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CARBON DIOXIDE EMISSIONS, URBANIZATION AND GLOBALIZATION: A DYNAMIC PANEL DATA

Nuno Carlos Leitão
Polytechnic Institute of Santarém, and CEFAGE, University of Évora, Portugal
E-mail: nunocarlosleitao@gmail.com

Muhammad Shahbaz
Department of Management Sciences, COMSATS Institute of Information Technology, Lahore, Pakistan
Email: shahbazmohd@live.com

Abstract

This study investigates the existence of environmental Kuznets curve (EKC) for carbon dioxide (CO_2) emissions and its relationship with economic growth, energy consumption and globalization over the period of 1990-2010. We apply a dynamic panel data (GMM-system estimator) using the data of selected 18 countries. This estimator permits to solve the problems of serial correlation, heteroskedasticity and endogeneity for some explanatory variables. The environmental consequences of economic growth are according to environmental Kuznets (EKC) hypothesis. Globalization seems to be a main engine that provides a way to enhance production intensively by utilizing abundant domestic resources efficiently. The energy consumption has positive impact on CO_2 emissions. Urbanization improves environmental quality by lowering CO_2 emissions, i.e an inverted-U shaped relationship between urbanization and CO_2 emissions.

Keywords: Carbon Dioxide (CO2), Environmental Kuznets Curve (EKC), Economic Growth, Energy Consumption

JEL classification: C32, F18, Q56

1. Introduction

The environmental Kuznets curve (EKC) emerged during the 1990s with the empirical work of Grossman and Krueger (1991) and Shafik and Bandyopadhay (1992). The topic EKC took the attention of the academic community after the publication of the World Development Report (1992). Bank for Reconstruction and Development's (IBRD) had a crucial role in the concept of EKC. IBRD has demonstrated the importance of environmental sustainability and economic growth.

The literature demonstrates that developed countries are less polluting when compared with emerging or developing economies. The Heckscher-Ohlin theorem shows that developing economies using factor endowments as labor and natural resources. Developed countries use innovation and human capital to produce goods and services. We note that the concept of sustainable development is associated with renewable energy, which is less polluting.

This paper contributes in existing literature by investigating the Kuznets hypothesis. We select the following countries: Australia, Belgium, Brazil, Canada, China, Denmark, France, Germany, Netherlands, Spain, Portugal, Japan, Korea, Thailand, Italy, United Kingdom, US and Russia for the period 1990-2010.

There are a large number of empirical studies that stress the relationship between the environmental pollution and economic growth based on time series, unit root and cointegration approaches. Our study is based on a different concept with rigor empirical approach. This paper examines the dynamic relationship among CO_2 emissions, GDP, quadratic GDP, and energy consumption by using a GMM-system estimator. The GMM-system estimator (GMM-SYS) permits to solve the problems of serial correlation, heteroskedasticity and endogeneity for some explanatory variables. Indeed the EKC literature uses the energy consumption, international trade, financial development and urbanization as the explanatory variables. There is a gap on literature; the globalization has not been used as a control variable. This variable has an important role, i.e. globalization is the main engine that provides a way to enhance production intensively by utilizing abundant domestic resources efficiently.

The structure of this paper is as follows. The next section presents the literature review and empirical studies. Section 3 shows the methodology. Section 4 presents the empirical results. The final section provides conclusions.

2. Literature review

Grossman and Krueger (1991) is the pioneering model, which evaluates the inverted U-shaped relationship between income per capita and various pollutants indicators. This relationship became known in the literature as the environmental Kuznets curve (EKC). Munasinghe (1999) explained that EKC implies a non linerar relationship. Developed countries usually use renewable energy and clean technologies. In other words, emerging economies have higher levels of pollution due to use of inefficinet energy technologies.

Following the previous studies, CO_2 emmisons are positively correlated with the level of per capita income. The recent studies of Song et al. (2008), Jalil and Mahmud (2009) and Zhang and Cheng (2009) validated an inverted U-shaped in case of China. However, the study of Friedl and Gertner (2003) shows that linear and quadratic GDP were not appropriate for Austrian. Friedl and Gertner (2003) presented an N-shaped curve between GDP and CO_2 emissions. Kraft and Kraft (1978), Yoo and Kwak (2010), and Reynolds and Kolodzieji (2008) consider that energy promotes economic

growth. However, Yuan et al. (2007), Odhiambo (2009), and Halicioglu (2009) found negative association between energy consumption and economic growth.

The recent study of Shahbaz et al. (2013) analyse the relationship between economic growth, energy consumption and CO_2 emissions for period of 1980-2010 in case of Romania. The authors applied the ARDL bounds testing approach to investigate the long run cointegration. This study confirms long run relationship between economic growth, energy consumption and energy pollutants. Shahbaz et al. (2013) show that democratic regime contributes to decline CO_2 emissions using efficient economic policies and financial development.

Shahbaz et al. (2012) reported that EKC hypothesis is validated for Pakistan and energy cosumption is major contributor to CO_2 emissions. Tiwari et al. (2013) investigate the correlation between coal consumption, economic growth, trade openness and CO_2 emissions. This research shows the existence of cointegration for long run between coal consumption, economic growth, trade openness and CO_2 emissions in India. Sayed and Sek (2013) investigate the EKC hypothesis for developed and developing countries using a panel data for the period of 1961-2009. The authors concluded that developed countries have higher turning points of inverted U-shape curve i.e. real GDP per capita while developing countries have higher turning point of inverted U-shaped curve is once SO_2 emissions is used measure of environmental degradation.

3. Methodology and data

This research uses a panel data. The static panel data have some problems in serial correlation, heteroskedasticity and endogeneity of some explanatory variables. The estimator GMM-system (GMM-SYS) permits the researchers to solve the problems of serial correlation, heteroskedasticity and endogeneity for some explanatory variables. These econometric problems were resolved by Arellano and Bond (1991), Arellano and Bover (1995) and Blundell and Bond (1998, 2000), who developed the first differenced GMM (GMM-DIF) estimator and the GMM system (GMM-SYS) estimator. The GMM-SYS estimator is a system containing both first differenced and levels equations. The GMM- SYS estimator is an alternative to the standard first differenced GMM estimator. To estimate the dynamic model, we applied the methodology of Blundell and Bond (1998, 2000), and Windmeijer (2005) to small sample correction to correct the standard errors of Blundell and Bond (1998, 2000). The GMM system estimator that we report was computed using STATA. The GMM-system estimator is consistent if there is no second order serial correlation in the residuals (m2 statistics). The dynamic panel data model is valid if the estimator is consistent and the instruments are valid. The standard equation of EKC can be written as:

$$C_t = \beta_0 + \beta_1 Y_t + \beta_2 Y_t^2 + \beta_3 G_t + \beta_4 E_t + \beta_5 U_t + \beta_6 CU_t + \delta t + \eta_i + \varepsilon_{it} \qquad (1)$$

The dependent variable is the carbon dioxide emissions of 18 countries for the period of 1990-2010. We select the following countries: Australia, Belgium, Brazil, Canada, China, Denmark, France, Germany, Netherlands, Spain, Portugal, Japan, Korea, Thailand, Italy, United Kingdom, US and

Russia. The data is obtained from world development indicators (CD-ROM, 2012). All the variables are in the logarithm form; ηi is the unobserved time-invariant specific effects; δt captures a common deterministic trend; ε_{it} is a random disturbance assumed to be normal, and identical distributed (IID) with E (ε_{it})=0; Var (ε_{it}) $= \sigma^2 \succ 0$, where C_t is carbon dioxide emissions metric tons per capita. The data includes carbon dioxide emissions produced during consumption of solid, liquid, and gas fuels and gas flaring; E_t is energy consumption per capita ; Y_t (Y_t^2) is real GDP (squared) per capita; the index of globalization (G_t) proposed by Dreher (2006) represents three dimension of globalization: economic; social and political (see Dreher, 2006; Dreher, Gaston (2008). We decided to introduce globalization as a control variable, since this provides information about the economic structures of countries. The economic globalization involves two components - the actual flows (trade, foreign direct investment, and portfolio investment and income payments to foreign nationals) and the restrictions (import barriers, tariff rate, taxes on international trade, and capital account restrictions). The social globalization involves three characteristics: data on personal contact (telephone traffic, transfer, tourism, and foreign population); the information flows (internet hosts, internet users, cable televisions), and cultural proximity (McDonald's restaurants (per capita). The political globalization is composed by embassies in country, membership in international organizations and participation in UN Security Council missions; U_t is urban population, i.e. the percentage of a country's urban population living in that country's largest metropolitan area, and CU_t is corruption. According to Heritadge Research, the corruption erodes economic freedom by introducing insecurity and uncertainty into economic relationships. The score for this component is derived primarily from Transparency International's Corruption Perceptions Index (CPI) for 2011, which measures the level of corruption in 183 countries.
The model can be rewritten in the following dynamic representation:

$$C_t = C_{t-1} + \beta_0 + \beta_1 X_{it} - \varrho\beta_1 X_{t-1} + \delta t + \eta_i + \varepsilon_{it} \qquad (2)$$

According to the literature, there is a positive correlation between of energy consumption with CO_2 emissions ($E_t > 0$). The environmental hypothesis consider that $Y_t > 0$, and a negative sign to $Y_t^2 < 0$. Urbanization ($U_t < 0$) is negatively correlated with CO_2 emissions reported by Grossman and Krueger (1991), Halicioglu (2009), Martínez-Zarzoso and Maruotti (2011). The study of Martínez–Zazoso and Matoutti (2011) shows an inverted U-shaped relationship between urbanization and CO_2 emissions for developing countries.

Agenor (2003) shows that globalization leads to greater integration of economies and societies. Globalization is a main engine that provides a way to enhance production intensively by utilizing abundant domestic resources efficiently ($G_t > 0$). The studies of Mauro (1998), Tanzi and Davoodi (2010), and Wihardi (2010) demonstrate that corruption is negatively correlated with CO_2 emissions for developed countries. According to the literature we expected a negative sign ($CU_t < 0$).

4. Empirical results

Table 1 presents the summary statistics for each variable such as C_t, G_t, U_t and CU_t appear to have only little differences. However, this is not the case for Y_t (Y_t^2) and E_t.

Table 1- Summary Statistics

Variables	Mean	Std. dev.	Min	Max
C_t	1.30	0.00	1.29	1.31
Y_t	4.24	0.07	4.12	4.32
Y_t^2	8.81	0.33	7.60	9.29
G_t	1.92	0.02	1.86	1.94
E_t	3.98	0.00	3.88	3.91
U_t	1.95	0.56	0.51	2.70
CU_t	1.80	0.00	1.79	1.81

Before estimating the panel regression model, we have conducted a test for unit root of the variable. In the following tables, we present the results of panel unit root test ADF-Fischer Chi square.

Table 2 - Panel unit root test results: (C_t) ADF-Fischer Chi square regression

ADF-Fischer Chi square	Intercept and trend Statistic	Probability
Inverse chi-squared	91.82	0.00
Inverse normal	-4.93	0.00
Inverse logit	-5.24	0.00
Modified inv. chi-squared	6.58	0.00

Table 2a - Panel unit root test results: (G_t) ADF-Fischer Chi square Regression

ADF-Fischer Chi square	Intercept and trend Statistic	Probability
Inverse chi-squared	111.14	0.00
Inverse normal	-5.16	0.00
Inverse logit	-6.40	0.00
Modified inv. chi-squared	8.85	0.00

Table 2b- Panel unit root test results: (U_t) ADF-Fischer Chi square Regression

ADF-Fischer Chi square	Intercept and trend Statistic	Probability
Inverse chi-squared	124.95	0.00
Inverse normal	-3.02	0.00
Inverse logit	-6.31	0.00
Modified inv. chi-squared	10.48	0.00

Table 2c- Panel unit root test results: (CU_t) ADF-Fischer Chi square Regression

ADF-Fischer Chi square	Intercept and trend Statistic	Probability
Inverse chi-squared	60.36	0.00
Inverse normal	-3.21	0.00
Inverse logit	-3.13	0.00
Modified inv. chi-squared	2.87	0.00

We can observe CO_2 emissions using GMM-system estimator in Table 3. The model presents consistent estimates, with no serial correlation (the Arellano and Bond test for Ar(2)). The specification Sargan test shows that there are no problems with the validity of instruments used. The Windmeijer (2005) finite sample correction is used. The model presents all significant variables (C_t, Y_t, Y_t^2, G_t, E_t and U_t), with the exception the coefficient of CU_t. The lagged dependent variable (C_t) presents a negative sign. This result shows that in long run the impact of emissions of carbon dioxide decreased.

Linear and non-linear real GDP (Y_t and Y_t^2) are according to the perspectives of inverted U-shaped between economic growth and CO_2 emissions. These results are according to previous studies (Song et al., 2008; Halicioglu, 2009; Fodha and Zaghdoud, 2010; Lean and Smyth, 2010; Shahbaz et al., 2012; Tiwari et al., 2013). The results show that growth increases with the emissions of energy at initial stage economic development and however, in a mature stage the energy emission tends to decrease.

The coefficient of globalization (G_t) presents a positive impact on carbon dioxide emissions i.e. the globalization is a main engine that provides a way to enhance production intensively by utilizing abundant domestic resources efficiently.

Table 3 - GMM-System

Dependent variable: C_t		
Independent Variables	Coefficient	Expect Signs
C_{t-1}	-0.02 (-5.50)***	(-)
Y_t	0.05 (20.44)***	(+)
Y_t^2	-0.02 (-5.04)***	(-)
G_t	0.06 (8.501)***	(+)
E_t	0.56 (15.52)***	(+)
U_t	-0.76 (-4.87)***	(-)
CU_t	-0.001 (-0.67)	(-)
C	-0.75 (-2.89)***	
Arellano-Bond test for Ar(2) (P-value)	0.34	
Sargan test (P-value)	1.00	
N	203	

The null hypothesis that each coefficient is equal to zero is tested using one-step robust standard error. T-statistics (heteroskedasticity corrected) are in round brackets. P-values are in square brackets; *** - statistically significant at the 1 per cent level. Ar(2) is tests for second–order serial correlation in the first-differenced residuals, asymptotically distributed as N(0,1) under the null hypothesis of no serial correlation (based on the efficient two-step GMM estimator). The Sargan test addresses the over-identifying restrictions, asymptotically distributed X^2 under the null of the instruments' validity (with the two-step estimator).

The variable energy consumption (E_t) presents a positive expected sign i.e. the findings are in line with the literature such as Hamilton and Turton (2002), Friedl and Getzner (2003), Liu (2005), Ang and Liu (2001), Say and Yücel (2006), Ang (2008), Halicioglu (2009), Jalil and Mahmud (2009). This result permits to infer that energy consumption is crucial in economic activity. The economic growth

is promoted by increasing energy demands. The coefficient urbanization (U_t) is negatively correlated with CO_2 emissions. This result is according to previous studies (Grossman and Krueger, 1991; Halicioglu, 2009; Martínez-Zarzoso and Maruotti, 2011, and Sharma, 2011), i.e. an inverted-U shaped relationship between urbanization and CO_2 emissions. This result reflects that population of large cities cause environmental degradation.

5. Conclusions

In recent years, research on the relationship between economic growth and CO_2 emissions has increased. The objective of this study was to analyze the link between carbon emissions, economic growth, energy consumption, urbanization and globalization. Econometrics estimations support the hypothesis formulated. Our results are robust with theoretical models. We find a positive correlation of income per capita with carbon emissions i.e. inverted U-shaped relationship between income per capita and carbon emissions. The impact of energy consumption shows that the labour-intensive products are more polluting. Globalization is a main engine that provides a way to enhance production intensively by utilizing abundant domestic resources efficiently. The present study opens new insights for policy makers to obtain and sustain economic growth by improving environmental quality and using energy efficiently.

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