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Determinants of Air Pollution: An Economic Perspective

Ali Kakar, Bilal Sarwar, Jamal Mustafa

Faculty of Management Sciences, Balochistan University of Information Technology, Engineering and Management Sciences, Quetta

Abstract

The objective of this study was to explore the economic determinants of air pollution. The study analyzed the effect of energy consumption, population growth, trade openness, and Foreign Direct Investment (FDI) on air pollution in Pakistan using time series data for the period of 1960 to 2008. This study was conducted through the log-log model of Multiple Linear Regression (MLR) analysis. The empirical results of this study suggests that all the predictors taken in the study are significant at a 5 % level of significance, while energy consumption is the most significant determinant in the emissions of carbon dioxide (CO_2) in Pakistan which is followed by population growth, foreign direct investment and trade openness.

Keywords: Air pollution, Energy demand, Multiple Regression Analysis

Corresponding author's email: *bilal.sarwar@buitms.edu.pk*

INTRODUCTION

In the modern era, energy can be termed as the key mean to make a modern society. From our homes to space, energy pervades the major role. Services like lighting, cooling, heating, transportation all require the use of energy. On the other hand, for the manufacturing of goods and to attain the economic development of human societies, the role of energy is obvious. By definition energy is the ability to do some useful work. There are many sources of it mainly renewable and non-renewable. Renewable energy sources are those that cannot be exhausted and the non-renewable are those that can be subject to an end. Renewable sources mainly include solar, wind, biomass, and hydro etc. while the non-renewable sources are coal, natural gas and oil.

The world bank annual report 2006 stated that health problems arising as a result of environmental degradation include illness and premature mortality, diarrhea and typhoid accounts for almost 80% of the total damage cost in the country due to environmental degradation.

Pakistan is facing numerous environmental issues, ranging from deteriorating air and water quality and waste management at the urban front, to rapid deforestation, biodiversity and habitat loss, crop-failure and desertification and land degradation in rural areas. The increased realization is there that climate change has compounded these issues (ESP, 2008-09). A vicious circle of poverty is inherently affecting environmental degradation, whereby the everyday dependency of the poor on natural resources combined with exploding population and rapid urbanization is exerting immense pressures on the environment. But still we could not find any research studies that can cater for the causal relationship between the energy use, economic growth and environmental degradation in case of Pakistan. Therefore, there was a need to find out this relationship between the variables mentioned above so that some appropriate measures might be taken for economic growth without polluting the environment. Many environmental externalities associated with the generation of energy from different sources which cause severe environmental and health problems, for example, the environmental quality has been adversely affected by the use of low-quality coal in eastern and central Europe. Developing countries are more dependent on imported fossil fuels to meet the energy demand for their growing economies (Akarca and Long, 1979, 1980).

Greene and Leiby (1993) explored the same question of the rising costs of foreign dependence on the foreign monopoly of oil supplies. The monopoly profits gained by the oil exporting cartel have increased the pressure on natural resource exploitation. This leads to the fact that the poor in such countries have become relatively more vulnerable than the rich.

The relationship between energy consumption and resulted environmental degradation has been explored by many researchers. By using the United States data over the period of 1947-1974, the study conducted by Kraft and Kraft (1978) has indicated the existence of unidirectional causality running from output to energy consumption. Following this monumental research contribution, various researchers explored this relationship by using different data sets, different countries, different variables and controlled variables and through employing various estimation and econometric techniques, Akarca and Long (1980); Hwang and Gum (1991).

Environmental Kuznets Curve (EKC) hypothesis postulates the relationship between economic development and environmental quality and is of the inverted U-shaped curve, i.e. environmental damage first increases then decreases with income. Antwier et al. (2001) and Coxhead (2003) postulated that this non-linear relationship between environmental pollution and income levels can be elaborated through three effects, namely: scale, composition and technique effects.

Heli and Selden (1999), Dinda and Coondoo (2006), and Managi and Jena (2008) all have explored the above-stated nexus by incorporating an additional variable of international trade.

For economic growth we need more energy, similarly efficient energy use needs a higher level of economic development. This is indicating the existence of a two-way causal relationship. Research conducted on this logic includes Masih and Masih (1996), Yang (2000), Wolde-Rufael (2006) Narayan and Singh (2007) and Narayan et al. (2008). Lise (2006) decomposes CO_2 emission over the years of 1980-2003 and found that CO_2 emission increased in the 1980s and in 1990s, but at the same time increasing energy intensity is behind the modest reduction in CO_2 emission. Say and Yucel (2006), by using regression model, pointed out a positive relationship between economic activities and CO_2 emission. The causality between energy consumption and level of economic activities was also investigated by Soytas et al. (2003); Engle-Granger co integration technique was used in this research. Edal et al. (2008) used the Johansan Co integration approach and found the existence of two-way causal relationship between energy consumption and national income for the period of 1970-2006.

There are two schools of thoughts that the masses must be mobilized to find out ways and means to enhance the relationship between energy consumption and economic growth. The first weakening approach (Pachauri, 1977; Tyner, 1978) has little attention to the direction of causality. The second approach is, causality approach (Odhiambo, 2009; Yuan et al. 2010), where there is high stress on the direction of causality. The result of these four possible relationship shows that the answer is mixed. With advances in econometric techniques, more recent studies tend to focus on the cross-section countries with panel data (Lee, 2005; Narayan et. Al., 2008; Apergis and Payne, 2009a, 2009b). It is true that per capita energy consumption in developing countries is relatively low than the developed part of the world, but the sources of energy being used in developing countries are more environmentally inefficient.

MATERIALS AND METHODS

To investigate the relationship of energy consumption, population growth, trade intensity, and Foreign Direct Investment (FDI) with Air Pollution (Environmental degradation) for Pakistan using time series data extracted from the World Development Indicators (WDI) for the period of 1960 to 2008, MLR (log-log model) was used.

Empirical Model

The empirical model was used to quantify the impacts of energy demand, trade liberal-

ization and population growth on air pollution. The model was illustrated as:

$$AP_t = \beta_1 + \beta_2 ED + \beta_3 OT + \beta_4 Pop + \beta_5 FDI + \mu_t$$

Where:
ED=Energy Consumption *(Electricity Demand in megawatts/year)*
Pop = Population Growth *(Annual population of the country)*
AP = Air Pollution. (CO_2 (carbon dioxide emissions (kt)) *[proxy for Air Pollution]*
OT= (Import + Export to GDP) *(Economic openness or Trade intensity)*
FDI = Foreign Direct Investment in US $.
β = Partial Slope coefficient of predictors
μ = Error Term
In this study, Air Pollution (AP) was taken as a dependent variable while Energy Demand (ED), Trade Openness (OT), Population growth (Pop) and Foreign Direct Investment (FDI) were the independent variables.

Econometric Technique
The multiple linear regression technique (MLR) was used to estimate above mentioned log-linear model because the OLS could not be used here because of more than one independent variable.
By using the estimation software (MegaStat-2007), the following MLR model was estimated:

$$\ln AP_t = \beta_1 + \beta_2 \ln ED + \beta_3 \ln OT + \beta_4 \ln Pop + \beta_5 \ln FDI + \mu_t$$

Assumptions of the Model
"The key assumptions of MLR are as:
MLR1: The population model is linear in parameters.
MLR 2: A sample, $\{x_{i1}, x_{i2}, \ldots\ldots\ldots\ldots, x_{ik}, y_{i1}\}$: i=1,2,…,n}, is random.
MLR 3: E , $(u| x_1, x_2 , \ldots\ldots\ldots x_k) = 0$ Zero conditional mean
MLR 4: None of x is content (nonzero sample variation in x). There are no exact linear relationships among x, s.
MLR 5: Homoscedasticity, Variance $(u| x_1, x_2 , \ldots\ldots\ldots x_k) = \sigma^2$
MLR 6: the population error, u, is independent of $x_1, x_2 , \ldots\ldots\ldots$ x, u is normally distributed with zero mean and Variance σ^2, u~ Normal $(0, \sigma^2)$.

The estimated model was evaluated on the basis of above mentioned assumptions of MLR."

Limitations of the Model
Though energy demand is different in many aspects, but for this study comparison Energy Demand (ED) has been used as a proxy variable for energy use.
Although the trade openness is a vast area itself, but the ratio of import and export to the GDP has been used as an indicator of trade openness in this study. Moreover, trade openness means the absence of taxes and trade barriers to a great extant in this research study.
Instead of taking population growth rate which is a common practice in research, annual population of the country is taken for the convenience of this study as a proxy.

Data Source
All the time series data, on the above mentioned variables, was extracted from World Development Series from the period of 1960 to 2008.

RESULTS AND DISCUSSION

In this study we analyzed the impact of energy consumption, population growth, and trade openness on the economic development of Pakistan (GDP). The log-log model was used. All the variables were significant as a 5% level of significance, and were having a positive relationship, inferring to the point that all the predictors are adding to environmental degradation in Pakistan for the sample period of the study.

Regression Analysis
The results of the estimated equation were:
Ln AP = 10.25 + 0.0335 ln ED + 0.00925 ln Pop + 722.44 ln OT + 0.0075 ln FDI
As the model was in log-log form, the estimated coefficients were showing the percentage of the corresponding elasticities of the variables. Trade openness was having the highest impact on air pollution. As more energy (nonrenewable in case of Pakistan) is used for the production to export, therefore, emission of CO_2 (proxy of Air Pollution) is associated with the use of more energy. The coefficient establishing the linkages between

air pollution and population growth was the smallest. Again it is ambiguous because more population means more deterioration of the environment, but in this research study the results are ambiguous due to time series data. All the predictors i.e. Energy use, population growth, trade openness, and FDI were significant at a 5% level of significance as the *p-values* were 0.002, 0.0025, 0.0054, and 0.0063 respectively less than 0.05. There was a positive relationship of all predictors of the study with Air pollution during the sample period, (Table 1).

Table 2 reveals the model summary of the study. The R Square value of 0.862 suggests that almost 86 percent of the variation in the dependent variable is explained by all the independent variables combined. Table 3 discloses that the overall model is also significant at 5 percent level of significance.

Table 01: Regression results

Variables	*coefficients*	*Std. error*	*t-value*	*p-value*
Intercept	10.2518	0.2471	41.488	4.25
ln ED	0.0335	0.0064	5.24	0.002
ln Pop	0.0093	0.0043	2.12	0.0025
ln OT	722.44	213.29	3.38	0.0054
ln FDI	0.0075	0.0022	3.53	0.0063

Source: Author' Calculation 95% confidence interval

Table 02: Model Summary

R^2	0.862	n	48
Adj. R^2	0.823	k	4
Std. Error	0.101		

Source: Author's calculation

Table 03: ANOVA

Source	*SS*	*df*	*MS*	*F*	*P-value*
Regression	14.8968	4	5.7242	89.39	0.008
Residual	0.6751	27	0.0102		
Total	15.1719	31			

Source: Author's calculation

APPENDIX: Definition and Source Variables used in the study

Energy use (kg of oil equivalent per capita)	Energy use refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport.	IEA Statistics © OECD/IEA 2012 (http://www.iea.org/stats/index.asp), subject to https://www.iea.org/t&c/termsandconditions/
Exports of goods and services (% of GDP)	Exports of goods and services represent the value of all goods and other market services provided to the rest of the world. They include the value of merchandise, freight, insurance, transport, travel, royalties, license fees, and other services, such as communication, construction, financial, information, business, personal, and government services. They exclude compensation of employees and investment income (formerly called factor services) and transfer payments.	World Bank national accounts data, and OECD National Accounts data files.
Imports of goods and services (% of GDP)	Imports of goods and services represent the value of all goods and other market services received from the rest of the world. They include the value of merchandise, freight, insurance, transport, travel, royalties, license fees, and other services, such as communication, construction, financial, information, business, personal, and government services. They exclude compensation of employees and investment income (formerly called factor services) and transfer payments.	World Bank national accounts data, and OECD National Accounts data files.
Population, total	Total population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship--except for refugees not permanently settled in the country of asylum, who are generally considered part of the population of their country of origin. The values shown are midyear estimates.	(1) United Nations Population Division. World Population Prospects, (2) United Nations Statistical Division. Population and Vital Statistics Report (various years), (3) Census reports and other statistical publications from national statistical offices, (4) Eurostat: Demographic Statistics, (5) Secretariat of the Pacific Community: Statistics and Demography Program, and (6) U.S. Census Bureau: International Database.

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