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The Relationship between Energy Consumption, Economic Growth and Sulphur Emissions by Panel Data Approach

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ABSTRACT

Many scholarshaveinvestigatedthe relationship between the economic growth (GDP)energy consumption (EC), and emissions. The main objective of this study is to examine the relationship between the economic growth (GDP), energy consumption (EC) and one of the common pollutant which is sulphuremissions SO_2 in European countries; Austria, Sweden, Norway, France and Finland, over the period 1950 to 2010 by applying the panel data approach and test the causality between the three variables. The significant results support the bidirectional causality relationship between the EC and SO_2 atsignificant level 5%. The estimated cross section effects model has high value of R^2 and R^2 adjusted than that in period effects model. SO_2 can be explained more than 86% and 51% by EC and GDP for cross section effect model and period effect model respectively. Moreover the results of EKC test support the inverted U curve. Whilst the turning point in period effect model is (4602.82 USD$) which is almost two times higher than that in cross section effects model (2690.37 USD$). In conclusion policy makers should consider the EC as effected factor towards the SO_2.

Keywords: Economic growth, panel data analysis,sulphuremission.

1. INTRODUCTION

The relationship between economic growth, energy consumption and environmental qualitybecomes an important issuewhich has high impact towards the non-renewable energy resources,and that why most of the developed countries have taken that issue seriously to save their environment atmosphere and to use their energy resources in efficient way. The consuming of energy resources becomes the sign of modern industrial civilization. However, Sulphur emission has risen permanently as energy combustion and human activitiesare increasing, which may significantly affect the global natural ecosystem. In the meantime, the non-renewable energy is overexploitation which leads to increase the effects into the environment, climate change and energy problems. The climate change pointedly threatens the sustainable existence and human beings. And that threat becomes the common point view of countries worldwide to address climate change and to decrease the emissions especially carbon dioxide emissions and sulphur emissionswhich it seems to be the direct way of handling the emissions problem. However, due to the possiblenegative impacts on economic growth, cutting back from energy use is likely to be the less travelled road.Sulphur deposition levels during the past, present, and future is the one of the most serious problem towards human health, ecosystems and net changes in radiative forcing which leads to climate changes, In particular in developing countries where they are suffering from environmental problems and acid deposition. Moreover the Sulphur emission is coupled with economic situation as the latter is relying in industrial production. In fact, pollution problems are being addressed and remedied in developing economies (Dasgupta et al. 2002).SO_2 is generated by the burning of fossil fuels, or the smelting of some raw minerals which contain sulphur. Also erupting volcanoes could be natural source of SO_2 emissions (Air Resources Board, 2001). Sulphur emission is widely shown to be the one of the pollutant that most strongly supports the EKC hypothesis.The effect of SO_2 has an important role towards economic growth and energy consumption. Due to that this study is interested to detect the relationship between those variables. Subsequently, it is very useful to make a clear idea about the relationship between economic growth, energy consumption and SO_2, and to test the Environmental Kuznets Curve (EKC) hypothesis.There are many researchers have shown their interested to detect that relationship by applying various methodologies for different time periods.

The objective of this study is to apply the SO_2 within multivariate model (GDP and EC) and to detect the effect of that relationship between them. In best of our knowledge most of previous studies employed the SO_2 in bivariate model by applying EKC only, while this study includes the effects of EC and consider it as a main variable in the estimated model.This paper is organized into four sections. Section 2 literature review, Section 3 data description and panel data method. Section 4 provides the empirical results and finally the conclusion and some suggestions to policymakers.

2. Literature Reviews

For the last few decades, numerous empirical studies have been conducted to detect the relationship between the economic growth, energy consumption and emissions pollutants. Roughly, there are three strands in literatures which relative with the economic growth, energy consumption and emissions pollutants nexus.

The first strand concentrates in the relationship between economic growth and pollutants, which exemplify by environmental Kuznets curve (EKC)hypothesis or inverted U-shaped. EKC hypothesis illustrates the relationship between the environmental degradation and economic growth. It shows an increasing in environmental degradation with an increasing in income (GDP) per capita in early stages, after reaching to a certain level of income the environmental degradation declines with increasing of the income per capita. Furthermore, when the EKC hypothesis applied to the emissions and income, economic growth could become a solution to the environmental degradation problem de Bruyn, (1997). Indeed, both developing and developed countries should sacrifice the level of economic growthCoondoo and Dinda (2002). There are many of EKC empirical literatures; Dinda (2004) and Stern (2004) have surveyed many of them. Those empirical studies have focused on some emissions such as sulphur SO_2 and carbon dioxide CO_2 in developed countries. Grossman and Krueger (1991) first study had examined that relationship then it followed by many other researchers (e.g.; Selden and Song 1994; Shafik 1994; Panayotou 1997) but their findings got conflict results which due to variation in the target group or data periods, and by using common methods.However some results represent that relationship by nonlinear, inverted-U curve, N-shaped, J-shape and U-curve, while other studies have supported a positive or negative linear relationship.

First study had applied EKC hypothesis was by Grossman and Krueger (1991) in NBER working paper, they included the SO_2, dark matter, and suspended particulate matter (SPM) in the model. The main findings support the existence of EKC for both SO_2 and dark matter while a negative relationship between GDP and SPMAlsayed and Sek (2013). Selden and Song (1994) they applied the EKC for the following emissions SO_2, CO, NO_x and SPM, for developed countries. The output shows that the EKC has existed for all emissions. Stern and Common (2001) they focused to detect the EKC in SO_2emissions for 73 of developed and developing countries over the period 1960 to 1990 by considering time and countries effects. The finding supports the existence of inverted U curve. Alsayed &Sok (2013) focus in the relationship between GDP and other common emissions such as SO_2, CO_2, GHG, SPM_{10} and BOD for two group of countries; developed and developing countries by using data spanning from 1961 to 2009 with applying Panel data method. The main findings show a positive relationship between GDP and both of BOD and SPM_{10} emissions, while an inverted u curve have exist for the relationship between GDP and both of SO_2 and CO_2 emissions for developed countries group. Akbostanci et al. (2009) detect the relationship between GDP per capita, energy consumption and some of the common emissions such as CO_2, SO_2, PM_{10} at two levels in Turkey for 58 provinces over period 1968 to 2003 by applying panel data method and test the EKC hypothesis. The main findings show positive relationship between GDP and both of SO_2 and PM_{10} emissions at national level, while they provide an evidence of existence N shape at the level of provinces. Fodha et al. (2010) have interested to detect the relationship between the GDP per capita and two pollutants emissions per capita SO_2 and CO_2 in Tunisia. The main findings indicate that there is a positive linear relationship between CO_2 emissions and GDP, while it represents N-shape relationship between SO_2 and GDP per capita. M'henni (2005) applied EKC in Tunisia during the period 1980 to 1997 by employingGeneralized Method of Moments (GMM) for the following pollutants; CO_2 emissions, concentration of fertilizers and the cars numbers in traffic. The main findings show that there is no evidence of EKC existence for all variables. Millimet et al. (2003) detect the relationship between GDP and two emissions; NO_x and $SO_2$by applying traditional parametric regression and semi-parametricpartially linearregression models.The results support the existence of EKC for both emissions.

The second strand of economic energy literatures focusesinto the causality relationshipbetween economic growth (GDP) and energy consumption (EC), that relationship since the pioneering work of Kraft and Kraft (1978) becomes starting point in many fields such as environmental science, economics, climatology and other fields. In additional of that, Engle and Granger (1987) concept has been applied in various researches during the last three decades, first study used for power demand in America by Engle et al. (1989), since that it becomes the mainstream method for testing the relationship between two different variables. However after that study, many other researchers follow to investigate that relationship by employing miscellaneous techniques and methods into different data spanning, while their findings has failed to acquire unanimous results. Some study supported bidirectional causality relationship between EC and GDP while other study shows a unidirectional running from EC to GDP or the revers, and other study support that there is no relationship between the variables. Glasure and Lee (1997) investigated the causality relationship between GDP and EC in Singapore and South Korea over the period 1961 to 1999 by using the co-integration and error-correction methods. The main finding that there is bidirectional casualty relationship between EC and GDP in South Korea. Oh and Lee (2004) examined the causality between the EC and GDP for South Korea over the period 1970 to 1999 by applying the vector error correction model (VECM). The results support the existence of a bidirectional causal relationship between EC and GDP in long term while in short term a unidirectional causality relationship from EC to GDP. Furthermore in other study for same previous author Altinay and Karagol (2004) examined the causal relationship between electricity consumption and GDP in Turkey for the period from 1950 to 2000. The findings yielded a clear evidence of unidirectional causality run from the electricity consumption to GDP.Dergiades et al. (2013) investigate the causal relationship between EC and GDP in Greece over the period 1960 to 2008 by applying unit root tests and linear and non-linear methods. The novelty is to use a combination of non-linear causality techniques along with applying a quality weighted scheme in construction of energy consumption series. They applied Hiemstra and Jones non-parametric test for non-linear causality. The output supports the unidirectional causal running from EC to GDP in both linear and non-linear methods.

Third strand combine of two previous strands which interested to test the relationship between the economic growth, energy consumption and pollutants emissions. Recently some studies had shown their interested to investigate that relationship, but most of them have used CO_2 as a proxy of environment emissions, and some other have used GHG, while we could not find any study have used SO_2 emissions. Yang, Z., & Zhao, Y.(2014) investigated the relationship among GDP, EC and CO_2 emissions in India for annual data spanning from 1979 to 2008 by applying Granger causality tests and directed acyclic graphs (DAG). The findings support that a unidirectional causality relationship running from EC to GDP, and the another unidirectional causality running from EC to CO_2, while there is a bidirectional causality between CO_2 and GDP. Menyah and Rufael (2010)concentrated in South Africa, and their findings illustrate that a unidirectional causality relationship running from pollutant emissions to GDP and from EC to GDP and to CO_2 emissions only.Chebbi(2010) examined the causal relationship between EC, GDP and CO_2 emissions in Tunisian. The main findings show that the EC and GDP cases CO_2 emissions. Ghosh (2009) investigated same that relationship with including other variables such as investment and employment but in India, whilethe results show that there is no causality relationship between the main variables. Chang (2010)applied the multivariate causality test into GDP, EC and CO_2emissions in Chinese. The results indicated that GDP Granger causes ECwhich leads to CO_2emissions.Tang &Tan (2013) examined the relationship between GDP, energy prices, electricity consumption and technology innovation in Malaysia over the period 1970 to 2009 by applying Granger causality test and ARDL method. The novelty of that is the including of technology innovation as a main variable in the estimated model; they used the amount of patenting activities as a proxy for technology innovation. The significant results indicate that all variables in study are co-integrated. GDP effects electricity consumption positively while the later has been affected negatively in long run by energy prices and technology innovation. In additional of the aforementioned studies Table 1 summarizes some of empirical studies which interested into the linkages between, economic growth, energy consumption, and emissions with main details such as the method, time series, and main findings Zaidi et, al. (2015).

The objective of this study is to examine the relationship betweenSO_2, GDP and EC in multivariate model. In best of our knowledge that in all of the aforementioned studies have employed the CO_2 as a main variable in bivariate or multivariate model, but there is no study had examined SO_2 as a main variable in multivariate model.It is strongly recommended to include that variable in the model. Besides that in method part the data has been transformed by natural logarithm form to reduce the heteroscedasticity.This paper is organized into four sections. Section 2 illustrates data description. Section 3 indicates the details of panel data approach and empirical results. Section 4 provides a conclusion and recommendation to policymakers.

Table 1: shows the causality results between EC and GDP for multivariate framework.

Author	Methodology	Year	Scope	Additional variables	Findings & Results
Masih and Masih (1997)	JJ, VDC & IRF	1961-1990 A	Korea Taiwan	Consumer prices	GDP ↔ EC GDP ↔ EC
Glasure (2002)	JJ & VDC	1961-1990 A	Korea	Energy prices	EC ↔ GDP
Ghali and El-Sakka (2004)	JJ, VDC & VEC	1961-1997 A	Canada	Capital & EMP	EC ↔ GDP

Soytas and Sari (2006)	TY & VDC	1971-2002 A	China	labor force & capital	EC—GDP
Jobert and Karanfil(2007)	JJ	1960-2003 A	Turkey	IVA	EC—GNP EC—IVA
Odhiambo (2010)	Cointegration, ARDL & ECM.	1972-2006 A	South Africa Kenya congo	energy prices	EC → GDP EC → GDP GDP → EC
Alkhathlan&Javid (2013)	ARDL, VECM	1980-2011 A	Saudi Arabia	CO_2	EC — GDP
Yang, Z., & Zhao, Y. (2014)	Granger causality & DAG.	1979-2008 A	India	CO2	EC → GDP EC → CO2

Notes: The unidirectional causality, bidirectional causality and no causality between EC & GDP have been represented by the symbols →, ↔ and — respectively. For the Abbreviations of methods; JJ: Johansen-Juselius causality test, TY: Toda-Yamamoto, VECM: vector error correction model. ARDL: autoregressive distributed lag bounds test. EG: Engle-Granger. VDC: forecast error variance decomposition. ECM: error correction model. While the abbreviation of main variables and scope; GNP or GDP represent the economic growth. EC: energy consumption. IVA: Industrial value added. $CO_{2:}$ carbon dioxide emissions. EMP: Employment.

3. Description of Data

This empirical study includes the following variables;GDP gross domestic product per capita which measured by USD$, while energy consumptionmeasured by kt of oil equivalent per capita. Finally Sulphur dioxide emission (SO_2) valued by a bottom-up mass balance method calibrated to country-level, whichhave chosen as a proxy environment quality. However the target group in this study are chosen from European continent and those countries considered as developed countries such as; Austria, Finland, France, Sweden and Norway. The data has been collected from World Bank website for a series from 1950 to 2010 annually.

4. Methodology

To investigate the relationship between GDP, EC and SO_2 we have applied the following methods; Panel unit root tests, panel co-integration test, panel data analysis.

Panel unit root test

This test should be applied before doing the analysis toverify if the data are stationary or not stationary, if it is stationary then we further the analysis without doing co-integration test. The later has been developed in the beginning of 1985, it illustrates that even if the time series data are non-stationary, may the linear combinations of those time series is stationary, and the pre-requirement before doing the co-integration tests is to check that all data variables are integrated by order 1 in levels.

Panel co-integration analysis

The co-integration analysis has introduced by Pedroni (1999), many scholars have applied that test to examine the relationship between GDP, EC with considering other variables as a main variables. The advantage of Pedroni (1999) test is to examine the heterogeneous panels by allowing detecting theheterogeneous slope coefficients, fixed effects and individual deterministic trends.The panel co-integration testincludes seven regressors based on seven residual based statistics for heterogeneous and homogenous panels. Panel v-statistic is one side test, and if it's resulted by large positive values it reject the null hypotheses which illustrates that no co integration between the variables. In the other hand for the remaining other six variables the rejection of null hypotheses when the test results a large negative values.

Panel causality test

After doing the co-integration Pedroni test as shown in previous section, the direction of causality relationship between GDP, SO_2 and EC has been examined by applying Granger Causality test. Moreover the optimal lag lengths have been selected by Schwarz Bayesian Information Criterion (SBIC). And the serial correlation test has been conducted by using LM statistics, which tests the autocorrelation in the errors of regression model. The null hypothesis indicates that there is no serial correlation however the alternative hypothesis supports the existence of the serial correlation.

Dynamic Panel data analysis

The advantages of dynamic panel data analysis that itallows to detect the dynamics changes in short time seriesand it considers two dimensions; temporal and spatial in the analysis of data due to that it could show more accurate result for the estimation model.

$$y_{it} = \alpha + \beta' X_{it} + \varepsilon_{it}$$

$$\varepsilon_{it} = \mu_i + u_{it}$$

Where μ_i is error term of time series,while in random effect model both of mean error μ_i and random error u_{it} are randomized with normal distribution, moreover those error components are uncorrelated with independent variables (Baltagi, 2005).

There are twoequations of the estimated models; cross section and period effects model and it has applied with taken the natural logarithms form to reduce the heteroscedasticity.

Cross section effect model

$$\text{Ln SO}_2 = \alpha_i + \beta_1 \text{ Ln EC}_{it} + \beta_2 \text{Ln(GDP}_{it}) + \beta_3 \text{ Ln(GDP}_{it})^2 + \varepsilon_{it}$$

Period effect model

$$\text{Ln SO}_2 = \gamma_t + \beta_1 \text{ Ln EC}_{it} + \beta_2 \text{Ln(GDP}_{it}) + \beta_3 \text{ Ln(GDP}_{it})^2 + \varepsilon_{it}$$

Where β_1, β_2 and β_3 are represent the coefficients of long-run elasticity estimates of SO_2 emissions forEC, GDP and GDP^2 respectively.

Diagnostic tests

Hausman testhas been applied to choose the appropriate estimated model between FE and RE models. The Null hypothesis of Hausman test indicates that RE fit the data more than the FE model, but the alternative hypothesis illustrates that the FE model is more appropriate (Yaffee, 2003). Second diagnostic test called redundant test which uses to compare between fixed effects model and pooled model. The null hypothesis indicates that pooled model fits the data more than the FE model, while the alternative hypothesis illustrates that FE model fits the data more than the pooled model(Greene and Zhang, 2003).

The application of EKC Hypothesis

Depending of the estimated coefficients, the turning point (TP) could be calculated by $TP = Exp(-\beta_2 /2\beta_3)$. Whilst If the estimated coefficients $\beta_2 = \beta_3 = 0$ that means there is no relationship between GDP and SO_2, If $\beta_2 > 0$ and $\beta_3 >= 0$, there is positive relationship between GDP and SO_2. If $\beta_2 < 0$ and $\beta_3 >= 0$, there is negative relationship between GDP and SO_2. If $\beta_2 > 0$, $\beta_3 < 0$ the inverted U-shaped relationship between GDP and SO_2. If $\beta_1 < 0$, $\beta_2 > 0$ U-shaped relationship between GDP and SO_2.

5. Discussion and Results

Descriptive statistics

The panel data in this study includes the following variables GDP, EC and SO_2 for some of European countries Austria, France, Finland, Norway and Sweden. The panel data has been collected annually from World Bank website for data spanning over the period 1960 to 2010. Some of the description statistics have shown in Table2;

Table 2Descriptive statistics of the variables

Variables	Mean	Median	Maximum	Minimum	Std. Dev.
GDP	18816.68	14758.11	93366.81	935.46	1674.85
EC	4178.35	4087.64	7100.052	1546.26	133.61
SO_2	654.01	346.16	4324.814	22.84	93.09

Panel unit root tests

In this study Im, Pesaran and shin (Im et al; 2003) unit root test has been used to detect the stationarity for all variables (GDP, EC and SO_2) in levels and in first differences with trend and without trend.The resultssupport that most of the variables are not stationarity at 5% significant levelin level analysis,while in the first difference, all variable are stationarity at 1% significant level,which allows to examine the co-integration in order of level 1. Table 3 shows the results of IPS panel unit root test.

Table 3 The results of IPS panel unit root tests

Tests	level		1st difference	
Trend	Without trend	With trend	Without trend	With trend
SO_2	2.1	0.32	-6.47***	-5.20***
EC	-1.88	-0.0017	-15.57***	-14.05***
GDP	6.31	-0.585	-9.45***	-8.81***
GDP_2	10.9	6.1	-1.39*	-7.35***

*P-values of Optimal lag determination is based on Schwarz Bayesian Information Criterion (SBIC) which are significant at 1% level ***; at 5% level ** and at 10% level **

Panel co-integration analysis

The Panel co-integration analysis has been conducted with consider the within and between dimension for the intercept analysis and intercept and trend. The results support the rejection of the null hypothesis which illustrates that the panel are not co-integrated, due to that we accept the alternative hypothesis which indicates that the variables are co-integrated at 1% significant level, for intercept and trend analysis. Table (4) shows the results of that test.

Table 4 The result of Panel co-integration analysis

Tests	Intercept	Intercept and trend
Within dimension Test statistics		
Panel v-statistic	0.047	4.44***
Panel p-statistic	0.27	-4.66**
Panel PP-statistic	-0.186	-3.34***
Panel ADF statistic	-0.378	-4.36***
Between dimension Test statistics		
Panel rho statistic	1.38	-6.05***
Group PP-statistic	0.57	-6.36***
Group ADF statistic	-0.075	-5.54***

*Panel co-integration results are significant at 1% level ***; at 5% level ** and at 10% level *.*

Panel Causality Results

The results of LM statistics support the null hypothesis as the values of LM test is 17.35, which illustrates that there is no serial correlation. In the other hand the results of Granger Causality test have been summarized in table 5. The results support the feedback hypothesis, in other word the results show bidirectional causality relationship between the EC and SO_2 atsignificant level 5%. However there is no any causality relationship between the other variables.

Table 5 the result of Panel Granger causality test

Source of causation	Δ Ln GDP	Δ Ln EC	Δ Ln SO_2
Δ Ln GDP	------	7.44***	1.41
Δ Ln EC	2.34	------	2.34**
Δ Ln SO_2	0.38	0.76	------

*Results are significant at 1% level ***; at 5% level ** and at 10% level *.*

Diagnostic tests

Hasuman test have beenapplied to compare between theestimatedrandom effects model RE and fixed effectsmodel FE.The significant results show that the RE fits the data more than FE in cross section effect model while in period effects model the FE model fits the data more the RE. Table 6 show the results of Hasuman test.

Table 6Hausman test

Cross-section effects	Period effects
4.66	9.68**

*Chi-Sq test are significant at 1% level ***; at 5% level ** and at 10% level *.*

The next step after deciding that FE estimated model is appropriate model is to make new comparison betweenthe later and pooled model by employing the redundant test.The significant findings support that the pooled model fits the data more than theFE at 1% significant level.Redundant test results have shown in Table 7.

Table 7 Redundant Test

Cross-section effects	Period effects
----------	0.84

*F test values are significant at 1% level ***; at 5% level ** and at 10% level *.*

Estimation model

This part of results indicates the estimated models for each case; the estimated cross section effects model has high R^2 and R^2 adjusted than the period effects model and most of their coefficients are significant at 1% significant level.SO_2 can be explained more than86% and 51% by EC andGDP for cross section effect model and period effect model respectively.In other hand the coefficients in both of estimated models RE and Pooled are closer together, except in the coefficient of Ln GDP^2, which in period effects model (0.39) about two times more than that in cross section effect model (0.61). The conclusion of that we can rely in cross section effects more than in period effects specifications. Table 8 summarized the results.

Table 8 Estimation Models

The Estimation	Best Model Fitted the Panel Data	
	Cross-section effects	Period effects
Coefficients	RE	Pooled
α	-23.88***	-31.06
β1 Ln (EC)	-0.83**	-0.71
β2 Ln (GDP)	6.16***	10.29
β3 Ln $(GDP)^2$	-0.39*	-0.61
Statistics Tests		
R-squared	0.86	0.516
Adjusted R2	0.85	0.514

*The estimated Coefficients is significantly different from zero, * at 10%; ** at 5%. *** at 1%. β1 β2 and β3 are coefficient for EC, GDP and GDP^2 respectively.*

Turning points values by USD$

The turning points have been calculated by using the significant coefficients from the estimated models in Table 8. The results of EKC test support the inverted U curve in both cases. The turning point in period effect model is (4602.82 USD$) which is almost two times higher than that in cross section effects model (2690.37 USD$). Table 9 shows the turning point values for each model.

Table 9 Turning Points

Cross-section effects	Period effects
2690.37 USD	4602.82 USD

6. Conclusions

The main objective ofthis study is to examine the relationship between the economic growth (GDP), energy consumption (EC) and SO_2in European countries over the period 1950 to 2010.by applying thepanel data approach.The significantresults support the bidirectional causality relationship between the EC and SO_2 atsignificant level 5%. The estimated cross section effects model has high value of R^2 and R^2 adjusted than that in period effects model. SO_2 can be explained more than 86% and 51% by EC and GDP for cross section effect model and period effect model respectively. Moreover the results of EKC test support the inverted U curve in period effect model and cross section effect model. The turning point in period effect model is (4602.82 USD$) which is almost two times higher than that in cross section effects model (2690.37 USD$).

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