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Global relationships among energy, environmental and macroeconomic variables with income and regional considerations

Christos Agiakloglou[1+]
Michael Gkouvakis[2]

[1,2]*Department of Economics, University of Piraeus, Greece.*
[1]*Email: agiaklis@unipi.gr*
[2]*Email: mgkouvakis@unipi.gr*

(+ Corresponding author)

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ABSTRACT

This study investigates relationships between energy, environmental, agricultural and macroeconomic variables for 43 countries taking also into consideration income and regional effects. The aim of this research is to investigate the overall attitude of these countries towards energy consumption, economic growth and the environment at a global level, a result that could play an important role for policy recommendations for each country under its particular characteristics. Panel data estimations techniques along with Granger causality, cointegration tests and error correction models are used to extract meaningful results from the data, while data are split based on countries' income (High income versus Medium and Low income) and countries' region (Africa, Asia, America and Europe). The results show that the relationships of these variables alter according to the data formation, especially under income categorization, while under regional categorization agricultural and forest variables play a dominant role in the economic activity of each region supporting also long-term relationships with energy and macroeconomic variables. These results can raise awareness for different policy recommendations on the environment, as it seems that it is important to consider the overall growth stage of the country and not just the region to which it belongs.

Contribution/ Originality: To the best of our knowledge, it is the first research paper that includes variables like forest and agricultural land, as well as agricultural production to capture relationships with other energy, environmental and macroeconomic variables, considering also income and regional aspects.

1. INTRODUCTION

Economic growth and the environment share a common path under which the overall conditions for human life on our planet are determined. The search for higher income comes at a cost to our society by affecting the quality of our life. In this sense, the global economy must face all major environmental challenges to protect our ecosystem, although it is difficult to assess the level of economic development that is sustainable. However, it is relatively feasible to investigate the relationship between economic and environmental performance in its quest to provide us with higher standards of well-being, as well as to explore the role of environmental policy in managing the supply and the use of natural resources.

Energy, for example, as a critical component of economic development, motivated many researchers to study its relationship with some important macroeconomic and other variables, since the increased use of energy through polluting energy sources, such as fossil fuels, caused serious environmental problems related to climate change and global warming, forcing, in essence, governments and policy makers to find more environmentally friendly sources of energy, known as green energy, to reduce the main polluter which is carbon dioxide (CO_2). Likewise, agriculture, which also plays a vital role in economic progress, has inspired researchers to study its relationship with environmental and other macroeconomic variables, as excess agricultural production, needed to support economic growth, is expected to reduce the quantity of water as well as the quality due to the use of chemical fertilizers. Indeed, agriculture is affected by the geopolitical structure of the earth and especially by the changes in land use caused by farming of uncultivated land, forest degradation, livestock rearing and overgrazing, creating additional environmental problems and altering the overall structure of forests and agricultural land, a situation that led governments and policy makers to take actions regarding production activity and environmental protection measures.

The relationship between economic growth and the environment, through energy and CO_2 emissions, has been extensively examined in the literature, where much interest in energy economics has focused on the direction of causality between energy consumption and economic growth to derive policy implications (see, for example, (Apergis & Payne, 2009; Belke, Dobnik, & Dreger, 2011; Lise & Montfort, 2007; Soytas, Sari, & Ewing, 2007)). On the other hand, Huang, Hwang, and Yang (2008) and Rajbhandari and Zhang (2018) considered a panel VAR (Vector Autoregressive) approach to examine the relationship between energy consumption and economic growth, while Menegaki (2011); Inglesi-Lotz (2016) and Fatima, Shahzad, and Cui (2021) applied fixed and random effects models to investigate the relationship between renewable energy, economic growth and CO_2 emissions. Furthermore, a significant part of the environmental economic research has been concerned in investigating the existence of the environmental Kuznets curve, which refers to the hypothesis that the relationship between environmental degradation and income per capita displays an inverted U shape, (see, for example, (Grossman & Krueger, 1995; Nguyen-Van, 2010; Panayotou, 1993; Stern, 2004)) while Jebli and Youssef (2017) and Adedoyin, Ozturk, Agboola, Agboola, and Bekun (2021) studied the relationship between agricultural growth and CO_2 emissions finding a bidirectional causality between these two variables, although, in general, few studies have been conducted regarding the effects caused by energy, pollution and economic growth to agricultural sector.

Therefore, it will be very interesting to investigate the relationship between economic growth, energy, and environment for many worldwide countries by considering, along with the traditional variables appeared in the literature, some other new variables regarding forest and agricultural land as well as agricultural production to capture environmental and agricultural effects in a different way. Moreover, very interesting results also emerged regarding the behavior of environmental and agricultural variables by considering income and regional effects that can help policy makers to proceed with targeted strategies and recommendations, based on the characteristics of each country in the region that belongs, so that every country can sustain economic growth and reduce its environmental footprint. The remainder of the paper is organized as follows. Section 2 presents the data along with some interesting preliminary findings regarding the relationships between the variables of the study. Section 3 describes the methodology and discusses the empirical results obtained from three different data sets, where the concluding remarks are presented in Section 4.

2. THE DATA

The study uses annual data on macroeconomic, energy and environmental variables, which are real GDP (Gross Domestic Product) per capita, real GDP (Gross Domestic Product) per capita from agricultural, forestry and fisheries activities, energy consumption by source type, CO_2 emissions per capita and the percentage of Agricultural and forest land over Total land from 43 countries worldwide from 1990 to 2018, while the data is obtained from

World Bank database and International Energy Agency (IEA).[1] The GDP per capita, the Agricultural GDP per capita as well as the CO_2 emissions per capita are transformed to logarithms, while energy consumption per source is separated between "Green" and "Conventional or non-Green" energy and the variable that it is used is the percentage share of "Green" Energy over Total Energy, called Energy Mix.[2] In addition, the data was divided into two sections according to income and region, i.e., countries with high income versus countries with other income that includes medium and low income, and countries from Africa, America, Asia, and Europe, where the clustering of the data was conducted based on the World Bank categorization.

Table 1 presents the mean and the standard deviation for all variables and for all sections of the data set. As can be seen from this table, the highest values of the logarithm of the real GDP per capita (Log_RGDP) are observed for high-income countries and for Europe. On the other hand, all mean values of the logarithm of the Agricultural real GDP (Gross Domestic Product) per capita (Log_AgriRGDP) are close to each another for all sections of the data with Europe and Africa having the highest and lowest values respectively. However, the contribution of the Agricultural sector to the GDP is the highest for other-income countries and for Africa, i.e., close to 72% on average, meaning that the countries in these areas are more Agricultural oriented.

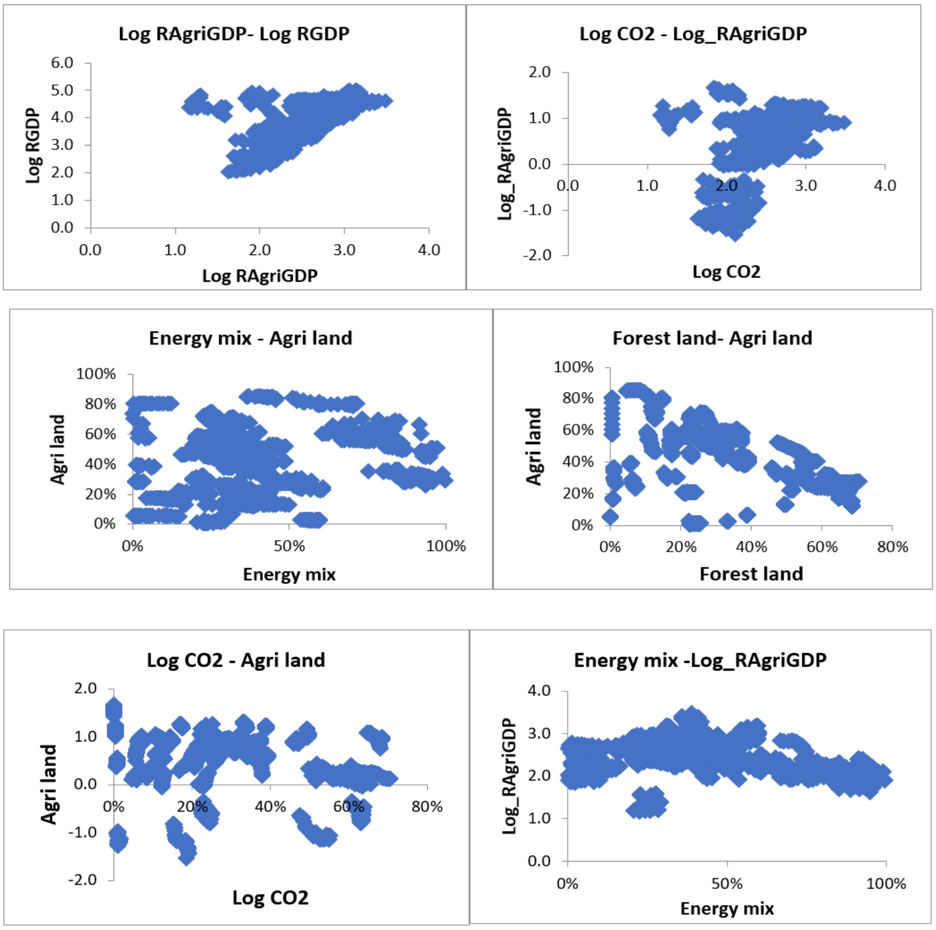

Figure 1. Scatter plots showing evidence of linear relationships.

[1] The 43 countries used in this study are in alphabetical order: Algeria, Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, China, Colombia, Ecuador, Ethiopia, France, Germany, Greece, India, Indonesia, Iran, Israel, Italy, Japan, Korea, Mexico, Morocco, Mozambique, New Zealand, Netherlands, Niger, Norway, Portugal, Qatar, Russia, Saudi Arabia, Singapore, South Africa, Spain, Thailand, Turkey, Togo, UK, Uruguay, USA and Zambia.

[2] Note that as "Green" energy is defined as the energy obtained from Nuclear and Renewable sources, while "non-Green" energy is defined as the energy obtained from Oil, Gas and in general Fossil fuels.

Table 1. Mean and standard deviation of all variables and all data cases.

	Obs.	Mean	Std	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.
All	1.247	3.88	0.69	0.56	0.63	40%	0.23	29%	0.19	41%	0.21	2.50	0.37
High income	667	4.4	0.27	0.94	0.25	31%	0.11	28%	0.17	40%	0.23	2.64	0.37
Other income	580	3.28	0.53	0.13	0.66	51%	0.28	31%	0.20	43%	0.17	2.33	0.29
Africa	232	2.9	0.50	-0.37	0.74	68%	0.29	23%	0.21	47%	0.21	2.14	0.24
America	261	3.93	0.41	0.58	0.38	32%	0.10	36%	0.18	40%	0.21	2.60	0.19
Asia	406	3.94	0.62	0.81	0.40	35%	0.21	28%	0.22	37%	0.22	2.47	0.46
Europe	348	4.40	0.3	0.89	0.11	33%	0.09	30%	0.11	45%	0.19	2.70	0.21

Moreover, the mean values of the logarithm of CO_2 emissions per capita (Log_CO_2) are higher for high-income countries and for Europe and Asia, contrary to energy mix where other-income countries and Africa have the highest mean values, a finding that suggests that countries with an increased share of green energy have lower pollution. The mean values of the percentage of Forest (Forest_Land) and Agricultural land (Agri_Land) over Total land remain at the same level for all areas of the study around 30% and 40% on average respectively. The other-income countries have higher values than high-income countries for both variables, while the highest values for forest and agricultural land are observed in America and in Africa, respectively, according to region categorization.

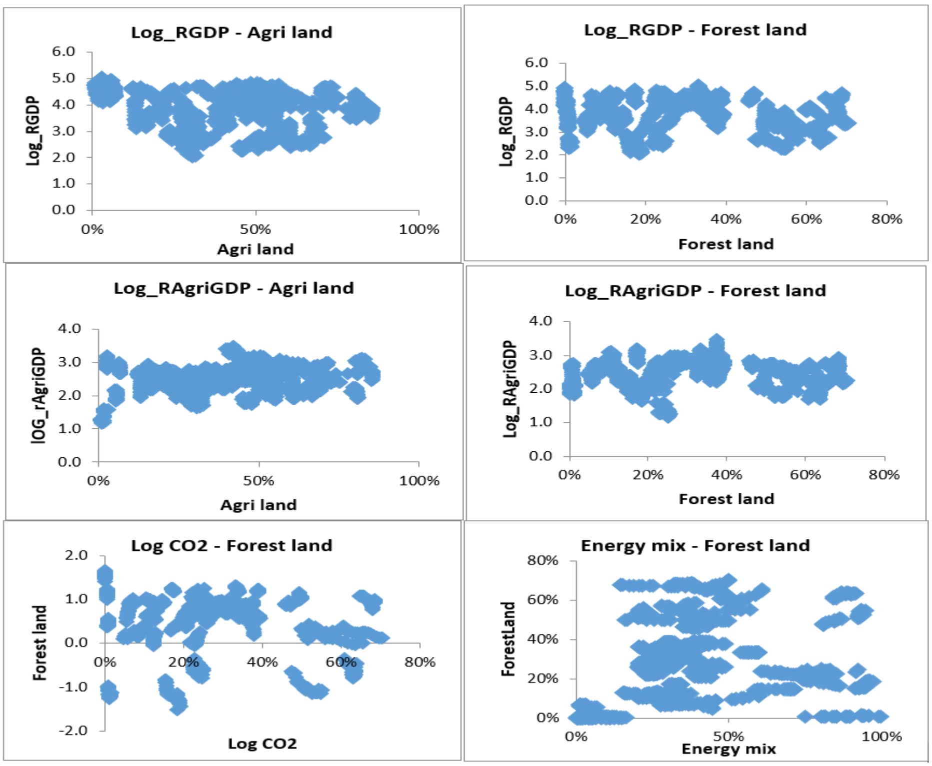

Figure 2. Scatter plots showing weak evidence of linear relationships.

Furthermore, Figure 1 presents scatter plots for selected bivariate cases that do indicate evidence of a relationship using data of all countries. As can been seen from this figure, positive relationships can be witnessed between the logarithm of the real GDP per capita and the logarithm of the real Agricultural GDP per capita, between the logarithm of CO_2 emissions per capita and the logarithm of the real Agricultural GDP per capita and between the energy mix and the percentage of agricultural land. On the other hand, negative relationships can be detected between the percentage of Forest land and percentage of Agricultural land, between the logarithm of CO_2 emissions per capita and the percentage of Agricultural land and between energy mix and the logarithm of the real Agricultural GDP per capita.

Likewise, Figure 2 presents scatter plots for the rest of the bivariate cases that do not indicate evidence of a relationship using data of all countries such as the logarithm of the real GDP per capita with either the percentage of the Agricultural land or the percentage of Forest land. Additionally, no relationship is observed between the logarithm of the real Agricultural GDP per capita with either the percentage of Agricultural land or with the percentage of Forest land as well as, the relationship between Forest land with either the logarithm of CO_2 emissions per capita or with energy mix.

3. EMPIRICAL RESULTS

Much of the research in environmental economics deals with building models that describe relationships that hold between parameters of different variables while looking for causality, a concept that is rarely taken for granted, although it plays an important role in understanding the behavior of a phenomenon not only in terms of finding which variable leads the creation of the phenomenon but also in terms of forecasting and policy making. The causality in this case is seeing as a covariation between two variables and it is determined by the data (data-driven). On the other hand, other attempts have avoided discussions on causality giving an intuitive explanation of the constructed (model-driven) functional relationship between variables seeing causality either as a temporal precedence or as a control for a "third variable". The empirical research begins by first investigating the direction of causality, a concept that has been proposed by Granger (1969) and has been examined in many environmental studies without being clearly defined, as all the variables involved in this research area are highly related, having a common path that it is very difficult to determine which variable is leading the way. For example, the relationship between economic growth and energy consumption has been thoroughly examined in the literature and found to be strong without being able to definitively determine the direction of their causality (see, for example, (Fuinhas & Marques, 2012; Huang et al., 2008; Narayan & Smyth, 2008)). Therefore, causality is examined for all variables using the entire panel data set as well as the two subsets of data constructed according to the income categorization of countries where the series were found to be stationary by applying the Im, Pesaran, and Shin (2003) panel unit root test.[3] The application of the IPS panel unit root test was conducted under the null hypothesis that "all panels contain unit roots" against the alternative hypothesis that "some panels are stationary". Hence, we proceed with stationarity since the null hypothesis of the IPS test is rejected, a result also confirmed by the application of the Levin, Lin, and Chu (2002) panel unit root test, which usually has a drawback regarding the power of the test, keeping in mind that rejecting the null hypothesis does not necessarily mean that all series are indeed stationary, as stated by Westerlund and Breitung (2009) and Westerlund and Breitung (2013). Table 2 reports the causality results obtained by applying the Granger causality test for panel data, for all countries together and for income categorization of the data, proposed by Juodis, Karavias, and Sarafidis (2021) a test that works for models with homogeneous or heterogeneous coefficients and accounts for the "Nickell bias" of the estimator using the Half Panel Jackknife (HPJ) method of Dhaene and Jochmans (2015).[4] Note that the JKS test is conducted based on the null hypothesis that "X variable does not Granger cause Y variable" against the alternative one that "X variable does Granger cause Y variable for at least one panel". However, as can be seen from this table, there is no evidence of a clear direction of causality, as most causal relationships are bilateral, except for a few unilateral cases in the income categorization of the data.[5] Indeed, all bivariate cases of all variables for the data set of all countries were found to support a bidirectional relationship between them, a finding which is also confirmed in the literature for a few of them. For example, evidence of bilateral causality can be found in Dogan and Aslan (2017) and Chaabouni and Saidi (2017) for the logarithm of CO_2 emissions with the logarithm of real GDP per capita, in Apergis and Payne (2010) and Omri, Mabrouk, and Sassi-Tmar (2015) for the Energy Mix with the logarithm of real GDP per capita and in Jebli and Youssef (2017) and Adedoyin et al. (2021) for the logarithm of CO_2 emissions with the logarithm of real Agricultural GDP per capita. However, for variables that have not been thoroughly examined in the literature, such as forest and agricultural land, this study finds bilateral causal relationships for these variables with all other variables, except when income is involved.

[3] The whole empirical analysis is conducted on STATA.

[4] Juodis et al. (2021) using a Monte Carlo analysis showed that their method outperforms, in terms of power, the granger causality test proposed from Dumitrescu and Hurlin (2012).

[5] It should be noted that evidence of unilateral causality for all countries was found at the 10% significant level only for the logarithm of CO_2 emissions causing the percentage of Agricultural land, a result that was not reported, since it was not adding value to the general picture of this study.

Table 2. Granger causality test results for all data and for income categorization.

	All	High	Other	All	High	Other	All	High	Other	All	High	Other	All	High	Other	All	High	Other
Log_RGDP				B	B	**B**	B	B	B	B	N	B	B	B	B	B	B	B
Log_CO2	B	B	B				B	Y	B	B	B	B	B	B	B	B	B	B
Energy Mix	B	B	B	B	N	B				B	B	B	B	B	B	B	B	B
Forest_Land	B	Y	B	B	B	B	B	B	B				B	B	Y	B	B	B
Agri_Land	B	B	B	B	B	B	B	B	B	B	B	N				B	B	Y
Log_AgriRGDP	B	B	B	B	B	B	B	B	B	B	B	B	B	B	N			

Note: The capital letters B, N and Y define Bilateral, No and Yes Causality from row to column variables, respectively.

In fact, evidence of unilateral causality is found for four cases only under income categorization of the data. For the high-income countries the percentage of forest land causes the logarithm of real GDP per capita, and the logarithm of CO_2 emissions causes the Energy mix, while for the other-income countries the percentage of agricultural land causes the logarithm of real Agricultural GDP per capita, and the percentage of forest land causes the percentage of agricultural land. Hence, high-income countries have the means to finance green energy production to decrease the pollution caused by CO_2 emissions, while at the same time their forest land tends to decrease in the name of economic development. In contrast, other-income countries tend to increase the use of agricultural land to increase agricultural production while reducing forest land.

Having recognized the absence of causality, the next step is to investigate the direction of the relationship between all variables and see if there are differences in the presence of income categorization. For this purpose, a multiple regression model is estimated using panel data regression analysis for fixed effects for all variable combinations having each time a different dependent variable for all countries and for income categorization.[6] The estimates of this effort are reported on Table 3, where the dependent variable appears on the first column of this table.

As can be seen from this table, most of the estimates are significant, while there are six cases in which the beta coefficient estimates have the same sign, three with a positive and three with a negative, for all three data sets and with all being significant. More specifically, positive relationships are found between the logarithm of real GDP per capita and the logarithm of CO_2 emissions, between the Energy Mix and the percentage of forest land, and between the logarithm of real GDP per capita and the percentage of forest land. The first relationship does not validate the existence of the Environmental Kuznets curve, since the sign of the beta coefficient remained the same regardless of the country's income specification (see, for example, (Marrero, 2010; Özokcu & Özdemir, 2017)) whereas the second relationship supports conditions for a better environment, since the increased use of renewable energy sources helps the expansion of forest land, an outcome that is crucial to prevent environmental degradation. The third relationship asserts that there is a tipping point at which, after a certain degree of economic development and deforestation, economic growth moves in tandem with environmental quality by supporting and ensuring the expansion of forest land (see, for example, (Antle & Heidebrink, 1995; Caravaggio, 2020; Foster & Rosenzweig, 2003)).

On the other hand, a negative relationship is found between the logarithm of CO_2 emissions and the Energy Mix, between the logarithm of CO_2 emissions and the percentage of forest land and between the percentage of forest land and the percentage of agricultural land. The first relationship states that renewable energy sources improve the environmental footprint as documented in the literature (see, for example, (Aydoğan & Vardar, 2020; Saidi & Omri, 2020; Zoundi, 2017)) whereas the second relationship declares, perhaps the most important environmental action, that the only way to reduce CO_2 emissions is to expand forest areas (see also (Waheed, Chang, Sarwar, & Chen, 2018)) in addition to switching to green energy production. The third relationship illustrates the substitution effect between forest land and agricultural land, stating that in order to expand the production of the agricultural sector, forest land must decrease.

[6] The selection of the fixed effects model against the random effects model is made by the Hausman (1978) test based on our data set.

Table 3. Coefficient estimates.

	All	High	Other	All	High	Other	All	High	Other	All	High	Other	All	High	Other	All	High	Other
Log_RGDP				0.67	0.52	1.19	-0.01*	0.14	-0.18	0.02	0.11	0.36	-0.09	0.09	0.11	0.34	-0.11	0.38
Log_CO2	0.83	0.78	0.43				-0.26	-0.36	-0.12	-0.04	-0.16	-0.09	0.02	-0.6	0.07	-0.11	0.64	-0.09
Energy mix	0.03*	0.82	-0.23	-0.79	-1.5	-0.44				0.24	0.08	0.35	0.15	-1.19	0.40	-0.22	2	-0.3
Forest_land	0.06	0.15	0.40	-0.04	-0.14	-0.24	0.17	0.02	0.28				-0.40	-0.44	-0.31	0.37	0.62	-0.08
Agri_land	-0.23	0.09	0.16	0.05	-0.44	0.26	0.09	-0.22	0.42	-0.36	-0.39	-0.45				0.56	1.08	-0.02*
Log_AgriRGDP	0.37	-0.04	0.59	-0.08	0.15	-0.44	-0.06	0.12	-0.34	0.13	0.17	-0.12	0.24	0.35	-0.02*			

Note: The asterisk (*) denotes insignificant estimates.

Therefore, for all the above pairs of variables, the income of the countries did not change the direction of their relationship, while for all other pairs of variables, the income played an important role in changing the relationship between them, especially in the presence of the two agricultural variables. Indeed, both agricultural variables produced conflicting results with all other variables, except for forest land and agricultural land, indicating that the agricultural sector is a very sensitive sector to income categorization. In fact, some of our findings are also supported by the literature. For example, the relationship between the agricultural sector and economic growth is found to be negative by Anderson (1987) and Anderson and Ponnusamy (2023) while Awokuse and Xie (2015) have detected a positive relationship for nine developing countries. Likewise, the relationship between the agricultural sector and CO_2 emissions is found to be positive by Raihan and Tuspekova (2022); Uddin (2020) and Raihan, Begum, Nizam, Said, and Pereira (2022) negative by Liu, Zhang, and Bae (2017) while the later study has also reported a positive relationship between the agricultural sector with the renewable energy sources.

In contrast to all the above, the only pair of variables that was affected by the country's income without the presence of any of the two agricultural variables is the logarithm of the real GDP per capita with the Energy Mix where their relationship was found to be positive for high-income countries, negative for other-income countries and insignificant for all countries. Perhaps, a possible explanation of this result is that the share of green energy has increased for high-income countries, as these countries can afford to finance such action, a finding that could also be related to the existence of the so-called energy mix Kuznets curve (see also (Kibria, Akhundjanov, & Oladi, 2019)).

Consequently, the separation of countries by income played an important role in differentiating the results obtained at the global level for the relationships between economic, environmental, forest and agricultural variables, noting also the significant role of the agricultural sector. Thus, it will be very interesting to study once more all the above relationships according to the geographical area of each country. For this purpose, the research is expanded to regions according to the following four geographical areas: a) Africa, b) America, c) Asia and d) Europe, where all variables, as before, are first examined for stationarity by applying the Im et al. (2003) and the Levin et al. (2002) panel unit root tests. Unlike the previous two cases, all variables under regional categorization were found to be non-stationary since the null hypothesis was accepted by both panel unit root tests, most likely due to the homogeneity of the data.

Therefore, the causality test, proposed by Juodis et al. (2021) is applied to the first difference of the series, knowing that all variables are non-stationary, and the result of this attempt is reported in Table 4. As can be seen from this table, no findings of causal relationships are revealed under the regional categorization, in contrast to the income categorization, where bidirectional causal relationships are discovered between the variables of this study. Indeed, only a few causal relationships are determined mainly by their regional characteristics, without however obtaining a uniform causal behavior across regions for the same pair of variables.

For example, the green energy plays a major role for causality in Africa, since the Energy Mix causes the logarithm of real GDP per capita as well as the logarithm of CO_2 emissions, while the dominant variable in America is the CO_2 emissions, since the logarithm of CO_2 emissions causes the logarithm of real GDP per capita and the percentage of forest land. On the other hand, the important variables for causality in Asia are the forest land, which causes all other variables except the logarithm of CO_2 emissions, and the logarithm of the real Agricultural GDP per capita which causes Energy Mix, Forest land and the percentage of Agricultural land. Lastly, in Europe, unlike all other regions, most cases support a bilateral causality, a finding that was also obtained for high-income countries, except for the logarithm of real Agricultural GDP per capita that causes the logarithm of the real GDP per capita.

Table 4. Granger causality test results for regional categorization.

	Africa	America	Asia	Europe	Africa	America	Asia	Europe	Africa	America	Asia	Europe	Africa	America	Asia	Europe	Africa	America	Asia	Europe	Africa	America	Asia	Europe
Log_RGDP					N	B	N	N	N	N	N	Y	N	Y	N	N	N	N	N	N	N	N	N	N
Log_CO2	N	B	N	N					N	N	N	B	N	Y	N	B	N	N	N	N	N	N	N	N
Energy mix	Y	N	N	N	Y	N	N	B					N	N	N	B	N	N	N	N	N	N	N	B
Forest_land	N	N	Y	N	N	N	N	B	N	N	Y	B					N	N	Y	B	N	N	B	N
Agri_land	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	N	B					N	N	N	N
Log_AgriRGDP	N	Y	N	Y	N	N	N	N	N	N	Y	B	N	N	B	N	N	N	Y	N				

Note: The capital letters B, N and Y define bilateral, no and yes causality from row to column variables, respectively.

Table 5. Cointegration test results for regional effects.

	Africa	America	Asia	Europe	Africa	America	Asia	Europe	Africa	America	Asia	Europe	Africa	America	Asia	Europe	Africa	America	Asia	Europe
Log_RGDP	N	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	Y	Y	Y	N	N
Log_CO2					Y	N	Y	N	N	N	N	N	Y	N	N	Y	N	N	N	N
Energy Mix									N	N	N	Y	N	N	N	Y	N	Y	N	Y
Forest_Land													N	N	Y	Y	N	Y	Y	Y
Agri_Land																	Y	N	Y	Y

Note: The capital letters N and Y define no and yes cointegration respectively.

To continue with this analysis and given that all variables are found to be non-stationary and in particularly I(1) processes, the Westerlund (2007) cointegration test for panel data is applied to all combinations of two variables to determine whether there is a long-run relationship between them and the results of this effort are reported in Table 5. However, only a few bivariate cases revealed evidence of cointegration with Europe having the largest number of cointegrated relationships and America the smallest one.

Furthermore, the variables that prevail in supporting long-term behaviors are agriculture, forest land and energy mix, a role that was not observed for these variables under income categorization, indicating most likely that the agricultural sector together with green energy plays an important role in overall economic and environmental activity of each country in the region. Finally, it should be noted that for this data categorization there were three bivariate cases that did not support cointegration for all four regions, namely the logarithm of the real GDP per capita with the logarithm of CO_2 emissions, the logarithm of the real per capita GDP with the percentage of forest land and the logarithm of CO_2 emissions with the logarithm of the real agricultural GDP per capita, perhaps the only consistent result derived from this analysis.

Table 6. Estimates of the long-run coefficient and the error correction term.

	Africa		America		Asia		Europe		
nt	**Coef.**	**ECT (-1)**	**Coef.**	**ECT (-1)**	**Coef.**	**ECT (-1)**	**Coef.**	**ECT (-1)**	dependent
Energy mix					-0.01*	-0.22	0.34	-0.08	Log_RGDP
Energy mix	-0.32	-0.27			-0.02*	-0.21			Log_CO2
Forest_land							0.62	-0.03	Energy mix
Agri_land							-0.07	-0.13	Log_RGDP
Agri_land	0.05	-0.11					0.16	-0.11	Log_CO2
Agri_land							-0.42	-0.07	Energy mix
Agri_land					1.32	-0.13	-0.33	-0.19	Forest_land
Log_AgriRGDP	0.78	-0.38	0.63	-0.25					Log_RGDP
Log_AgriRGDP			2.45	-0.27			0.62	-0.44	Energy mix
Log_AgriRGDP			-5.90	-0.14	-8.26	-0.10	0.54*	-0.42	Forest_land
Log_AgriRGDP	4.65	-0.16			6.80	-0.09	-0.70	-0.39	Agri_land

Note: All coefficients are significant at the 5% nominal level except for those with an asterisk (*) that are significant at the 10% nominal level.

Table 6 reports the coefficient estimates obtained from the cointegration analysis and more specifically it reports the coefficient of the long-run relationship between the two variables (denoted as Coef.) and the coefficient of the error correction term (ECT) [denoted as ECT (-1)] using the Pooled Mean Group estimator (PMG) technique, proposed by Pesaran, Shin, and Smith (1999) with one lag of both variables in the error correction model, chosen by AIC (Akaike Information Criterion), for all 21 cointegrated bivariate cases found in regional categorization. As can be seen from this table, no general statements can be made about common behaviors across regions, except that environmental and agricultural variables play a dominant role in supporting long-term behaviors with each other and with most of the other variables. It is also important to note that the results are consistent with some of those obtained under income categorization.

For example, there is a positive long-run relationship between the energy mix and the logarithm of real GDP per capita for Europe and a negative one for these variables for Asia, a finding also obtained for high-income and other-income countries respectively. Furthermore, the energy mix is negatively related to the logarithm of CO_2 emissions for Asia and Africa and positively to the percentage of forest land for Europe, results that are also revealed in the income categorization. Similarly, the percentage of agricultural land is negatively related in the long run to the energy mix and to the percentage of forest land in Europe, as found in the income specification, while the relationships of the percentage of agricultural land with the logarithm of real GDP per capita, which is negative in Europe, and with the logarithm of CO_2 emissions, which are positive in Europe and Africa, are not attained under income categorization.

Lastly and contrary to all the above there are some results that are quite contradictory with those obtained from the income specification. For example, the logarithm of the real agricultural GDP per capita is positively related with the logarithm of the real GDP per capita in Africa and in America, as well as with the Energy Mix in America and in Europe, while it is negatively related with the percentage of forest land in America and positively (negatively) with the percentage of agricultural land in Africa and Asia (Europe).

Likewise, no general statements can be made about a common behavior for the estimates of the error correction term for all cases, other than the sigh is negative for all cases, since its magnitude varies between regions, representing different rates of adjustment towards the long-run equilibrium. For example, the estimate of the error correction term between the logarithm of the real agricultural GDP per capita and the percentage of forest land is -0.18 and -0.10 for America and Asia, respectively, whereas for Europe is -0.42 representing a larger, in absolute terms, adjustment for these two variables in this region. The only case where the estimate of the long-run adjustment was the same for two regions was for the case of the percentage of agricultural land and the logarithm of CO_2 emissions, which was equal to -0.11 for both Africa and Europe.

Finally, the research was extended to investigate the behavior of all other variables that were not found to be cointegrated by running several regressions for panel data on first differences since the processes were found to be no-stationarity. Unfortunately, this effort did not produce any significant results even for the simple model without lags, blaming in essence the nature of the data for not finding short-term relationships under regional categorization.

4. CONCLUDING REMARKS

The relationship between environment and economic growth is very strong since the natural environment plays an important role in supporting economic activity, while economic development, as an effort to increase human well-being, creates dangerous climate changes that affect water resources, biodiversity and damages the environment. For this reason, many researchers have made remarkable efforts exploring the links and the dynamics of the relationships of these variables, including the subject of causality, a concept that is very important for governments and policy makers, using specific data sets for various countries.

Hence, this study examined the interactions of environmental, agricultural, and macroeconomic variables for 43 countries around the world, accounting for income and regional effects, hoping to determine whether a single pattern emerges regarding the environmental attitude of these countries, or whether this attitude varies across countries either in terms of income or in terms of regional characteristics. In addition, this study considered environmental and agricultural variables that have not been used in the literature to capture a better picture of how the environment is affected by economic development.

Perhaps the most interesting finding of this research is that the results obtained from this analysis do not support a single pattern regarding the relationships between environmental, agricultural, and economic variables globally, but differ between data specifications by country. For example, no clear direction of causality was found for all bivariate cases using the entire data set, as most causal relationships were bidirectional, as is also known in the literature, except for few univariate cases in income categorization. In contrast, no evidence of causality is revealed for most of the bivariate cases under regional categorization.

Moreover, this study notices the significant role of environmental and agricultural variables in the overall economic activity for all the countries considered in this research under a specific categorization of the data. Indeed, the environmental and agricultural variables have a different effect on all other variables in the income categorization, while in the regional categorization the agricultural sector plays an important role in determining the long-term relationships with the energy and economic variables. Therefore, for policy recommendations on the environment, it is important to consider the overall growth stage of the country and not just the region to which it belongs.

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