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Modeling Driving Factors of Carbon Dioxide Emissions: Quantile Regression Evidence from Different Country Groups

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Abstract

The relationship between CO2 emissions and various macroeconomic variables has stimulated a large empirical literature. However, this literature has relied on a mean-based regression framework in which the analysis is focused on the mean effects of covariates on pollution level. In this paper, we use quantile regression to reexamine the determinants of CO2 emissions across different points of the distribution of CO2 emissions for 59 countries. The results support some findings in the literature, but also provide new conclusions. The impact of energy consumption is positive and larger in low pollution countries. Openness to trade increases pollution in African and American countries at the lower levels of pollution and in European countries at the lower and higher levels of pollution. On the contrary, foreign trade is good for environment in Asian countries, especially in those at the left tail of the distribution of CO2 emissions. Urbanization reduces pollution in African countries while it contributes to pollution in Asian and European countries. In American countries, urbanization increases CO2 emissions at the lower levels of pollution and reduces it at the higher levels of pollution. These findings suggest that pollution control policies should be tailored differently across low and high pollution countries.

Keywords: Carbon dioxide (CO2) emissions, Energy use, GDP, trade, quantile regression
JEL Classification: C23, F18, O50, Q53.

1. Introduction

The issues of global warming and climate change are becoming a subject of intense interest all over the world. The 1992 Rio Eart Summit, the 1997 Kyoto Agreement and more recently the 2015 Conference of the Parties (COP21) have called the international attention upon the potential instruments to tackle this problem. It is well known that the driver of climate change is the increasing level of greenhouse gas emissions in the atmosphere. As Carbon dioxide (CO_2) is the most greenhouse gas, it has captured more attention from policymakers, international organizations and researchers. Policymakers and international organizations are attempting to make the control of pollution an important part of their agenda through agreements and protocols. Researchers are attempting to understand what factors are driving CO_2 emissions. Thus, a growing body of studies has been accumulated during the last decades to uncover the driving factors of CO_2 emissions. Studies in this field may be divided into two main lines of research. The first stand of the literature focused on the relationship between economic growth and CO_2 emissions, testing the validity of the Environmental Kuznets Curve (EKC) hypothesis. The empirical evidence from this literature is mixed. For example, while some studies found evidence supporting the EKC hypothesis (see Dinda and Coondoo, 2006; Apergis and Payne, 2009; Jalil and Mahmud, 2009; Lamla, 2009; Iwata *et al.* 2010), others found no support for this hypothesis or mixed results (see Dinda *et al.* 2000, Perman and Stern, 2003; Martinez-Zarzoso and Bengochea-Morancho, 2004; Galeotti *et al.* 2006; Aslanidis and Iranzo, 2009; Baek, 2015). Some of these studies are likely to suffer from the omitted variables bias problem. A second line of research investigated the relationship between CO_2 emissions and economic growth including into the nexus the impact of other economic variables such as energy consumption, trade openness, financial development, foreign direct investment or urbanization. These studies also provided mixed results and the evidence regarding the impact of some variables remains unclear (see Smyth and Narayan, 2015 for a recent review). For example, Antweiler *et al*. (2001) found that trade is good for the environment in a panel of 44 countries. Aka (2008) found that economic growth contributes to the degradation of air quality, while trade is beneficial to the environment in the case of Sub-Saharan Africa. Martinez-Zarzoso and Maruotti (2011) analyzed the impact of urbanization on CO_2 emissions for a panel of 88 developing countries and found mixed results. The effect of urbanization is positive for low urbanization levels. Sharma (2011) investigated the determinants of CO_2 emissions for the global panel of 69 countries. He found that GDP per capita and urbanization are two of the main determinants of CO2 emissions in the global panel, while trade openness, per capita total primary energy consumption and per capita electric power consumption have statistically insignificant effects on CO2 emissions. The effect of GDP per capita is positive while that of urbanization is negative. Akin (2014) investigated the case of 85 countries and found a positive relationship between CO_2 emissions, energy consumption and per capita income. Trade openness decreases CO_2 emissions after a threshold level. Examining the case of MENA region, Jalil (2014) found that per capita GDP, energy consumption, foreign direct investment and agriculture production have significant impact on CO_2 emissions. Finally, Sadorsky (2014) found that GDP per capita, population and energy intensity have positive impact on CO_2 emissions in emerging economies while urbanization is found to have no significant impact.

A number of researchers have recently argued that the mixed findings in existing literature may reflect differences in econometric methodologies and model specification (e.g. Smyth and Narayan, 2015; Westerlund *et al*. 2015). A major limitation of existing studies is that they have been conducted in a mean-based regression framework, in which one implicitly assumes that possible differences in terms of the impact of exogenous variables along the distribution of CO_2 emissions are not significant. However, theory does not provide any guide as to why we should focus the analysis on the mean effects only. Further, the assumption of a mean shift is a testable hypothesis in a statistical framework. We argue that it is informative to analyze the entire CO_2 emissions distribution instead of just the mean level. This is important because the way in which variables affect CO_2 emissions can be different in high and low pollution countries. It is likely that 'dirty' and 'clean' economies respond differently to factors that spur polluting activities. Furthermore, it is possible that pollution feeds on itself particularly in developing countries where environmental protection policies are weak.

Unlike the previous studies, this paper contributes to the empirical literature by reexamining the determinants of CO_2 emissions using the quantile regression methodology introduced by Koenker and Bassett (1978). The quantile regression is superior to mean-based estimation procedures in the following two respects. First, the results derived from a least squares regression method lack robustness in presence of outliers and non-normal distributions. Second, as quantile regression covers the entire distribution of the dependent variable, it can reveal the asymmetric and non-linear effects of exogenous variables on CO_2 emissions. The quantile regression has been used widely in many areas of applied economics. But to the best of our knowledge, our paper is the first to analyze the determinants of CO_2 emissions at different points of the pollution distribution.

The remainder of the article is organized as follows. Section 2 outlines the estimation methodology and describes the data. Section 3 discusses the empirical results, while Section 4 concludes.

2. Model, Data and Methodology

2.1 Empirical Model

Based on the empirical literature, we specify the empirical model as follows:

$$CO_{2it} = \theta_0 + \theta_1 E_{it} + \theta_2 I_{it} + \theta_3 I_{it}^2 + \theta_4 T_{it} + \theta_5 U_{it} + \mu_{it} \tag{1}$$

where i is for country i in the panel, t refers to the time period, CO_2 stands for per capita carbon dioxide emissions, E is energy use per capita, I stands for income measured by real GDP per capita, T is trade openness and U is urbanization rate.

It is hypothesised that higher energy use results in more CO_2 emissions. Therefore the expected sign of θ_1 is positive. Under the EKC hypothesis, the sign of θ_2 is expected to be positive whereas a negative sign is expected for θ_3. The expected sign of θ_4 is mixed depending on stage of economic development of country. In the case of developed countries, it is expected to be negative as countries develop, they reduce the production of pollution intensive goods and instead import these from other countries with less restrictive environmental protection laws (Jalil and Mahmud, 2009; Kohler, 2013). In the case of developing countries, the sign on trade is expected to be positive. The expected sign of θ_5 is positive as urbanization exerts pressure on urban resources and environment.

2.2. The Quantile Regression Approach

In the classical econometric techniques, the component around which the dependent variable randomly fluctuates is the conditional mean. Thus, previous studies using these methods deliver the average effects of explanatory variables over the whole distribution of the dependent variable. However, in this study we are interested in studying the impact of exogenous variables on the entire distribution of CO_2 emissions. Therefore we rely on the quantile regression method which was first introduced by Koenker and Bassett (1978) and discussed in further works (see Koenker and Machado, 1999; Koenker and Hallock, 2001). This method has two main advantages. First, compared to OLS regression, it is more robust to outliers and to non-normal distribution. Second, it allows for the estimation of the effect of explanatory variables at different points of the distribution of the dependent variable.

The quantile regression model can be formulated as follows:

$$q(CO_{2it} / \Omega_t) = \theta_{0\tau} + \theta_{1\tau} E_{it} + \theta_{2\tau} I_{it} + \theta_{3\tau} I_{it}^2 + \theta_{4\tau} T_{it} + \theta_{5\tau} U_{it} + \mu_{it} \tag{2}$$

where $q(CO_{2it} / \Omega_{it})$ is the conditional quantile of CO_2 and Ω_t contains the available information known at time t. Eq. (2) can be written as follows:

$$y_{it} = x_{it}\theta_\tau + \varepsilon_{it} \tag{3}$$

where $x_{it} = \left(1, E_{it}, I_{it,}, I_{it}^2, T_{it}, U_{it}\right)$ is the vector of explanatory variables; θ_τ are the $k \times 1$ regression coefficients at the τ-th quantile of the dependent variable y.

Contrary to OLS which is based on minimizing the sum of squared residuals, the τ-th quantile regression estimator of θ minimizes an asymmetrically weighted sum of absolute errors:

$$\min_\theta \left[\sum_{y_{it} \geq x_{it}\theta_\tau} \tau \left| y_{it} - x_{it}\theta_\tau \right| + \sum_{y_{it} \leq x_{it}\theta_\tau} (1-\tau) \left| y_{it} - x_{it}\theta_\tau \right| \right] = \min_\theta \sum_{t=1}^{T} \phi_\tau \left(y_{it} - x_{it}\theta_\tau \right) \tag{4}$$

where $\phi_\tau(z)$ is a loss function defined as $\phi_\tau(z) = |z| + (2\tau - 1)z$, $0 < \tau < 1$.

The quantile regression method allows the marginal effects of covariates to change at different points in the conditional distribution by estimating θ_τ using several different values of τ. It is in this way that quantile regression allows for parameter heterogeneity in the response of the dependent variable to explanatory variables.

2.3. Data and Descriptive Statistics

The empirical analysis uses data for 59 countries divided into five groups: 15 Sub-Saharan African countries, 13 American countries, 10 Asian countries, 13 European countries, and 8 MENA member countries. The list of countries is presented in Table 1. The countries were chosen based on data availability. We use annual time series for real GDP per capita expressed in constant 2000 US dollar, per capita energy consumption in kg oil equivalent, per capita CO_2 emissions measured in metric tons, trade openness measured as ratio of exports plus imports of goods and services to GDP, and urbanization measured as the share of the urban population in total population. All the data are obtained from the 2015 World Development Indicators by the World Bank. The sample period varies across regions and has been dictated by availability of the data for all the series. All the data were converted into natural logarithms.

Table 1: List of countries and sample period

Regions	Countries	Sample period
Sub-Saharan Africa	Benin, Cameroon, Congo democratic, Congo Republic, Cote d'Ivoire, Gabon, Ghana, Kenya, Mauritius, Nigeria, Senegal, South Africa, Togo, Zambia, Zimbabwe	1976-2011
America	Argentina, Bolivia, Brazil, Canada, Chile, Colombia, Ecuador, Guatemala, Honduras, Mexico, Peru, Uruguay, Venezuela	1971-2011
Asia	Bangladesh, China, India, Indonesia, Malaysia, Pakistan, Philippines, Singapore, Sri Lanka, Thailand	1971-2011
Europe	Austria, Finland, Greece, Turkey, Belgium, Denmark, France, Italy, Luxembourg, Portugal, Spain, Sweden, UK	1971-2011
MENA	Algeria, Egypt, Iran, Jordan, Morocco, Oman, Saudi Arabia, Tunisia	1976-2011

Table 2 presents some summary statistics of the data. They show a great variability across groups. As can be seen, European countries have greater per capita GDP, are more urbanized, are greater consumers of energy and pollute more, followed by American and MENA countries. The Kurtosis shows values exceeding 3 in most cases, suggesting that the series have heavy tails. The Jarque-Bera test statistic suggests that the CO_2 emissions series shows a non-normal distribution, which supports the use of quantile regression technique to study the entire distribution instead of relying on the mean.

Table 2: Descriptive statistics

Variables	Obs.	Mean	Std. Dev.	Min	Max	Kurtosis	Skewness	JB
Panel A: Sub-saharan African countries								
CO2 emissions	540	-0.652	1.221	-3.391	2.387	3.536	0.807	65.21 (0.000)
Energy use	540	6.280	0.627	5.336	8.000	3.655	1.153	129.44 (0.000)
GDP	540	6.899	0.946	5.279	9.514	2.857	0.945	80.87 (0.000)
GDP squared	540	48.502	13.931	27.872	90.527	3.133	1.125	114.43 (0.000)
Trade	540	4.170	0.421	1.843	5.055	5.413	-0.773	184.83 (0.000)
Urbanization	540	3.631	0.338	2.602	4.454	3.528	-0.281	13.42 (0.000)
Panel B: American countries								
CO2 emissions	533	0.596	0.937	-0.885	2.901	3.167	0.792	56.37 (0.000)
Energy use	533	6.830	0.784	5.402	9.033	4.471	1.395	221.13 (0.000)
GDP	533	8.062	0.867	6.660	10.523	3.840	0.878	84.22 (0.000)
GDP squared	533	65.758	14.690	44.355	110.742	4.591	1.199	184.13 (0.000)
Trade	533	3.760	0.510	2.446	4.916	3.028	-0.307	8.42 (0.014)
Urbanization	533	4.193	0.275	3.386	4.549	2.801	-0.910	74.49 (0.000)
Panel C: Asian countries								
CO2 emissions	410	0.082	1.255	-3.282	2.950	2.745	0.212	4.18 (0.123)
Energy use	410	6.364	0.910	4.449	8.905	3.304	0.529	20.77 (0.000)
GDP	410	7.003	1.191	5.013	10.495	3.722	1.069	87.04 (0.000)
GDP squared	410	50.463	18.297	25.135	110.156	4.673	1.437	189.00 (0.000)

Variables	Obs.	Mean	Std. Dev.	Min	Max	Kurtosis	Skewness	JB
Trade	410	4.018	0.921	1.605	6.085	2.850	0.292	6.22 (0.044)
Urbanization	410	3.497	0.527	2.066	4.605	3.067	0.500	17.197 (0.000)
Panel D: European countries								
CO2 emissions	533	2.034	0.567	0.293	3.703	4.126	-0.135	29.817 (0.000)
Energy use	533	8.064	0.612	6.307	9.474	3.118	-0.532	25.522 (0.000)
GDP	533	10.052	0.602	8.081	11.382	4.628	-1.075	161.640 (0.000)
GDP squared	533	101.411	11.730	65.309	129.561	4.226	-0.845	96.968 (0.000)
Trade	533	4.104	0.534	2.208	5.853	4.559	0.643	90.817 (0.000)
Urbanization	533	4.286	0.189	3.662	4.581	4.792	-1.242	208.547 (0.000)
Panel E: MENA countries								
CO2 emissions	288	1.202	0.863	-0.458	3.005	2.267	0.359	12.628 (0.001)
Energy use	288	6.951	0.845	5.457	8.981	2.488	0.541	17.219 (0.000)
GDP	288	8.028	0.902	6.271	9.998	2.324	0.567	20.939 (0.000)
GDP squared	288	65.265	14.968	39.321	99.977	2.391	0.724	29.657 (0.000)
Trade	288	4.221	0.385	2.649	5.006	3.759	-0.483	18.136 (0.000)
Urbanization	288	4.069	0.214	3.648	4.415	1.818	-0.097	17.210 (0.000)

Note: JB refers to the Chi2 statistic from the Jarque-Bera test of normality, with p-values in parentheses.

3. Results and Discussion

We present in Tables 3–7 the quantile regression estimates of the determinants of CO_2 emissions. We report results for the 10th, 25th, 50th, 75th and 90th quantiles. For comparison purposes we also report results of pooled OLS estimates showing the mean effects of all covariates. All estimates were obtained using STATA. Figures 1–5 illustrate how the magnitude of the coefficients of the covariates varies over quantiles of the CO_2 emissions distribution.

The OLS results indicate that energy consumption increases CO_2 emissions in all panels. In addition, the inverted U-shaped relationship between CO_2 emissions and GDP is found for all panels, providing support for the EKC hypothesis. However, the impacts of trade and urbanization differ across regions. While CO_2 emissions and trade are positively related in European and MENA countries, they are negatively linked in Asian countries, and not significantly related in African and American countries. Also, urbanization increases pollution in American, Asian and European countries while it is associated with lower pollution in African and MENA countries.

The quantile regression results suggest some important differences across different points in the conditional distribution of CO_2 emissions. The estimates reject equality of the estimated coefficients for most variables. The impact of energy consumption on CO_2 emissions is positive in all specifications. Its impact is larger in African, American, Asian and MENA countries with lower levels of pollution. For African countries, the effect of energy on pollution follows an inverted U-shaped relationship across quantiles whereas for Asian and MENA regions the effect shows a decreasing trend with quantiles. For example, for Asian countries, a 1% increase in energy consumption increases CO_2 emissions by 1.61% at the lower level of pollution but by 1.34% at the higher level of pollution. By contrast, in European countries, the impact of energy use is positive and increasing as we move from lower to higher quantiles. For example, a 1% increase in energy consumption increases CO_2 emissions by 0.34% in the left tail of the pollution distribution but by 0.88% in the right tail of the distribution. The hypothesis of equality of coefficients across quantiles cannot be rejected for GDP and GDP squared for African and MENA countries, suggesting that magnitude of the effect of GDP is similar across quantiles.

Another important result is the coefficient on trade. The coefficient is not significant in the OLS regression for African and American countries. In the quantile regression the coefficient is positive and significant in African countries for the 0.10 and 0.25 quantiles; however, it is insignificant for the 0.5 quantile (median) and higher. This suggests that openness to trade increases pollution at the lower levels of pollution while at the higher levels of pollution the effect of trade is not significant. For American countries, the effect of trade is significantly positive for lower quantiles and significantly negative for the median. In the case of Asian countries, the effect of trade is negative and increases (less negative) with quantiles. This result consistent with the OLS regression suggests that trade is good for environment in Asian countries, especially in countries at the left tail of the distribution of CO_2 emissions. By contrast, the results for European countries indicate that trade increases pollution at all quantiles, but the effect is relatively large at the bottom and the top tails of the distribution. The results for MENA countries indicate that the hypothesis of equality of coefficients across quantiles cannot be rejected for trade openness.

With respect to urbanization, the effect for African countries shows an inverted U-shaped relation with quantiles. The effect is significantly negative for lower and middle quantiles and for the top tail of the pollution distribution, suggesting that urbanization reduces pollution for countries at the lower and higher parts of the distribution of CO_2 emissions. In the panel of American countries, urbanization increases CO_2 emissions for lower and middle quantiles whereas it becomes good for environment at higher levels of pollution. The effect of urbanization is positive across quantiles for Asian and European countries. The effect increases with quantiles in Asian countries and is larger in magnitude at higher levels of pollution, i.e., at the right tail of the distribution. For MENA countries the null hypothesis of equality of coefficients across quantiles cannot be rejected.

Table 3: Determinants of CO_2 emissions for African countries

	OLS	Quantile Regression					Test of symmetry[1]		Test of equality[2]
		q10	q25	q50	q75	q90	q10=q90	q25=q75	
Energy use	1.142* (19.27)	1.231* (9.02)	1.303* (19.26)	1.245* (10.93)	1.201* (19.01)	0.915* (23.82)	5.15* (0.023)	1.73 (0.189)	13.31* (0.000)
GDP	2.807* (7.24)	2.287* (4.27)	2.538* (8.91)	2.076* (2.44)	2.441* (4.67)	2.077* (3.64)	0.08 (0.783)	0.06 (0.804)	0.26 (0.906)
GDP squared	-0.152* (-5.59)	-0.119* (-2.98)	-0.125* (-5.75)	-0.104** (-1.74)	-0.136* (-3.75)	-0.101* (-2.63)	0.11 (0.743)	0.10 (0.750)	0.26 (0.901)
Trade	0.064 (1.08)	0.265* (1.98)	0.184* (3.36)	0.006 (0.04)	-0.006 (-0.10)	0.035 (0.49)	2.40 (0.121)	7.96* (0.005)	2.28** (0.059)
Urbanization	-0.202* (-2.76)	-0.472* (-3.81)	-0.439* (-6.07)	-0.147** (-1.62)	0.092 (1.02)	-0.311* (-2.66)	0.89 (0.344)	29.79* (0.000)	9.24* (0.000)
Constant	-19.335* (-12.32)	-18.434* (-8.00)	-19.782* (-18.52)	-17.180* (-4.56)	-18.226* (-8.76)	-14.188* (-5.93)	1.70 (0.193)	0.61 (0.433)	1.41 (0.228)

Note: The numbers in parentheses are *t-statistics* computed from heteroskedasticity-robust standard errors. Quantile regression results are based upon 1000 bootstrapping repetitions. The asterisks ** and * denote significance at the 10% and 5% levels, respectively. (1) F-statistic and associated p-values for symmetry test. (2) F-statistic and associated p-values are reported for the test of equality of the coefficients across quantiles (i.e. q10=q25=q50=q75=q90)

Table 4: Determinants of CO_2 emissions for American countries

	OLS	Quantile Regression					Test of symmetry[1]		Test of equality[2]
		q10	q25	q50	q75	q90	q10=q90	q25=q75	
Energy use	1.001* (22.32)	1.281* (21.21)	1.318* (32.98)	1.064* (19.84)	1.059* (26.05)	1.042* (22.35)	10.77* (0.001)	29.41* (0.000)	10.42* (0.000)
GDP	0.955* (3.39)	2.611* (10.89	2.225* (4.69)	0.716* (2.31)	1.257* (4.57)	1.107* (4.10)	19.90* (0.000)	4.39* (0.036)	9.87* (0.000)
GDP squared	-0.052* (-3.19)	-0.154* (-9.79)	-0.135* (-5.35)	-0.043* (-2.41)	-0.074* (-5.26)	-0.067* (-4.47)	18.10* (0.000)	6.40* (0.011)	9.39* (0.000)
Trade	-0.015 (-0.72)	0.137* (6.32)	0.103* (2.44)	-0.068* (-3.04)	-0.031 (-1.66)	0.009 (0.27)	10.04* (0.001)	9.01* (0.002)	14.41* (0.000)
Urbanization	0.371* (5.09)	0.255 (5.80)	0.318* (2.96)	0.516* (2.92)	-0.033 (-0.29)	-0.269** (-1.88)	13.07* (0.000)	6.33* (0.012)	7.21* (0.000)
Constant	-11.993* (-10-16)	-20.981* (-19.02)	-19.359* (-10.74)	-11.513* (-10.64)	-11.471* (-11.06)	-9.608* (-9.44)	66.47* (0.000)	20.22* (0.000)	22.81* (0.000)

Table 5: Determinants of CO_2 emissions for Asian countries

	OLS	Quantile Regression					Test of symmetry[1]		Test of equality[2]
		q10	q25	q50	q75	q90	q10=q90	q25=q75	
Energy use	1.343*	1.610*	1.547*	1.398*	1.356*	1.340*	4.93*	1.66	1.25
	(34.77)	(13.19)	(9.85)	(19.67)	(47.84)	(81.21)	(0.026)	(0.199)	(0.287)
GDP	1.119*	1.640*	1.602*	0.848*	0.309	0.078	26.39*	15.61*	9.17*
	(5.79)	(5.50)	(5.67)	(3.02)	(1.11)	(0.64)	(0.000)	(0.000)	(0.000)
GDP squared	-0.078*	-0.117*	-0.106*	-0.056*	-0.031	-0.018*	28.34*	10.81*	7.83*
	(-6.09)	(-6.59)	(-5.05)	(-3.75)	(-1.60)	(-2.07)	(0.000)	(0.001)	(0.000)
Trade	-0.283*	-0.405*	-0.389*	-0.327*	-0.172*	-0.073	20.84*	7.63*	6.89*
	(-6.06)	(-6.60)	(-7.25)	(-4.38)	(-2.26)	(-1.49)	(0.000)	(0.006)	(0.000)
Urbanization	0.598*	0.261*	0.197**	0.362*	0.744*	0.861*	29.34*	18.83*	16.49*
	(8.65)	(2.41)	(1.78)	(5.33)	(7.64)	(20.80)	(0.000)	(0.000)	(0.000)
Constant	-13.304*	-15.394*	-14.910*	-11.901*	-10.810*	-10.402*	29.34*	12.32*	8.08*
	(-19.87)	(-16.98)	(-13.08)	(-14.08)	(-11.83)	(25.13)	(0.000)	(0.000)	(0.000)

Note: The numbers in parentheses are *t-statistics* computed from heteroskedasticity-robust standard errors. Quantile regression results are based upon 1000 bootstrapping repetitions. The asterisks ** and * denote significance at the 10% and 5% levels, respectively. (1) F-statistic and associated p-values for symmetry test. (2) F-statistic and associated p-values are reported for the test of equality of the coefficients across quantiles (i.e. q10=q25=q50=q75=q90)

Table 6: Determinants of CO_2 emissions for European countries

	OLS	Quantile regression					Test of symmetry[1]		Test of equality[2]
		q10	q25	q50	q75	q90	q10=q90	q25=q75	
Energy use	0.646*	0.347*	0.537*	0.639*	0.833*	0.886*	13.93*	16.07*	8.93*
	(13.75)	(2.39)	(8.21)	(9.41)	(13.39)	(30.38)	(0.000)	(0.000)	(0.000)
GDP	2.018*	6.226*	1.579*	1.686*	1.091*	1.404*	8.87*	0.66	3.81*
	(6.58)	(3.84)	(2.61)	(3.39)	(5.70)	(8.36)	(0.003)	(0.415)	(0.004)
GDP squared	-0.106*	-0.324*	-0.077*	-0.082*	-0.058*	-0.080*	7.80*	0.33	4.16*
	(-6.45)	(-3.71)	(-2.33)	(-3.27)	(-4.98)	(-9.47)	(0.005)	(0.565)	(0.002)
Trade	0.250*	0.182*	0.067	0.020	0.092*	0.145*	0.26	0.29	2.54*
	(8.00)	(2.58)	(1.58)	(0.40)	(2.93)	(6.56)	(0.613)	(0.591)	(0.039)
Urbanization	0.228*	0.831*	0.447*	0.413*	0.451*	0.573*	2.78**	0.00	3.19*
	(3.12)	(6.24)	(5.23)	(6.27)	(4.61)	(6.98)	(0.096)	(0.975)	(0.013)
Constant	-14.720*	-35.074*	-12.608*	-13.530*	-11.867*	-13.840*	7.21*	0.07	4.36*
	(-10.35)	(-4.42)	(-4.45)	(-6.05)	(-12.22)	(-19.35)	(0.007)	(0.793)	(0.001)

Note: The numbers in parentheses are *t-statistics* computed from heteroskedasticity-robust standard errors. Quantile regression results are based upon 1000 bootstrapping repetitions. The asterisks ** and * denote significance at the 10% and 5% levels, respectively. (1) F-statistic and associated p-values for symmetry test. (2) F-statistic and associated p-values are reported for the test of equality of the coefficients across quantiles (i.e. q10=q25=q50=q75=q90).

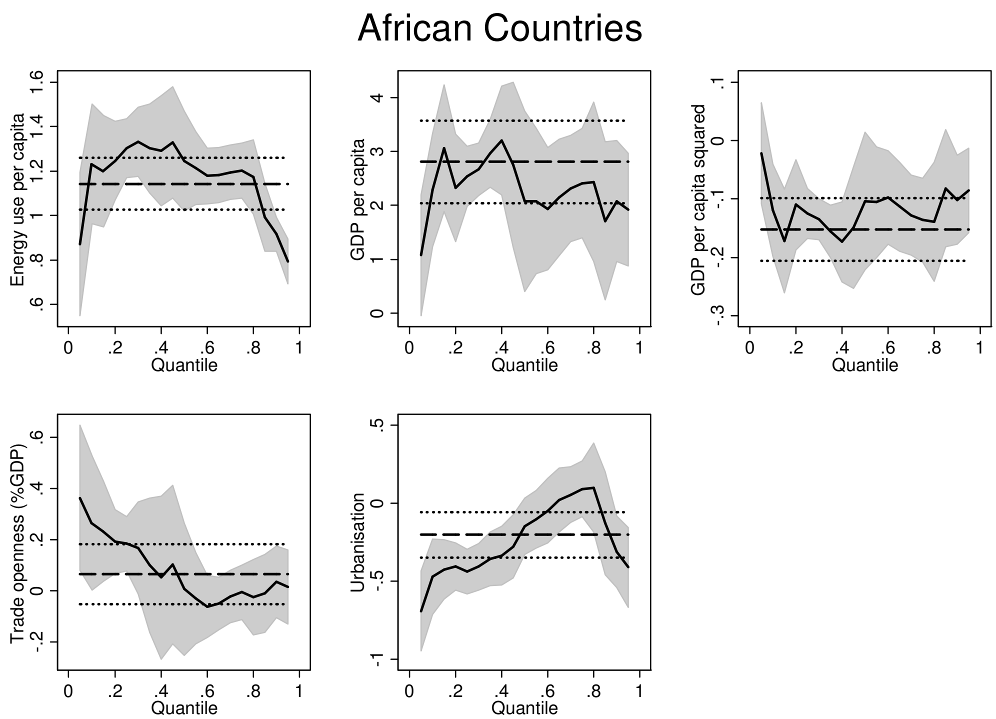
Table 7: Determinants of CO_2 emissions for MENA countries

	OLS	Quantile regression					Test of symmetry[1]		Test of equality[2]
		q10	q25	q50	q75	q90	q10=q90	q25=q75	
Energy use	0.766*	0.929*	0.887*	0.857*	0.674*	0.526*	30.89*	6.44*	11.03*
	(17.53)	(18.87)	(30.90)	(42.64)	(8.01)	(9.11)	(0.000)	(0.011)	(0.000)
GDP	1.014*	0.475	0.151	0.591	0.809*	1.008*	0.94	2.39	0.95
	(2.70)	(1.11)	(0.38)	(1.52)	(1.98)	(2.51)	(0.333)	(0.123)	(0.433)
GDP squared	-0.041**	-0.029	-0.006	-0.025	-0.027	-0.031	0.00	0.66	0.44
	(-1.80)	(-1.14)	(-0.27)	(-1.13)	(-1.09)	(-1.35)	(0.954)	(0.417)	(0.780)
Trade	0.086**	-0.047	-0.037	0.020	0.046	0.034	1.13	1.78	0.92
	(1.74)	(-1.21)	(-0.96)	(0.78)	(0.82)	(0.51)	(0.288)	(0.183)	(0.451)
Urbanization	-0.535*	0.186	0.230	-0.087	-0.161	-0.117	1.09	3.04**	1.20
	(-3.04)	(0.85)	(1.24)	(-0.54)	(-0.78)	(-0.55)	(0.297)	(0.082)	(0.309)

	OLS	Quantile regression					Test of symmetry[1]		Test of equality[2]
		q10	q25	q50	q75	q90	q10=q90	q25=q75	
Constant	-7.771* (-5.97)	-7.922* (-5.90)	-6.667* (-5.16)	-7.611* (-5.99)	-7.592* (-5.52)	-7.940* (-6.81)	0.00 (0.991)	0.42 (0.517)	0.39 (0.815)

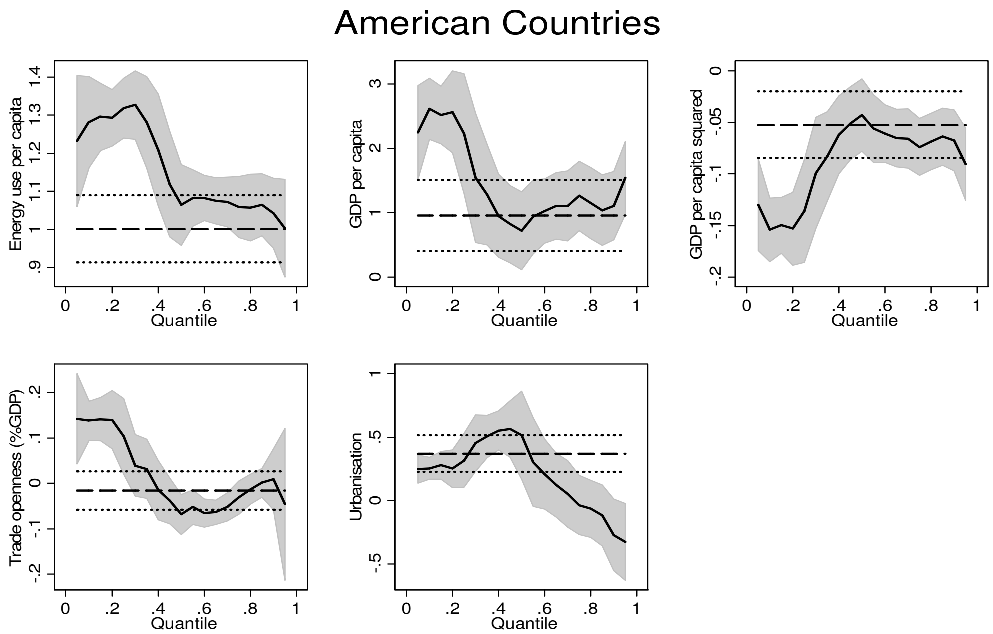
Note: The numbers in parentheses are *t-statistics* computed from heteroskedasticity-robust standard errors. Quantile regression results are based upon 1000 bootstrapping repetitions. The asterisks ** and * denote significance at the 10% and 5% levels, respectively. (1) F-statistic and associated p-values for symmetry test. (2) F-statistic and associated p-values are reported for the test of equality of the coefficients across quantiles (i.e. q10=q25=q50=q75=q90)

Figure 1: OLS and quantile regression estimates over the conditional quantiles of CO_2 emissions: evidence for Sub-saharan African countries.



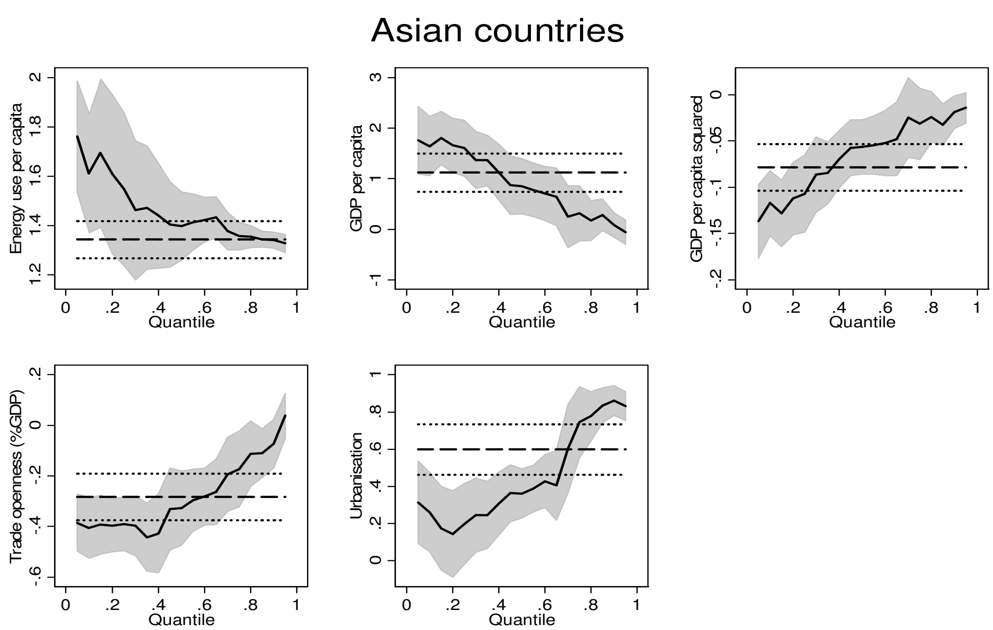
Note: The x-axis represents the conditional quantile of CO_2 emissions. The horizontal dashed line represents the OLS estimates. The two dotted lines depict the 95 percent confidence intervals for the OLS estimates. The solid line represents the quantile regression estimates; and the shaded grey area plots the 95 percent confidence band for the quantile regression estimates.

Figure 2: OLS and quantile regression estimates over the conditional quantiles of CO_2 emissions: evidence for American countries.



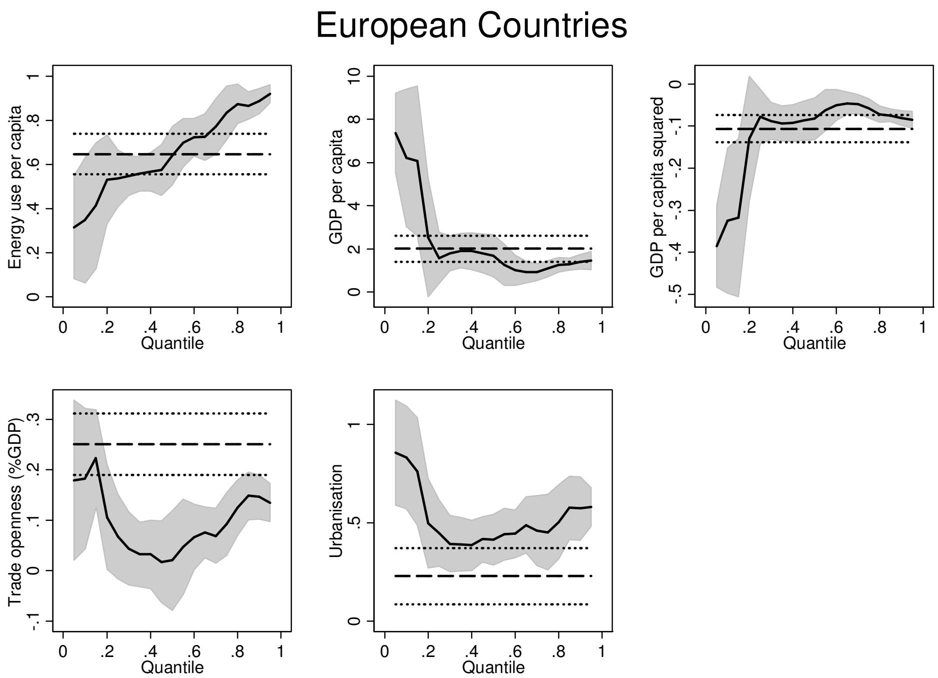
Note: The x-axis represents the conditional quantile of CO_2 emissions. The horizontal dashed line represents the OLS estimates. The two dotted lines depict the 95 percent confidence intervals for the OLS estimates. The solid line represents the quantile regression estimates; and the shaded grey area plots the 95 percent confidence band for the quantile regression estimates.

Figure 3: OLS and quantile regression estimates over the conditional quantiles of CO_2 emissions: evidence for Asian countries.



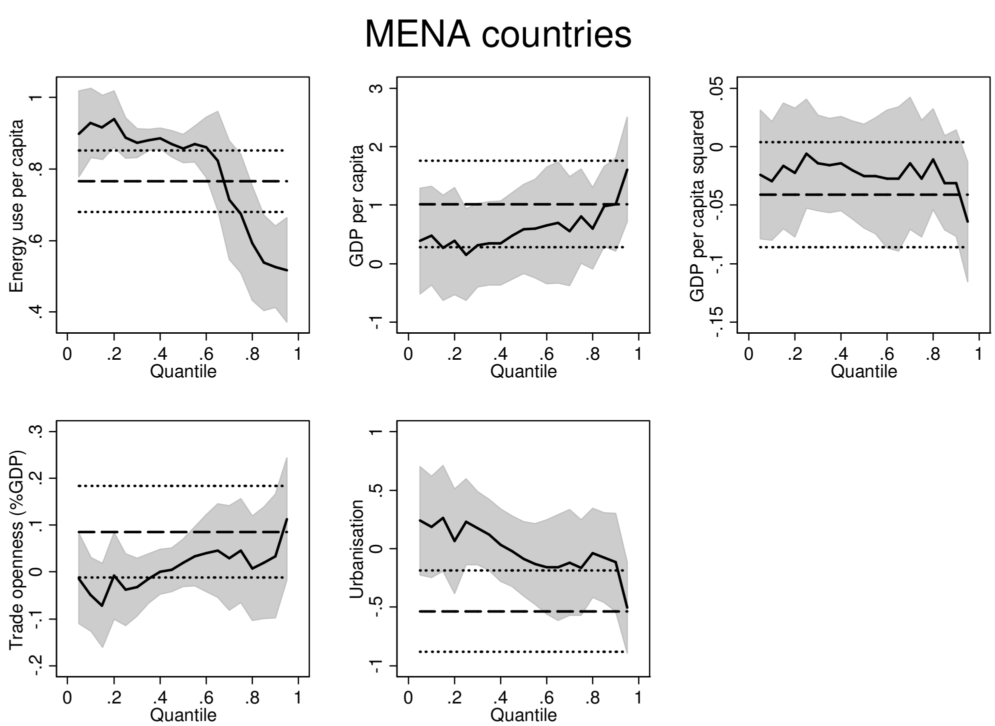
Note: The x-axis represents the conditional quantile of CO_2 emissions. The horizontal dashed line represents the OLS estimates. The two dotted lines depict the 95 percent confidence intervals for the OLS estimates. The solid line represents the quantile regression estimates; and the shaded grey area plots the 95 percent confidence band for the quantile regression estimates.

Figure 4: OLS and quantile regression estimates over the conditional quantiles of CO_2 emissions: evidence for European countries



Note: The x-axis represents the conditional quantile of CO_2 emissions. The horizontal dashed line represents the OLS estimates. The two dotted lines depict the 95 percent confidence intervals for the OLS estimates. The solid line represents the quantile regression estimates; and the shaded grey area plots the 95 percent confidence band for the quantile regression estimates.

Figure 5: OLS and quantile regression estimates over the conditional quantiles of CO_2 emissions: evidence for MENA countries



Note: The x-axis represents the conditional quantile of CO_2 emissions. The horizontal dashed line represents the OLS estimates. The two dotted lines depict the 95 percent confidence intervals for the OLS estimates. The solid line represents the quantile regression estimates; and the shaded grey area plots the 95 percent confidence band for the quantile regression estimates.

4. Conclusion

The existing literature on the determinants of pollution has yield mixed results. However, the literature has mainly used the mean regression framework and has not yet examined the role of the distribution of pollution across countries in explaining the driving factors of pollution. This paper examines the determinants of CO_2 emissions using quantile regression analysis. The quantile regression allows us to analyze whether or not the factors that affect pollution do so in the same way for high and low pollution countries. By using data from 59 countries divided into five panels, we examine how the effects of some factors such as energy use, income, trade and urbanization vary with the level of pollution.

Our results support some findings in the literature, while others reveal sensitivity to the distribution of CO_2 emissions. In many cases, quantile regression estimates are quite different from those from OLS regressions. For example, energy consumption increases pollution but its impact is larger in magnitude in low pollution countries. This suggests that energy conservation policies in low pollution economies may be more beneficial. Further, openness to trade increases pollution in African and American countries at the lower levels of pollution and in European countries at the left and right tails of the distribution. On the contrary, foreign trade is good for environment for Asian countries, especially in countries at the left tail of the pollution distribution. With respect to urbanization, we found that it decreases pollution in African countries and contributes to pollution in Asian and European countries. In American countries, urbanization increases pollution at the bottom tail of the pollution distribution and reduces pollution at the top tail of the distribution.

Another implication of our findings is that pollution control policies are unlikely to succeed equally across countries with different pollution levels. For instance, greater openness to trade is unlikely less effective in reducing pollution in low pollution African and American countries, while urbanization control policies will not be good for the environment for all those countries. To be effective, pollution control policies should be tailored differently across the low and high pollution countries, especially with respect to the role of foreign trade and urbanization.

References

[1] Aka B. F. (2008), “Effects of Trade and Growth on Air Pollution in the Aggregated Sub Saharan Africa”, *International Journal of Applied Econometrics and Quantitative Studies*, 5(1), 5–14.
[2] Akin, C.S. (2014), “The Impact of Foreign Trade, Energy Consumption and Income on CO2 Emissions”, *International Journal of Energy Economics and Policy*, 4(3), 465–475.
[3] Antweiler, W., Copeland B. and Taylor M. S. (2001), “Is Free Trade Good for the Environment? *American Economic Review*, 91(4), 877–908.
[4] Apergis N. and Payne, J. E. (2009), “CO2 Emissions, Energy Usage, and Output in Central America”, *Energy Policy*, 37, 3282–3286.
[5] Aslanidis N. and Iranzo S. (2009), “Environment and Development: Is there a Kuznets curve for CO2 emissions?” *Applied Economics*, 41(6), 803–810.
[6] Baek, J. (2015), Environmental Kuznets curve for CO2 emissions: the case of Artic countries, Energy Economics, 50: 13–17.
[7] Dinda, S. and D. Coondoo (2006), Income and emission: A Panel data-based Cointegration Analysis, *Ecological Economics*, 57(2), 167–181.
[8] Dinda, S., Coondoo, D., Pal, M. (2000). Air quality and economic growth: an empirical study. *Ecological Economics* 34, 409–423.
[9] Friedl B. and Getzner M. (2003), “Determinants of CO2 Emissions in a Small Open Economy”, *Ecological Economics*, 45,133–148.
[10] Galeotti M., Lanza A. and Pauli F. (2006), “Reassessing the Environmental Kuznets Curve for CO2 Emissions: A Robustness Exercise”, *Ecological Economics*, 57, 152–163.

[11] Iwata H., Okada K. and Samreth S. (2010), "Empirical Study on Environmental Kuznets curve for CO2 in France: the role of nuclear energy", *Energy Policy*, 38, 4057–4063.

[12] Jalil A. (2014), "Carbon Dioxide Emission in the Middle East and North African (MENA) Region: A Dynamic Panel Data Study", *Journal of Emerging Economies and Islamic Research*, 2(3), 1–13.

[13] Jalil A. and Mahmud S. (2009), "Environment Kuznets Curve for CO2 Emissions: a Cointegration Analysis for China", *Energy Policy*, 37(12): 5167–5172.

[14] Kohler, M. (2013). CO2 emissions, energy consumption, income and foreign trade: A South

[15] African perspective. *Energy Policy* 63, 1042–1050.

[16] Koenker, R. and G. J. Bassett (1978). Regression quantile, *Econometrica*, 46, 33–50.

[17] Koenker,R. and Hallock, K. (2001), Quantile Regression. *Journal of Economic Perspectives*, 15(4), 143–156.

[18] Koenker, R. and J. A. F. Machado (1999). Goodness of fit and related inference processes for quantile regression, *Journal of the American Statistical Association*, 94, 1296–1310.

[19] Lamla, M. (2009). Long-run determinants of pollution: A robustness analysis, *Ecological Economics*, 69: 135–144.

[20] Martinez-Zarzoso I. and Bengochea-Morancho A. (2004), "Pool Mean Group Estimation for an environemanl Kuznets curve for CO2", *Economics Letters*, 82(1), 121–126.

[21] Martinez-Zarzoso, I. and Maruotti, A. (2011), "The Impact of Urbanization on CO2 Emissions: Evidence from Developing Countries", *Ecological Economics*, 70(7): 1344–1353.

[22] Perman, R.and Stern, D.I. (2003). Evidence from panel unit root and cointegration tests that the environmental Kuznets curve does not exist. *The Australian Journal of Agricultural and Resource Economics* 47, 325–347.

[23] Sadorsky, P. (2014), "The Effect of Urbanization on CO2 Emissions in Emerging Countries", *Energy Economics*, 41:147–153.

[24] Sharma S. S. (2011), "Determinants of Carbon Dioxide Emissions: Empirical Evidence from 69 Countries", *Applied Energy*, 88(1), 376–382.

[25] Smyth, R. and P. K. Narayan (2014), "Applied econometrics and implications for energy economics research", *Energy Economics*, 50: 351–358.

[26] Westerlund, J., Thuraisamy, K. and Sharma, S. (2015), "On the use of panel cointegration tests in energy economics", *Energy Economics* 50: 359–363.