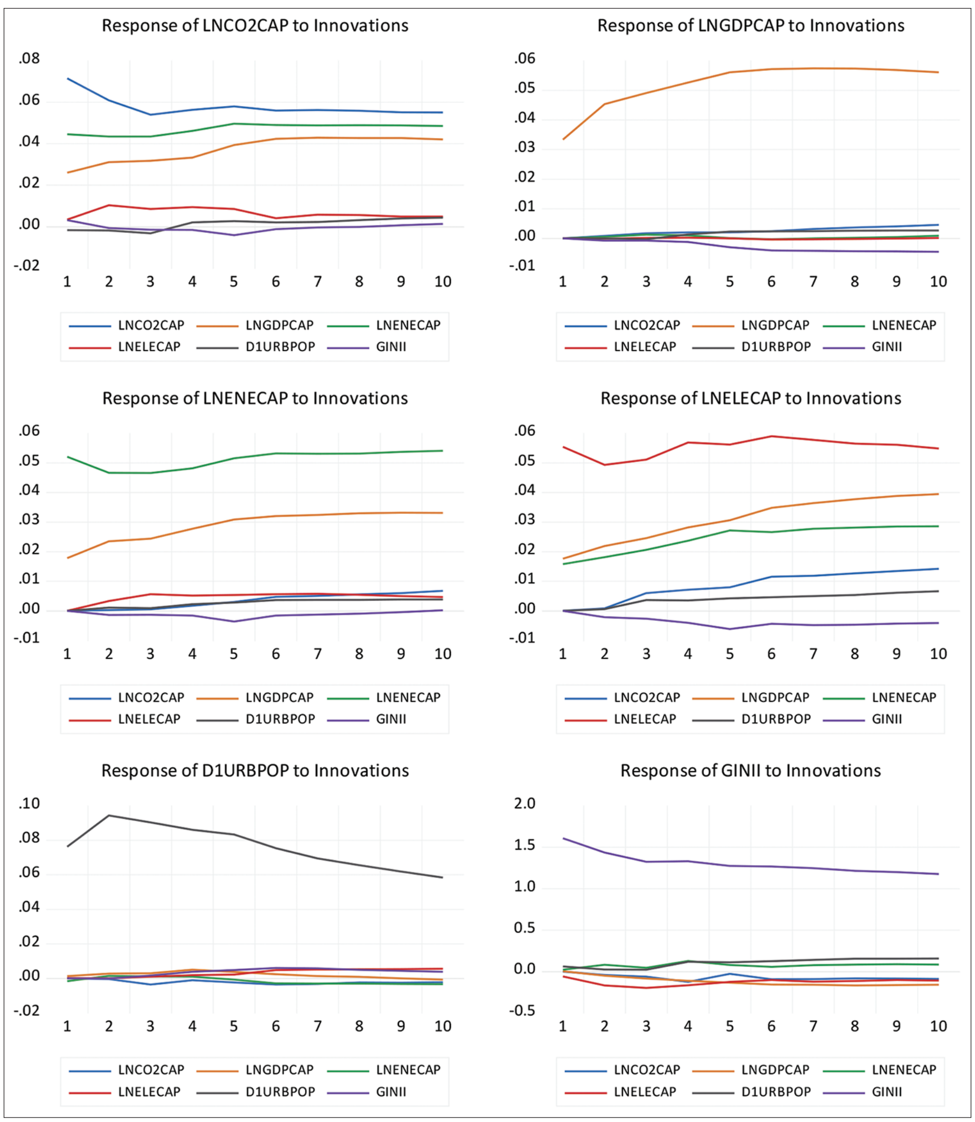
As may be observed in the impulse-response graphs reported in Figure 3, the response of DLn CO_2CAP to innovations is most notorious with respect to Ln CO_2CAP, LnENECAP and LnGDPCAP, LnELECAP, in decreasing order of intensity, and only very slightly to DURBPOP and GINII. Moreover, DLnGDPCAP responds to innovations from LnGDPCAP, and only marginally to others. DLnENECAP responds mostly to innovations from LnENECAP, LnELECAP, and LnGDPCAP. Also, DLnELECAP responds to innovations from LnELECAP, LnGPDCAP and LnENECAP, and after several years responds to Ln CO_2CAP, DURBPOP and GINII. Furthermore, D2URBPOP mainly responds to innovations from DURBPOP. Finally, DGINII mainly responds to innovations from GINII.

A panel VAR is useful to understand the underlying relationships across the variables. Panel VAR models are frequently used in macroeconomics and finance to address a variety of empirical questions. They are particularly appropriate to capture both static and dynamic interdependencies, treat the links across units in an unrestricted fashion, incorporate time variations in the coefficients and the variance of the shocks, and account for cross-sectional dynamic heterogeneities (Canova and Ciccaletti 2013). Using the country GDPCAP values for 1990 as selection criteria, the sample countries were divided in terciles: low, medium, and high. For each tercile, a Panel Vector Autoregression (PVAR) model was estimated using the first differences of Ln CO_2CAP, LnGDPCAp LnENECAP and LnELECAP, and the second differences of URBPOP, as well as the first lag of these variables as independent variables. Collinearity among independent variables was small, according to the variance inflation factor (VIF), which reached a maximum value of 1.37, when the usual benchmark is five. Similar models were estimated considering subsamples from terciles based on GINII and URBANPOP in 1990. Tables 6 and 7 show these results.

5. EVIDENCE ON THE KUZNETS CURVE

Evidence of the existence of an aggregate dynamic Kuznets relationship is confirmed if the marginal change of CO_2CAP

Figure 3: Impulse-response, whole VEC model



Source: Authors' own elaboration

Table 6: Relations between emission per capita and previous year growth per capita

GDPCAP	Mean CO_2CAP	Mean GDPCAP	Elasticity		d CO_2CAP_t/dGDPCAP$_{t-1}$
High	0.8476557	38726	0.7286	***V	0.0000159
Medium	4.537029	11742	0.2287	**	0.0000884
Low	11.24205	3276	0.2287		0.0007848
URBPOP	Mean CO_2CAP	Mean GDPCAP	Elasticity		d CO_2CAP_t/dGDPCAP$_{t-1}$
High	10.4188	33349	0.0876	V	0.0001028
Medium	5.5284	16594	0.5048	***	0.0001682
Low	1.1604	3954	0.3292	*	0.000026
GINII	Mean CO_2CAP	Mean GDPCAP	Elasticity		d CO_2CAP_t/dGDPCAP$_{t-1}$
High	2.4561	8686	0.4882	***	0.0014048
Medium	4.9089	12713	0.7286	***	0.0002813
Low	5.6046	18789	0.7037	***	0.0000175

Low, medium, and high refer to the respective tercile division of the countries with respect to GDPCAP, URBPOP and GINII in 1990. Elasticity is the elasticity of CO_2CAP_t to $GDPCAP_{t-1}$. ***,**, and *refers respectively to a statistically significant level of 1%, 5% and 10%. V refers that the coefficient of the tercile is statistically different to the one on the previous tercile with a statistically significant level of 1%. In each tercile, d CO_2CAP_t/d$GDPCAP_{t-1}$ estimation is as follows, ln (CO_2CAP_t)= ln (A)+ ηln($GDPCAP_{t-1}$) or CO_2CAP_t = A ($GDPCAP_{t-1}$. Thus, d CO_2CAP_t/d$GDPCAP_{t-1}$ = ηA ($GDPCAP_{t-1}$= ηA (1/$GDPCAP_{t-1}$. Also, if $GDPCAP_{t-1}$ > 0, A > 0, and 0 < η < 1, then d CO_2CAP_t/d$GDPCAP_{t-1}$ > 0. Moreover, if $GDPCAP_{t-1}$ > 0, A > 0, and η < 0, then d CO_2CAP_t/d$GDPCAP_{t-1}$ < 0. Source: Authors' own elaboration

Table 7: Elasticities of CO_2 emissions per capita

A. Elasticity of CO_2 per capita to 1-year lagged energy use per capita			
Countries with GDP	Low	Medium	High
	0.1613	0.3720***	–0.0753
Countries with urban population:	Low	Medium	High
	–0.0712	0.0092*	0.3271***
Countries with Gini Index:	Low	Medium	High
	0.20143	0.0287	0.2323***
B. Elasticity of CO_2 per capita to 1-year lagged electricity use per capita			
Countries with GDP:	Low	Medium	High
	–0.07978	0.278263**	–0.08419
Countries with urban population:	Low	Medium	High
	0.109989	0.254118**	0.327069***
Countries with Gini Index:	Low	Medium	High
	0.74378***	0.189812	0.255955**

***, **, *refers to statistical significant at 1%, 5%, and 10% level, respectively. Robust standard errors. PVAR models with 1-year lagged independent variables. Source: Authors' own elaboration

relative to the previous year's GDPCAP (d CO_2CAP_t/d$GDPCAP_{t-1}$) marginal change decreases with GDCAP. The literature often cites that CO_2 emissions increase with Gross National Income, but after an inflection point the emissions start decreasing and show a Kuznets curve (Shafik, 1994; Stern, 2004; Jalil and Mahmud, 2009; Ozturk, 2010; Farhani and Reheb, 2012; Tiwari et al. (2013); Haseeb et al., 2019; and Ucan et al., 2014).

This work postulates a dynamic Kuznets relationship in which d CO_2CAP_t/d$GDPCAP_{t-1}$ diminishes with GDPCAP in the large sample of countries included in our database. The choice of GDPCAP instead of gross national income per capita (GNICAP) is due to the fact that the WBDB GNICAP series have fewer observations than the GDPCAP series, and GDPCAP and GNICAP have a strong correlation (0.9959). Table 6 shows that the d CO_2CAP_t/d$GDPCAP_{t-1}$ in high GDPCAP countries (0.0000159) is smaller than d CO_2CAP_t/d$GDPCAP_{t-1}$ in medium GDPCAP countries (0.0000884), and the latter is yet smaller than the d CO_2CAP_t/d$GDPCAP_{t-1}$ for low GDPCAP countries (0.0007858). This relation is observed even though the elasticities (η) of CO_2CAP_t to $GDPCAP_{t-1}$ are not decreasing with the 1990 GDPCAP grouping. In high GDPCAP countries, the η of CO_2CAP_t to $GDPCAP_{t-1}$ is 0.7286, which is above 0.2287, value that corresponds to medium GDPCAP countries.

The proportion of urban population to total population (URBPOP) has a positive correlation with economic growth per capita (GDPCAP), as reported in Table 2. However, according to Table 6 results, the marginal change for d CO_2CAP_t/d$GDPCAP_{t-1}$ in the lower tercile of the proportion of urban population (0.000026) is smaller than the marginal change in the medium tercile (0.0001682).

On the other hand, if, according to Table 2, the GINI index level (GINII) has a negative relationship with economic growth per capita (GDPCAP), the proposed dynamic Kuznets relation implies that the marginal change of CO_2CAP_t to the marginal change of $GDPCAP_{t-1}$ should increase with the GINII level. Again, according to Table 6, the marginal change (0.0000175) for countries in which GINII was low in 1990 is smaller than that for countries in the middle tercile (0.00002813), and again, the latter is smaller than that corresponding to the upper tercile (0.0014048). Therefore, an extension of the dynamic Kuznets relation based on the GINI index holds for our global sample.

6. DISCUSSION OF EMPIRICAL RESULTS

The Kuznets relation can be interpreted as a mixture of an income effect and a substitution effect. At low levels of income (or GDP), the income effect dominates, and more economic growth results in more energy use of all sources, including electricity, and more CO_2 emissions. At higher levels of income, more economic growth can induce the substitution of highly polluting energy sources for more efficient ones, including electricity production, which results in even less CO_2 emissions. It is important to mention that even tough elasticities are not marginal changes, they provide information about the direction of change.

On the basis of Tables 6 and 7, if 1-year lagged GDP per capita increases in 1%, countries with high GDP per capita experience a more substantial increase in the percentage of CO_2 emissions per capita than medium and low GDP per capita countries. The elasticity of CO_2 emissions per capita to 1-year lagged GDP per capita is higher in high GDP per capita countries than in medium or low GDP per capita countries. The medium GDP per capita countries use less efficient CO_2 emitter sources of energy and electricity than low GDP per capita and high GDP per capita countries. Medium GDP per capita countries have elasticities higher of CO_2 per capita to 1-year lagged energy use per capita and CO_2 per capita to 1-year lagged electricity use per capita than high and low GDP per capita countries.

Countries with a medium proportion of urban population to total population have a more considerable increase in the percentage of CO_2 emissions per capita if 1-year lagged GDP per capita increases in 1% than countries with a high or a low proportion of the urban population to the total population. The elasticity of CO_2 emissions per capita to the 1-year lagged GDP per capita is higher in countries with a medium proportion of the urban population to total population than in countries with a low or a high proportion of the urban population to the total population. Countries with a high ratio of urban population to total population use more efficient sources of energy and electricity in terms of CO_2 emissions than countries with a medium ratio of urban population to total population. In turn, countries with a medium ratio of urban population to total population use more efficient sources of energy and electricity in terms of CO_2 emissions than countries with a low level of urban population. Countries with a high ratio of urban population to total population have an elasticity of CO_2 per capita to 1-year lagged energy use per capita and elasticity of CO_2 per capita to 1-year lagged electricity per capita lower than countries with medium urban population to total population ratio. Likewise, medium urban population countries have higher elasticity of CO_2 per capita to 1-year lagged energy use per capita and higher elasticity of CO_2 per capita to 1-year lagged electricity per capita than countries with a low level of urban population.

If 1-year lagged GDP per capita increases in 1%, countries with a medium or low Gini index have a more significant increase in the percentage of CO_2 emissions per capita than countries with a high Gini index. The elasticity of CO_2 emissions per capita to the 1-year lagged GDP per capita is higher in countries with a medium or a low Gini index than in countries with a high Gini index. Countries with medium values of the Gini index use more efficient sources of energy and electricity in terms of CO_2 emissions than countries with a low or a high Gini index. Finally, countries with a medium Gini index have elasticities of CO_2 per capita to 1-year lagged energy use per capita and CO_2 per capita to 1-year lagged electricity use per capita lower than countries with low and high Gini index.

7. CONCLUSIONS

Summarizing the empirical finding reported in the paper, changes in CO_2 emissions per capita, energy consumption per capita, electricity use per capita, and the proportion of the urban population to the total population have statistically significant relationships among them. The relation of these variables with changes in the Gini Index is not statistically significant.

The principal component analysis illustrates that the first component considers the positive relation of economic growth with energy use, electric consumption, and CO_2 emissions. The second component reflects the relationships of urbanization to economic growth, reductions in inequality, CO_2 emissions, and energy use. The third one shows that a reduction of inequality is associated with a reduction in the process of urbanization.

The Granger analysis illustrates how CO_2 emissions can depend on economic growth, energy use, and electricity use, as well as the bidirectional relation between energy use and electricity. It also reveals the dependence of energy use and inequality on the urbanization process.

The panel VEC model results show that the logarithms of the GDP per capita, energy consumption per capita, electricity use per capita, changes in the proportion of the urban population to the total population, and the Gini index are cointegrated with the logarithm of CO_2 emissions per capita in a long-term relationship. In the short run, the changes in the logarithm of CO_2 emissions depend on the cointegration equations of CO_2 emissions with GDP (+), energy consumption (–), and Gini Index (–). The changes in the logarithm of the CO_2 emissions also depend on lagged differences of the logarithm of CO_2 emissions per capita, the logarithm of the GDP per capita, the logarithm of electricity use per capita, changes in the proportion of the urban population to the total population, and the Gini index. The short-term response of the changes in the logarithm of the CO_2 emissions per capita is mainly related to impulses from CO_2 emissions, energy consumption per capita, GDP per capita, and electricity use per capita.

Finally, the panel VAR analysis of subsamples based on terciles defined with countries' 1990 GDP per capita data shows a classical dynamic Kuznets relationship. Also, the marginal change of CO_2 emissions per capita to the previous year of GDP per capita decreases with GDP per capita. An extended dynamic Kuznets type relation does not hold based on the terciles estimated with the urban population classification for 1990. Still, it holds when considering terciles based on the Gini index in that year.

REFERENCES

Aali-Bujari, A., Venegas-Martínez, F., Palafox-Roca, A.O. (2017), Impact of energy consumption on economic growth in major OECD economies (1977-2014): A panel data approach. International Journal of Energy Economics and Policy, 7(2), 1-8.

Acaravci, A., Ozturk, I. (2010), On the relationship between energy consumption, CO_2 emissions and economic growth in Europe. Energy, 35(12), 5412-5420.

Alam, M.J., Begum, I.A., Buysse, J., Rahman, S., Van Huylenbroeck, G. (2011), Dynamic modeling of causal relationship between energy consumption, CO_2 emissions and economic growth in India. Renewable and Sustainable Energy Reviews, 15(6), 3243-3251.

Aldy, J.E. (2005), An environmental Kuznets curve analysis of U.S. state-level carbon dioxide emissions. Journal of Environment and Development, 14(1), 48-72.

Ang, J.B. (2007), CO_2 emissions, energy consumption, and output in France. Energy Policy, 35(10), 4772-4778.

Antonakakis, N., Chatziantoniou, I., Filis, G. (2017), Energy consumption, CO_2 emissions, and economic growth: An ethical dilemma. Renewable and Sustainable Energy Reviews, 68, 808-824.

Apergis, N., Payne, J.E. (2009), Energy consumption and economic growth: Evidence from the commonwealth of independent states. Energy Economics, 31(5), 641-647.

Bartleet, M., Gounder, R. (2010), Energy consumption and economic growth in New Zealand: Results of trivariate and multivariate models. Energy Policy, 38(7), 3508-3517.

Beckerman, W. (1992), Economic growth and the environment: Whose growth? Whose environment? World Development, 20(4), 481-496.

Bella, G., Massidda, C., Mattana, P. (2014), The relationship among CO_2 emissions, electricity power consumption and GDP in OECD countries. Journal of Policy Modeling, 36(6), 970-985.

Cai, Y., Sam, C.Y., Chang, T. (2018), Nexus between clean energy consumption, economic growth and CO_2 emissions. Journal of Cleaner Production, 182, 1001-1011.

Canova, F., Ciccarelli, M. (2013), Panel Vector Autoregressive Models: A Survey. Frankfurt: ECB Working Paper, No. 1507, European Central Bank (ECB).

Chang, C.C. (2010), A multivariate causality test of carbon dioxide emissions, energy consumption and economic growth in China. Applied Energy, 87(11), 3533-3537.

Demir, C., Cergibozan, R., Gök, A. (2019), Income inequality and CO_2 emissions: Empirical evidence from Turkey. Energy and Environment, 30(3), 444-461.

Dinda, S. (2004), Environmental Kuznets curve hypothesis: A survey. Ecological Economics, 49(4), 431-455.

Dritsaki, C., Dritsaki, M. (2014), Causal relationship between energy consumption, economic growth and CO_2 emissions: A dynamic panel data approach. International Journal of Energy Economics and Policy, 4(2), 125-136.

Eddrief-Cherfi, S., Kourbali, B. (2012), Energy consumption and economic growth in Algeria: Cointegration and causality analysis. International Journal of Energy Economics and Policy, 2(4), 238-249.

Fan, H., Hossai, M.D. (2018), Technological innovation, trade openness, CO_2 emission and economic growth: Comparative analysis between China and India. International Journal of Energy Economics and Policy, 8(6), 240-257.

Farhani, S., Rejeb, J.B. (2012), Energy consumption, economic growth and CO_2 emissions: Evidence from panel data for MENA region. International Journal of Energy Economics and Policy, 2(2), 71-81.

Gao, J., Zhang, L. (2014), Electricity consumption-economic growth-CO_2 emissions nexus in Sub-Saharan Africa: Evidence from panel cointegration. African Development Review, 26(2), 359-371.

Ghosh, S. (2010), Examining carbon emissions economic growth nexus for India: A multivariate cointegration approach. Energy Policy, 38(6), 3008-3014.

Gorus, M.S., Aydin, M. (2019), The relationship between energy consumption, economic growth, and CO_2 emission in MENA countries: Causality analysis in the frequency domain. Energy, 168, 815-822.

Haseeb, M., Abidin, I.S.Z., Hye, Q.M.A., Hartani, N.H. (2019), The impact of renewable energy on economic well-being of Malaysia: Fresh evidence from auto regressive distributed lag bound testing approach. International Journal of Energy Economics and Policy, 9(1), 269-275.

Huang, B.N., Hwang, M.J., Yang, C.W. (2008), Causal relationship between energy consumption and GDP growth revisited: A dynamic panel data approach. Ecological Economics, 67(1), 41-54.

Jalil, A., Mahmud, S.F. (2009), Environment Kuznets curve for CO_2 emissions: A cointegration analysis for China. Energy Policy, 37(12), 5167-5172.

Kaika, D., Zervas, E. (2013), The environmental Kuznets curve (EKC) theory-Part A: Concept, causes and the CO_2 emissions case. Energy Policy, 62, 1392-1402.

Kraft, J., Kraft, A. (1978), On the relationship between energy and GNP. Journal of Energy and Development, 3, 401-403.

Kuznets, S. (1955), Economic growth and income inequality. American Economic Review, 45, 1-28.

MacKinnon, J.G., Haug, A.A., Michelis, L. (1999), Numerical distribution functions of likelihood ratio tests for cointegration. Journal of Applied Econometrics, 14, 563-577.

Mahmoodi, M. (2017), The relationship between economic growth, renewable energy, and CO_2 emissions: Evidence from panel data approach. International Journal of Energy Economics and Policy, 7(6), 96-102.

Mikayilov, J.I., Hasanov, F.J., Galeotti, M. (2018), Decoupling of CO_2 emissions and GDP: A time-varying cointegration approach. Ecological Indicators, 95, 615-628.

Narayan, P.K., Popp, S. (2012), The energy consumption-real GDP nexus revisited: Empirical evidence from 93 countries. Economic Modelling, 29(2), 303-308.

Niu, S., Ding, Y., Niu, Y., Li, Y., Luo, G. (2011), Economic growth, energy conservation and emissions reduction: A comparative analysis based on panel data for 8 Asian-Pacific countries. Energy Policy, 39(4), 2121-2131.

Nnaji, C.E., Chukwu, J.O., Nnaji, M. (2013), Electricity supply, fossil fuel consumption, CO_2 emissions and economic growth: Implications and policy options for sustainable development in Nigeria. International Journal of Energy Economics and Policy, 3(3), 262-271.

Omri, A. (2014), An international literature survey on energy-economic growth nexus: Evidence from country-specific studies. Renewable and Sustainable Energy Reviews, 38, 951-959.

Ozturk, I. (2010), A literature survey on energy-growth nexus. Energy Policy, 38(1), 340-349.

Ozturk, I., Acaravci, A. (2010), CO_2 emissions, energy consumption and economic growth in Turkey. Renewable and Sustainable Energy Reviews, 14(9), 3220-3225.

Pao, H.T., Tsai, C.M. (2010), CO_2 emissions, energy consumption and economic growth in BRIC countries. Energy Policy, 38(12), 7850-7860.

Payne, J.E. (2010), A survey of the electricity consumption-growth literature. Applied Energy, 87(3), 723-731.

Saboori, B., Sulaiman, J., Mohd, S. (2012), Economic growth and CO_2 emissions in Malaysia: A cointegration analysis of the environmental Kuznets curve. Energy Policy, 51, 184-191.

Salazar-Núñez, H.F., Venegas-Martínez, F., Tinoco-Zermeño, M.A. (2020), Impact of energy consumption and carbon dioxide emissions on economic growth: Cointegrated panel data in 79 countries grouped by income level. International Journal of Energy Economics and Policy, 10(2), 218-226.

Sezgin, Z. (2013), Ecological modernization at the intersection of environment and energy. International Journal of Energy Economics and Policy, 3, 93-101.

Shafik, N. (1994), Economic development and environmental quality: An econometric analysis. Oxford Economic Papers, 46, 757-773.

Squalli, J. (2007), Electricity consumption and economic growth: Bounds and causality analyses of OPEC countries. Energy Economics, 29(6), 1192-1205.

Stern, D.I. (2004), The rise and fall of the environmental Kuznets curve. World Development, 32(8), 1419-1439.

Tiwari, A.K., Shahbaz, M., Adnan Hye, Q.M. (2013), The environmental Kuznets curve and the role of coal consumption in India: Cointegration and causality analysis in an open economy. Renewable and Sustainable Energy Reviews, 18(2013), 519-527.

Ucan, O., Aricioglu, E., Yucel, F. (2014), Energy consumption and economic growth nexus: Evidence from developed countries in Europe. International Journal of Energy Economics and Policy, 4(3), 411-419.

Yang, Z., Zhao, Y. (2014), Energy consumption, carbon emissions, and economic growth in India: Evidence from directed acyclic graphs. Economic Modelling, 38, 533-540.

Zhang, X.P., Cheng, X.M. (2009), Energy consumption, carbon emissions, and economic growth in China. Ecological Economics, 68(10), 2706-2712.