Error-correction based panel estimates of the relationship between CO2 emissions, energy usage and output in Gulf Cooperation Council countries

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2012

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Abstract

This study examines the causal relationship between carbon dioxide emissions, energy consumption and real output within a panel vector error correction model for six Gulf Cooperation Council (GCC) countries namely Bahrain, Kuwait, Saudi Arabia, Qatar and United Arab Emirates over the period 1980–2009. In the long-run, there is a dynamic relationship between carbon emissions and income, which confirms the presence of the Environmental Kuznets Curve (EKC) for GCC countries. The short-run dynamics results reveal a bi-directional causality between carbon and energy usage but reject the existence of EKC.

I. Introduction

Recently, the relationship between energy and economic growth has received a great deal of attention by scholars, governments and policymakers. Since the pioneering work of Kraft and Kraft (1978), several papers have been prepared by researchers to investigate the contribution of energy consumption and usage in economic growth. Overall results diverge from one country to another country and from one region to another one. Some papers find evidence of unidirectional relationship between energy consumption and economic growth (Morimoto and Hope, 2004; Lee, 2005; Al-Iriani 2006) and some other find bidirectional relationship (Jumbe, 2004; Akinlo, 2008 Mahadeven and Asafu-Adjaye, 2007), while many others find no causality between the two variables (Huang *et al*., 2008). Despite the abundance of literature and the importance of energy in GCC countries, there is no article -to the best of knowledge- which analyzes the relationship between energy emission, energy consumption and economic growth in the region. Nowadays, the GCC region is becoming among the most pollutants in the world; therefore, investigation the weight of energy in economy is crucial. According to BP statistical report (2010), the consumption of energy has been increased drastically in the gulf countries passing from 157 Million tons in 1999 to 263 Million tons in 2010, hence an increase of 67.5%. Regarding natural gas, the consumption was 11.9 Billion cubic feet per day in 2003; it becomes 21.7 Billion cubic feet per day in 2010, thus a change of 82.35%. Between 1998 and 2008, GDP per capita for the GCC as a whole was US$156,080 and it becomes US$ 255,593 hence it increased by 54.83% with Bahrain and Qatar experiencing the strongest increases at 93% and 63%, respectively. Therefore, we think of a positive relationship between carbon emission, energy consumption and economic growth in GCC countries and this is the central aim of this

paper. The remainder of the paper is as follows: section 2 presents the econometric methodology and data, section 3 analyzes the empirical results and section 4 concludes.

II. The Econometric methodology and Data

The long-run relationship between carbon dioxide emissions, energy consumption and real GDP can be expressed as follows:

$$LCo2_{it} = \alpha_{it} + \beta_{1i} LEC_{it} + \beta_{2i} LY_{it} + \beta_{3i} LY_{it}^2 + \mu_{it} \quad (1)$$

Where $i=1,...,$N for each country in the panel and t=1,…,T refers to the time period. $Co2$ is the carbon dioxide emissions (measured in metric tons per capita); LEC is the energy use (measured in kt of oil equivalent per capita). Y is the per capita real GDP (measured in constant 2000 US dollars) and Y2 is the square of per capita real GDP. Variables of the equation (1) are in natural logarithms; the parameters β_1, β_2 and β_3 represent the long-run elasticity estimates of emissions with respect to energy usage, real GDP and squared real GDP, respectively.

The empirical study is based on a panel for six GCC countries, annual data from 1980 to 2008 from the World Bank Development Indicators (WDI). In the empirical investigation we examine the long-run relationship between carbon dioxide emissions, energy usage and real GDP (Y), then we study the short-run dynamic causal relationship between the variables. The basic testing procedure requires three steps. The first step is to test whether the variables contain a panel unit root to confirm the stationarity of each variable. The second step is to test whether there is a long-run cointegrating relationship between the variables. Finally the last step, if all variables are I (1) and cointegrated, short-run elasticities can be computed using the vector error correction

model (VECM) method. In this case, an error correction mechanism exists by which changes in the dependent variables are modeled as a function of the level of the disequilibrium in the cointegrating relationship, captured by the error-correction term (ECT).

To test for panel causality, a panel-based VECM is specified as follows:

$$\Delta LCo2_t = \alpha_1 + \sum_{i=1}^{p} \beta_{1i} \Delta LCo2_{t-i} + \sum_{i=1}^{q} \beta_{1i} \Delta LEC_{t-i} + \sum_{i=1}^{r} \beta_{1i} \Delta LY_{t-i} + \sum_{i=1}^{s} \beta_{1i} \Delta LY^2_{t-i} + \lambda_1 ect_{t-1} + \mu_{1t} \quad (2)$$

$$\Delta LY_t = \alpha_2 + \sum_{i=1}^{p} \beta_{2i} \Delta LCo2_{t-i} + \sum_{i=1}^{q} \beta_{2i} \Delta LEC_{t-i} + \sum_{i=1}^{r} \beta_{2i} \Delta LY_{t-i} + \sum_{i=1}^{s} \beta_{2i} \Delta LY^2_{t-i} + \lambda_2 ect_{t-1} + \mu_{2t} \quad (3)$$

$$\Delta LY_t^2 = \alpha_3 + \sum_{i=1}^{p} \beta_{3i} \Delta LCo2_{t-i} + \sum_{i=1}^{q} \beta_{3i} \Delta LEC_{t-i} + \sum_{i=1}^{r} \beta_{3i} \Delta LY_{t-i} + \sum_{i=1}^{s} \beta_{3i} \Delta LY^2_{t-i} + \lambda_3 ect_{t-1} + \mu_{3t} \quad (4)$$

$$\Delta LEC_t = \alpha_4 + \sum_{i=1}^{p} \beta_{4i} \Delta LCo2_{t-i} + \sum_{i=1}^{q} \beta_{4i} \Delta LEC_{t-i} + \sum_{i=1}^{r} \beta_{4i} \Delta LY_{t-i} + \sum_{i=1}^{s} \beta_{4i} \Delta LY^2_{t-i} + \lambda_4 ect_{t-1} + \mu_{4t} \quad (5)$$

Where ECT is expressed as follows:

$$ECT_t = Lco2_t - \beta_0 - \beta_1 Lec_t - \beta_2 Ly_t - \beta_3 Ly^2, \quad (6)$$

Where $t=1...T$, denotes the time period

III. Empirical results

Before estimating the long-run and short-run test of equation1, we use the panel unit root tests as proposed by Levin-Lin-Chu (LLC, 2002), Im, Pesaran and Shin (IPS, 2003), the Augmented Dickey–Fuller (F-ADF) and finally Philips–Perron (PP, 1998). The results[1] show that the test statistics for the log levels of CO2, EC, GDP and GDP2 are statistically insignificant. When we

[1] The results based on the ADF test are not reported here to conserve space but are available from the authors upon request.

apply the panel unit root tests to the first difference of the four variables, all four tests reject the joint null hypothesis for each variable at the 1 per cent level. Thus, from all of the tests, the panel unit roots tests indicate that each variable is integrated of order one.

Panel cointegration tests

The test results of Pedroni displayed in table 1 reveal the rejections of the null of no cointegration for all tests at 5 % level of significance except the group rho-tests and panel v-test. However, according to Pedroni (2004), the two Pedroni test statistics which do not reject the null hypothesis may have a very low power in the case of small time dimension. Therefore, one may conclude that our model is in fact panel cointegrated.

Table 1. Results of the balanced Panel Cointegration tests for GCC countries

Pedroni Residual Cointegration Test	*Statistics*
Panel v-Statistic *Weighted Statistic*	-1.360724
Panel rho-Statistic *Weighted Statistic*	-1.821637
Panel PP-Statistic *Weighted Statistic*	-2.54301 ***
Panel ADF-Statistic *Weighted Statistic*	-2.05354**
Group rho-Statistic	-0.37359
Group PP-Statistic	-1.73254**
Group ADF-Statistic	-1.392477**
Kao Test.	
ADF	-2.8082 (0.0025)***

Johansen Fisher Panel Cointegration Test

Null Hypo.	Max-Eigen.	Trace
None	44.90 (0.0000)***	46.61 (0.0000)***
At most 1	10.73 (0.5526)	13.85. (0.3103)
At most 2	8.321 (0.7596)	10.07 (0.6095)
At most 3	16.45 (0.1716)	16.45 (0.1716)

Note: The optimal lag lengths are selected using SBC suggest that the optimal lag length is1. Figures in parenthesis are probability values.

Trace test and Max-eigenvalue test indicate 1 cointegrating vector at the 0.01 level

,* Denotes the rejection of the null hypothesis at 5% and 1% level of significance

The Kao and Johansen Fisher tests suggest panel cointegration at 1% level of significance. Hence, there is strong statistical evidence in favor of panel cointegration among CO2 emissions, energy consumption, GDP and GDP2 for GCC countries.

Panel Long run and short run

The results of the long-run equilibrium relationship are presented in Table 2 below. It shows that the coefficient of LGDP is 61.02, which is positive and significant at the level of 1%. It means that a 1% increase in per capita real GDP will increase per capita emissions by 61.02% in the long- run. The coefficient of LGDP2 is negative (-2.92) and statistically significant at the level of 1%. This shows that when the real GPD per capita reach a certain level a 1% increase of its level will reduce the per capita emissions by 2.92%.

Table 2. CO2 Emission long-run elasticities

Dependent Variable: LCO2		
Regressors	coefficients	t-value
LENERGY	1.31	-2.340***
LGDP	61.02	-3.821***
LGDP2	-2.92	3.699***

Note: *** denotes significance of coefficients at 1% levels of significance

The respective positive and negative signs of the income and its square term together confirm the existence of Environmental Kuznets Curve in GCC countries. Accordingly, carbon emissions increase essentially with increase in income, reaches to its stabilization point, and then starts to decline with further increase in income.

As the objective of the study is to examine the dynamic relationship between dioxide emission, energy consumption and growth it is opportune to study the hypothesis of the presence of Environmental Kuznets Curve. Table 4 illustrates the results in which Dlco2 is the dependent variable. Results show that energy act positively and significantly at the level of 1% to CO2 emission. The results in Table 3 advocate that the Environmental Kuznets Curve (EKC) hypothesis does not hold in the short-run for GCC.

Table 3: CO2 emissions short-run elasticities for GCC countries

Dependant Variable Δlco2		
Regressors	**Coefficient**	**t-stat**
Δlgdp(-1)	0.418984	0.10271
Δlgdp2(-1)	0.006764	0.03368
Δlenergy(-1)	0.339961	3.28182***
Δ Intercept	-0.011295	-0.64327
Ect (-1)	-0.004521	-0.43969

Note: *** denotes significance of coefficients at 1% levels of significance

The existence of a panel long-run cointegration relationship among emissions, energy consumption, GDP and GDP2 suggests that there must be Granger causality in at least one direction. The results of causality tests based on the VEC model are reported in Table 4. The table has three major blocks illustrating the short-run effects, long-run effects represented by the error correction coefficients, and the joint short-run and long run effects, respectively.

Table 4: Results of causality tests based on VECM.

Variable	Short run (F-stats)				ECT (t-stats)	Joint short and long run (F-stats)			
	Δlco2	Δlgdp	Δlgdp2	Δlenergy		Δlco2	Δlgdp	Δlgdp2	Δlenergy
Δlco2	-	0.01	0.001	10.77***	-0.43	-	0.11	0.15	5.7***
Δlenergy	3.22*	0.06	0.132	-	1.20	2.18	0.85	0.78	-

Δlgdp	6.31**	-	1.211	0.001	1.90*	4.64**	-	2.64*	1.84
Δlgdp2	5.96**	0.001	-	0.008	1.62	4.02**	1.92	-	1.356

Note:*,**,*** Denote the rejection of the null hypothesis at 10%, 5% and 1% level of significance

The F-statistics for the short-run dynamics reveals a bi-directional causality between carbon and energy usage. This results support our findings reported in Table 5 in which energy usage is the only explanatory variable significant at the level of 1%. The results further show energy; GDP and GDP2 are influenced by CO2 emission. Based on these results, we may conclude that, in the short-run, there is unidirectional causality between growth and CO2 emissions.

Regarding error correction results, it is observed that deviation from the long-run equilibrium is only corrected by GDP per capita; the other variables appears to be weakly exogenous. This reveals the fact that any changes in CO2 emission, energy consumption and GDP2 that disturb long-run equilibrium are corrected by counter-balancing changes in the real GDP per capita. In this context, it may be concluded that GDP is caused by carbon emissions, energy consumption and GDP2 but these three variables are not caused by the former. Turning now to the right side of table 4, the joint Wald F-statistics results indicate in the carbon emission equation, error correction term and energy consumption are jointly significant at a level of 1%. On the other hand, each of GDP and GDP2 combined with error correction term are statistically insignificant. However, in the GDP and GDP2 equations, carbon emission equation and error correction term are jointly significant at a level of 5%.

IV. Concluding remarks

This study aims at analyzing the dynamic relationship between carbon dioxide emissions, energy consumption and real GDP for a panel of 6 GCC countries over the period 1980–2008 and to obtain policy implications of the results. First set of tests show the existence of a cointegration relationship and results of the long-run elasticities demonstrate that GDP per capita is positive and significant at the level of 1%. This means that a 1% increase in per capita real GDP will increase per capita emissions by 61.02% in the long- run. Indeed, these results confirm the existence of Environmental Kuznets Curve in GCC countries in the long-run. Turning now to the short-run dynamics; results reveal a bi-directional causality between carbon and energy usage. In the short run, energy usage is the only explanatory variable significant at the level of 1%. Our findings advocate that the Environmental Kuznets Curve (EKC) hypothesis does not hold in the short-run for GCC. Thus, the absence of causality from emissions to growth suggests that GCC countries can control their carbon emissions without troubling their economic growth.

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