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Energy and Environment

Energy Consumption, Carbon Dioxide Emissions and Economic Growth: Fresh Evidence From Panel Quantile Regressions

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This paper analyzes the association between energy consumption, carbon dioxide emissions and economic growth. The results from panel quantile regressions for 57 countries and three different regions support deviations from sustainable growth in the full sample, as well as the European and Asian country samples. Similar results are obtained from Middle East and African countries, but the deviations begin earlier. In the Latin American findings, the estimates reveal that carbon emissions (at all levels) and energy consumption (at the medium and high levels) exert a negative impact on economic growth, indicating the inability of these countries to achieve sustainable economic growth.

1. Introduction

The literature identifies that energy and long-run economic growth are closely associated in countries around the globe (Baz et al., 2019; Rahman & Velayutham, 2020; Salisu & Ogbonna, 2019). However, sustainable growth is not independent of environmental problems. Therefore, it is imperative that the empirical research explicitly includes both energy consumption and environmental indicators (Gorus & Aydin, 2019).

Admittedly, addressing economic growth only in the context of energy and the environment can have misleading results, while the complexity of the real world requires certain indicators that may be directly related to growth. The impact of foreign direct investment (*FDI*) on growth in relation to liberalization policies is also important (Anwar & Nguyen, 2011; Omri & Kahouli, 2014), given the profound role of *FDI* in new investments, up-to-date technologies, and managerial skills for the host countries (Pegkas, 2015). International trade, along with associated liberalization developments, seem to be also important for economic growth (Frankel & Romeri, 1999; Musila & Yiheyis, 2015). The literature emphasizes that economic growth also heavily depends on trade openness (Grossman & Helpman, 1991; Spilimbergo, 2000). In contrast, as the share of the state in the economy is gradually shrinking, the role of government expenditures in economic growth is another important determinant, although its impact has generated mixed results (Kelly, 1997; Knoop, 1999).

The goal of this paper is to explore the nexus between energy consumption (*EC*), carbon dioxide emissions (CO_2), gross capital formation (*GCF*), labor force (*L*), FDI, government expenditures (*GE*), trade openness (*TO*) and economic growth (*EG*) across 57 countries, spanning the period 1990-2018. The study contributes in three ways. First, the energy-environment-growth nexus is considered along with *GCF, L, FDI,* and *GE*. Second, the analysis focuses on 57 countries from the European and Asian regions (22 countries), Latin American and Caribbean regions (15 countries), and Middle Eastern and African regions (20 countries). Finally, the analysis adopts a panel quantile regression model. The advantage of this method is that it allows not only heterogeneity across countries, but also provides different estimates, with respect to the mean, at the tails of the distribution.

2. Literature review

In the literature that uses panel-country studies, Saidi and Hammami (2015) reach the conclusion that for 58 countries (i.e. European and North Asian, Latin American and Caribbean, and Middle Eastern, North African and Sub-Saharan), there is a positive impact of *EG* on *EC*, while CO_2 emissions cause higher energy consumption at a global level. In the case of European and North Asian, and Latin American and Caribbean countries, higher levels of EG and CO_2 emissions contribute to stronger *EC*. Similar country groups have also been employed by Acheampong (2018), who finds that *EC* negatively affects *EG* at the global level. Chen et al. (2016) show that energy use negatively impacts *GDP*. Gorus and Aydın (2019) consider the case of MENA countries. Their results signify the absence of any causal relationship between EG and environmental pollution, while Muhammad (2019), in the case of emerging and MENA countries, illustrates that *EG* improves with *EC* in both developed and emerging countries, while it declines in the case of MENA countries. He finds that CO_2 emissions increase across all countries due to stronger *EC*.

3. Model and Methodology

The empirical analysis makes use of a basic production function accounting framework:

$$GDP = f(EC,\ \mathrm{CO_2},\ FDI,\ L, K, GE, TO)$$

where *GDP* denotes real *GDP*.

To the best of our knowledge, this paper is the first attempt to apply panel quantile regressions to explore the association between CO_2, *EC* and *EG*. A special advantage is these estimators are robust to outliers and skewed distributions. Moreover, allowing for unobserved heterogeneity, this method enables the exploration of differences in the growth rates among slow, moderate and fast-growing cases. In our sample, certain countries can grow faster than others; by contrast, OLS regressions provide estimates that

Table 1: Panel quantile estimates (full sample)

	Quantiles				
Variables	10%	25%	50%	75%	90%
C	0.327*	0.341*	0.319*	0.307*	0.286
	[0.08]	[0.07]	[0.09]	[0.10]	[0.13]
CO_2	0.042**	0.049**	0.045**	-0.056**	-0.061***
	[0.03]	[0.02]	[0.02]	[0.02]	[0.01]
EC	0.058***	0.061***	0.065***	-0.074***	-0.078***
	[0.01]	[0.00]	[0.00]	[0.00]	[0.00]
L	0.063***	0.058***	0.052***	0.045***	0.041**
	[0.00]	[0.00]	[0.00]	[0.01]	[0.02]
FDI	0.039**	0.051**	0.054**	0.073***	0.079***
	[0.04]	[0.02]	[0.02]	[0.00]	[0.00]
GCF	0.044**	0.056**	0.068**	0.079***	0.084***
	[0.04]	[0.03]	[0.02]	[0.01]	[0.00]
GE	0.067***	0.069***	0.061***	0.058***	0.059***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
TO	0.074***	0.077***	0.075***	0.079***	0.081***
[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]

The estimates are for the full sample per quantile, with low-growth-10-25%; medium-growth-50%; and high-growth-75-90% representing the three quantile areas. The analysis employs the method proposed by Koenker (2004), based on the idea of penalized least squares interpretation of the classical random-effects estimators. Figures in brackets denote *p*-values. The asterisks ***, ** & * imply statistical significance at the 1%, 5% & 10% levels, respectively.

represent the effect from an independent variable on the 'average country'. The analysis employs the method proposed by Koenker (2004), which uses the idea of penalized least squares interpretation of the classical random-effects estimator.

4. Data

The analysis uses annual data, spanning the period 1990 to 2018 for 57 countries belonging to three groups, i.e. the European and Asian region (22 countries), the Latin American region (15 countries), and the Middle Eastern, North African, and the Sub-Saharan region (20 countries). Data on real *GDP* (constant 2010 US dollars), CO_2 emissions (metric tons per capita), *EC* (in kg of oil equivalent per capita), *FDI* net inflows as percentage of *GDP*, *GCF* (in constant 2010 US dollars), *TO* (the percentage of the sum of imports and exports to *GDP*), *GE* as percentage of *GDP*, and *L* measures (total workers) are obtained from the World Development Indicators database. All data are in logarithm form except those already in percentage terms.

5. Empirical analysis

Table 1 reports the estimates for the full sample per quantile (i.e., low-growth-10-25%; medium-growth-50%; and high-growth-75-90%). Focusing on EC, the results show that *EG* is heavily dependent on *EC* across all growth quantiles. The coefficient appears positive and statistically significant only up to medium-growth levels, where then turns out to be negative. Similarly, in terms of CO_2 emissions, the findings illustrate a positive effect on *EG* up to medium-growth levels, while at high levels of *EG* the coefficient turns out to be negative. In other words, at low growth levels, the growth process seems capable of sustaining environmental pollution. By contrast, at high levels, the evidence shows that countries do not invest in technologies that are environmentally friendly, implying that countries cannot achieve sustainable growth. Accordingly, although it is expected that strong *EG* records can be high-energy efficient, compensating for the presence of increased emissions, does not hold in our full-country case.

The findings come in conflict with the literature that performs analysis with respect to the mean of the distribution, indicating the negative effect of *EC* on *EG* at high growth levels, thus, putting in jeopardy the validity of the growth hypothesis at these levels.

Table 2 reports the estimates per geographical region. CO_2 and *EC* reveal a negative effect on *EG* at high levels, implying that European countries cannot exert an efficient control over sustainable growth targets at high *EG* rates. In the Latin American countries, the estimates document that CO_2 (at all levels) and *EC* (at the medium and high levels) exert a negative impact on *EG*, i.e. the inability of these countries to achieve sustainable *EG*. Finally, the results for the Middle East and African countries highlight that *EC* cannot support *EG* targets at high levels due to the presence of detrimental environmental effects.

6. Conclusion

This paper examines the impact of *EC* and CO_2 emissions on *EG* for 57 countries from three different geographical regions over the period 1990-2018. The results with respect to the full sample and the European and Asian regions suggest that *EG* is positively influenced by CO_2 and *EC* up to the medium growth levels, whereas it turned negative. The results imply that these economies witness deviations from

Table 2: Panel quantile estimates (country groups)

	Quantiles				
European and Asian countries					
Variables	10%	25%	50%	75%	90%
Constant	0.253	0.299	0.284	0.268	0.239
	[0.15]	[0.12]	[0.13]	[0.14]	[0.19]
CO_2	0.051**	0.058***	0.053***	-0.063***	-0.075***
	[0.02]	[0.01]	[0.01]	[0.01]	[0.00]
EC	0.063***	0.069***	0.072***	-0.046***	-0.059***
	[0.00]	[0.00]	[0.00]	[0.01]	[0.00]
L	0.058***	0.061***	0.062***	0.057***	0.050***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.01]
FDI	0.048**	0.059***	0.065***	0.077***	0.082***
	[0.02]	[0.01]	[0.00]	[0.00]	[0.00]
GCF	0.049**	0.061***	0.073***	0.080***	0.087***
	[0.03]	[0.01]	[0.00]	[0.00]	[0.00]
GE	0.062***	0.065***	0.060***	0.055***	0.057***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
TO	0.077***	0.080***	0.081***	0.085***	0.088***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Latin American countries					
Variables	10%	25%	50%	75%	90%
Constant	0.339*	0.348*	0.330*	0.319*	0.299*
	[0.07]	[0.06]	[0.08]	[0.09]	[0.10]
CO_2	-0.038**	-0.042**	-0.041**	-0.040**	-0.049**
	[0.04]	[0.03]	[0.03]	[0.03]	[0.02]
EC	0.051***	0.055***	-0.059***	-0.063***	-0.068***
	[0.01]	[0.00]	[0.00]	[0.00]	[0.00]
L	0.069***	0.073***	0.072***	0.079***	0.081***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
FDI	0.030**	0.033**	0.034**	0.042**	0.049**
	[0.05]	[0.05]	[0.05]	[0.04]	[0.03]
GCF	0.040**	0.044**	0.049**	0.054**	0.058**
	[0.05]	[0.05]	[0.04]	[0.03]	[0.02]
GE	0.078***	0.075***	0.081***	0.084***	0.089***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
TO	0.055***	0.059***	0.064***	0.069***	0.073***
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Middle East and African countries					
Variables	10%	25%	50%	75%	90%
Constant	0.405*	0.417*	0.438**	0.451**	0.432**
	[0.06]	[0.06]	[0.05]	[0.04]	[0.05]
CO_2	0.048**	0.053**	-0.059**	-0.064**	-0.072***
	[0.03]	[0.03]	[0.02]	[0.02]	[0.01]
EC	0.050***	0.064***	0.069***	-0.057***	-0.063***
	[0.00]	[0.00]	[0.00]	[0.01]	[0.00]
L	0.034**	0.039**	0.042**	0.046**	0.045**
	[0.04]	[0.04]	[0.03]	[0.03]	[0.03]
FDI	0.027*	0.030**	0.036**	0.035**	0.039**

	[0.06]	[0.05]	[0.05]	[0.05]	[0.04]
GCF	0.037**	0.036**	0.039**	0.044**	0.048**
	[0.05]	[0.05]	[0.05]	[0.04]	[0.03]
GE	0.035**	0.038**	0.040**	0.044**	0.048**
	[0.05]	[0.05]	[0.04]	[0.04]	[0.03]
TO	0.039**	0.037**	0.043**	0.048**	0.041**
	[0.05]	[0.05]	[0.04]	[0.04]	[0.05]

The estimates are for the full sample per quantile, with low-growth-10-25%; medium-growth-50%; and high-growth-75-90% representing the three quantile areas. The analysis employs the method proposed by Koenker (2004), based on the idea of penalized least squares interpretation of the classical random-effects estimators. Figures in brackets denote p-values. The asterisks ***, ** & * imply statistical significance at the 1%, 5% & 10% levels, respectively. Figures in brackets denote p-values.

sustainability targets at high growth rates. The Middle East and African countries can achieve sustainability up to high levels of growth, but they are affected by *EC* and CO_2 after the medium growth levels. The evidence from the Latin American countries indicates a negative effect from CO_2 emissions across all growth levels, i.e. they fail to achieve more sustainable growth.

The findings imply that European countries have come up with pioneering policies in terms of climate change and sustainability, but not at high growth levels. They need some long-run policies towards environmental investments. This is similar for the Asian, Middle East and African country groups. It is clear that more fundamental reforms are needed by the Latin American countries. They should encourage more environmentally friendly activities to mitigate carbon emissions.

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Appendix

Country samples.

European and Asian (22 countries): Albania, Belgium, Bulgaria, Denmark, France, Germany, Greece, Hong Kong, Hungary, Iceland, Ireland, Italy, Japan, the Rep. of Korea, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the UK.

Latin American (15 countries): Argentina, Bolivia, Brazil, Chile, Costa Rica, Ecuador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, Venezuela.

Middle East and African (20 countries): Algeria, Botswana, Cameroon, the Rep. of Congo, Cote d'Ivoire, Egypt, Ethiopia, Gabon, Ghana, Iran, Jordan, Kenya, Morocco, Mozambique, South Africa, Senegal, Sudan, Togo, Tunisia, Zambia.

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