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Bayesian Econometrics Approach in Determining of Effecting Factors on Pollution in Developing Countries (based on Environmental Performance Index)

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ABSTRACT: Emphasis on sustainable development and the need to protect the environment as well as the adverse effects of environmental pollution on the quality of life have made environmental protection one of the main concerns of economic policymakers. For this purpose, approaches to improve the quality of the environment and the factors affecting it have triggered extensive theoretical and empirical studies over the past few decades. These issues have caught the attention of economic analysts. Accordingly, the main objective of this study is to investigate pollution determinants in developing countries from 1996 to 2016, using Bayesian Model Averaging Method. Given the fact that the weighted mean square coefficient of GDP is positive, the Environmental Kuznets Curve (EKC) Hypothesis can be confirmed with a high degree of certainty. The probability of this variable's effect is 0.98%, being partially a component of each of the 10 optimal models which highlights the great importance of this variable to explain the environmental performance. Energy consumption variables for each unit of GDP and value added of industry sector are placed in the second and third ranks with effectiveness probability of 0.89 and 0.85, respectively. They also have a negative impact on environmental performance. Thus, energy consumption per unit of GDP is considered one of the elements of 8 out of 10 optimal models, while the value added of the industrial sector is an element of 7 out of 10 models. This highlights the relative importance of these variables in explaining environmental performance.

Keywords: Pollution, Environmental Quality, Environmental Kuznets Curve, Bayesian Model Averaging

INTRODUCTION

Environment is one of the most important elements of life and development, as it plays various roles in balancing the various components of life. It has been exploited freely and unlimitedly, resulting in its destruction as well as the creation of various contaminants in the area (Shahbaz et al., 2016). In late 1970s, the importance of trade and environmental issues grew, leading to protests by environmentalists against poor conditions of the environment due to the increasing expansion of trade, opposition, and expanded meetings around the world. In their opinion, due to liberalization and increase of exports, the amount of economic activities, the polluting ones included,

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expanded, giving an improper rise in the consumption of resources and energy (Fakher & Abedi, 2017). In most countries, especially the developing ones, economic growth is considered as the center of planning. Unfortunately, economic growth has unpleasant consequences, particularly in the environmental field. Developing countries are on the horns of a dilemma: either rapid economic growth, regardless of its environmental consequences, or adoption of a sustainable industrial development strategy, based on the combination of ecological and economic considerations. For these countries it is quite hard to select (Hollinger, 2008; Fakher, 2016).

Considering the importance of environmental pollution, the present study addresses the factors, affecting environmental performance, from economic, social, and political points of view. One of the problems to assess the factors, affecting air pollution, is that the variety of theories and the lack of a specific model in this regard, on one hand, and a large number of explanatory variables, potentially affecting pollution, on the other, does not offer the possibility of using a classical econometric model to the researcher. The lack of a specific framework to select explanatory variables and estimate different models of contamination has led to different policy outcomes and recommendations. One of the ways to overcome uncertainty in choosing the variables and selecting a model is to use econometric methods such as Bayesian Model Averaging.

There are several variables, which affect environment quality. They can be easily categorized into several general groups of economic variables, political variables, and social variables. The most important economic variable, considered in most studies, is economic growth. A number of studies argue that the environmental degradation level and economic growth have an inverted U-shaped relation, referred to as the Environmental Kuznets Curve (EKC) in the literature. The relation received serious attention after some scholars (Apergis & Ozturk, 2015; Jebli et al., 2016) examined it in their studies, concluding that the environment gradual degradation was a consequence of economic growth in its early stages, which in turn would improve the environmental conditions after achieving certain growth level. Some researchers, such as Kais and Mbarek (2015), Uddin et al (2017), Ozturk and Acaravci (2013), and Saboori et al. (2012), conducted various empirical studies to examine EKC hypothesis. Nonetheless, their results often disagreed. On the contrary, other studies, including those conducted by Shafik (1994) and Azomahou et al. (2006), showed a linear relation between CO_2 emission and economic growth, while Lean and Smyth (2010b) and Saboori et al. (2012) found an inverted U-shaped relation. Still, others believed that it was an N-shaped relation (e.g. Shafik, 1994; Friedl & Getzner, 2003) and some studies (e.g. Richmond & Kaufmann, 2006) even saw no relation between the two. Hao et al. (2016) and Charfeddine and KhediriK (2016) studied the relation between financial development and environmental quality. Their results showed that the impacts of financial development on environmental quality were positive. Nasreen et al. (2017) and Sbia et al (2017) showed that the increase in energy consumption and population density was detrimental for environmental quality in the long run; while the results of the study conducted by Charfeddine and KhediriK (2016) demonstrated a positive relation between electricity consumption and environmental quality. There are several studies, which investigated the influence of public sector corruption on environment. Results from some of these studies, including those conducted by Leitao (2016) and Umer et al. (2014), showed a negative relation between corruption and environment. The effect of financial direct investment on environmental quality was investigated by Seker et al.

(2015), indicating that the effect of FDI on CO_2 emissions was positive though relatively small.

The second group of variables that affect pollutant emissions are political variables. Nekooei et al. (2015), You et al. (2015), and Amadeh et al. (2013) examined the relation between democracy, government size, and environmental quality. Their results showed that democracy had a heterogeneous effect on CO_2 emission and the impact of government size on environmental quality was negative.

Social variables include income inequality, population density, and urbanization. The influence of income inequality on carbon emissions per capita have been examined by Hao et al. (2016) and Morse (2017), whose results showed that carbon emissions per capita increased as the income gap expanded. Rahman (2017) and, Li and Ma (2014) used the variables of population density and Urbanization into their model and argued that population density and Urbanization adversely affected environmental quality. Harati et al. (2015) examined the relation between human development and environmental quality, showing that there was a positive relation between the two.

Accordingly, the main objective of this study is to investigate the determinants of pollution in developing countries during the period between 1996 and 2016, using Bayesian Model Averaging Method.

Table 1. Introduction of research variables

Dependent Variable				
Row	**Variables**	**Definition**	**Abbreviation**	**Reference**
0	-	Environmental Performance Index	EPI	WDI
Explanatory Variables				
1	Economic Variables	Gross Domestic Product (The square of this variable is considered for the study of environmental Kuznets curve hypothesis)	GDP	WDI
2		Financial Development (Volume of liquidity to GDP) (The square of this variable is also considered)	FD	
3		Intersecting effect of financial development-economic growth	FD ∗ GDP	
4		Energy consumption per unit of GDP (as an indicator of energy efficiency in the production process)	GDPEU	
5		Gini coefficient index (Economic inequality)	GINI	
6		Corruption Perceptions Index (The amount of rental activities)	CPI	
7		Trade Openness (Total exports and imports to GDP)	TO	
8		Capital-labor ratio (The square of this variable is also considered)	K/L	
9		Capital-relative workforce ratio (The square of this variable is also considered)	RK/L	
10		Intersecting effect of trade openness - capital-relative workforce ratio (The square of this variable is also considered)	$(RK/L)_{it}T_{it}$	
11		Value added of industrial sector	INVA	
12		The FDI percent of GDP (FDI Inward)	FDII	
13		The FDI percent of GDO (FDI Outward)	FDIO	
14		Per capita consumption of electricity (kwh)	ELC	
15	Political Variables	Democracy index (Political Inequality)	DEMC	
16		Regulatory quality	RQ	
17		Government efficiency and effectiveness	GE	
18		Government size (The ratio of government expenditure to GDP)	GS	
19	Social variables	Human development Index	HHDI	
20		Literacy rate	LIT	
21		Population Growth	POPG	
22		Urbanization rate	URB	
23		Population density (per square kilometer)	DP	

Source: research findings

MATERIALS AND METHODS

The variables, used in this study, are panel data for the period of 1996-2016, obtained from different sources, including International Monetary Fund, quarterly bulletins, etc. The data, corresponding to FDI, are sourced from quarterly bulletins and volumes of IFS Yearbook. EPI is developed by Yale Center for Environmental Law and Policy and Center for International Earth Science Information Network in collaboration with the World Economic Forum and the Joint Research Centre of the European Commission. The rest of the variables are collected from World Development Indicator Database. This study uses 23 explanatory variables as determinants of environmental performance, which is presented in Table 1.

One of the most important challenges the modeling researchers are facing is a discrepancy about the potential variables that can be considered in the explanatory model. Of course, such disagreements often lead to differences in conclusions. So far, economists have been working hard to solve this problem. For example, one of their solutions was to perform sequential tests to remove the omitted variables or add the deleted variables to the model and test the hypothesis about their significance. However, these methods do not provide satisfactory results due to the invalidity of the hypothesis test for its incorrect model specification and cumulative and sequential errors. Nevertheless, in recent years, Bayesian econometrics has come up with an appropriate solution to overcome uncertainty about the selection of parameters and models through a method called "Meaning a Business Model", introduced by Jeffrey (1961) and developed by Leamer (1978). Later, Wasserman (2000) and Koop (2003) were among the researchers who developed methods that are more complete in this regard. Ever since 2000 the use of this method along with its recent years' extended versions has been considered by many researchers to examine the model uncertainty in regressions. The basic principle in this method is that it considers models and related parameters as random variables, estimating them in accordance with the previous information.

As aforementioned, the selection of potential variables suitable to be included in econometric model constitute one of the major challenges the researchers are faced with, particularly in cases where there are numerous relevant explanatory variables. However, no acceptable method of problem solving can be found among the existing traditional econometric models. The only available solution with the potentials to solve the model selection problem is “Bayesian econometrics”.

Many researchers have doubts about the variables that could be entered into the model and many examples can be mentioned in this regard. Such disagreements frequently cause differences in research results; however, the emergence of Bayesian Model Averaging (BMA) in recent decades has solved the uncertainty, surrounding the parameters issue and the model. For the estimation of BMA coefficients, the weighted averaging technique is used in relation with all the possible models. The weights, however, depend on the probability of the models.

RESULTS AND DISCUSSION

Table 2 shows the results of the weighted average of the coefficients, the mean standard deviation, and the probability of the effect (posterior inclusion probability) of each of the variables in question. Given the fact that the average weighted mean square coefficient of GDP is positive, the Environmental Kuznets Curve (EKC) can be confirmed with a very high confidence. The hypothesis here was interpreted in this way that in the early stages of economic growth (i.e., among countries with low income), countries with higher relative per capita income suffer more from pollution. However, in the higher stages of economic growth (i.e., among high-income countries), higher relative per capita income has led to a low level of pollution. The probability of this variable's effectiveness was 0.98%, being a part of each of the 10 optimal models' components, which emphasized the high importance of this variable in explaining environmental performance. The above mentioned results were in agreement with the results, reported by Jebli et al (2016), Apergis and Ozturk (2015), Lean and Smyth (2010), and Saboori et al. (2012). Whereas some research found a linear (e.g. Shafik, 1994; Azomahou et al., 2006) or even an N-shaped relation (e.g. Shafik, 1994; Friedl and Getzner, 2003) between CO_2 emission and economic growth, others showed no relation at all (e.g. Richmond and Kaufmann, 2006). One limitation of this branch of the literature is that they are likely to suffer from the omitted variable bias problem for the simple reason that their empirical model is only a bivariate one.

Regarding energy consumption, it can be observed that both energy consumption variables for each unit of GDP (introduced into the model as an efficiency index) and per capita consumption of electricity had a remarkable effect on environmental performance. The first index, with effectiveness probability of 0.89%, was one of the elements of 8 out of 10 optimal models, in which the current results were consistent with the findings of Nasreen et al., (2017) and, Ozturk and Acaravci (2013), along with per capita electricity consumption with probability of 0.68% that was one of the elements of the 7 out of 10 optimal models, for which the findings were in line with the results of Charfeddine and KhediriK (2016).

In addition, the value added of industrial sector and population growth play a significant role in explaining the environmental performance. The effectiveness probability of these variables, considered one of the elements of 7 models out of 10 optimal models, were 0.85 and 0.81, respectively. However, the variables of urbanization rate and population density were less significant. This result was in line with the findings of Li and Ma (2014), Rahman (2017), and Nasreen et al. (2017).

The effect of income inequality on environmental performance was negligible. The probability of the Gini coefficient was 0.47, having a negative effect, meaning that more inequality leads to more pollution. It can be argued that high-income people have an interest in production, and since activities to enhance environmental quality usually reduce their ability to produce, they have a personal incentive not to comply with environmental laws. This result was similar to that of Morse (2017) and Hao et al. (2016), who confirmed the positive relation between inequality and pollution.

The square of capital-labor ratio, the square of capital-relative workforce ratio, and intersecting effect of trade openness and capital-relative workforce ratio had a positive, positive, and negative coefficient respectively. Their effectiveness probability was equal to 0.09%, 0.10%, and 0.06%, respectively, indicating their weak relation with environmental performance. This result was in line with the findings of Managi et al. (2009); however, we expect the pollution in the initial ratios of capital-labor to increase as the capital share rises or the labor force in commodity production drops. Nevertheless, in higher ratios the opposite is true for this relation and the only study, investigating this relation, is the one by Managi et al. (2009), which confirmed it. Therefore, in early stages of industrialization, the use of capital rather than labor is associated with more pollution in the environment, yet after some degree of industrialization, the industry gradually moves towards the use of environmentally-friendly technologies, hence the continuation of industrialization will reduce the pollution of the environment.

For the corruption perception index, a negative effect was reported and its effectiveness probability in the model turned out to be 0.08%, indicating a weak relation between this index and the environmental performance. This result was similar to the findings of Leitao (2016) and Umer et al. (2014).

The intersecting effect of financial development-economic growth on environmental performance was positive; so, the increase in this variable improved the quality of the environment; however, effectiveness probability of this variable was relatively low (about 0.38%). The positive coefficient of this variable indicated financial development and economic growth in the presence of one another reduced environmental degradation, which was consistent with the findings of Charfeddine and KhediriK (2016) and Hao et al. (2016).

The FDI percent of GDP had a positive impact on environmental performance, with an effect of 0.52%. The positive coefficient of the variable "foreign direct investment" indicated that the volume of foreign direct investment in the polluting industries was very low and that investment in clean production had taken place. This result was inconsistent with the findings of Seker et al. (2015).

The positive impact of literacy rate on environmental performance shows that increasing environmental literacy in schools had been considered more. The quality of "regulations" variable with an inclusion probability of 0.15% and a coefficient of 0.028, had a positive effect on environmental performance, showing that it is beneficial to implement specific regulations that mainly aim at improving the quality of the environment in these countries. This result was also in line with the studies by Amadeh et al. (2013).

Human development with inclusion probability of 0.21% and a coefficient of 0.008 increased environmental performance. The reason for this was the promotion of the human capital index through raising public awareness and knowledge, which reduces the destructive effects of human activities on the environment. This result was also in line with the studies by Harati et al. (2015).

The government size had a negative impact on environmental performance; however, the inclusion posterior probability of this variable was low (about 0.29%), implying that the government's privilege of oil revenues led to an increase in government monopolies and executives in the country. As a result, it reduced competition and private sector investment. In other words, an increase in the size of the government means an increase of the body of government, which, in parallel, would increase environmental degradation. The obtained result was in line with the findings of Amadeh et al. (2013), Shahab, and Sadr Abadi (2015).

Other variables such as government efficiency and effectiveness, democracy, and population density had a relatively low impact on environmental performance.

After applying the Bayesian Model Averaging, 10 optimal models can be presented with the highest probability of analysis in Table 3.

Variables with a value of 1 are those, placed after 11,000 iterations or 10,000 effective iterations in the column of variables for the first 10 models. Table 4 gives the probability of occurrence of each of the 10 optimal models, based on two analytical and numerical methods. Accordingly, the probability that the best model presented in Table 3 (Model 1) could be the best one to explain the environmental performance among the 10 estimated models was approximately 38%.

The results also show that the total number of times of the selection or iteration of 10 optimal models in the sampling process was 12380 out of 10,000 effective iterations; therefore, it can be concluded that the probability of occurrence of the above 10 optimal models was 48/69% in 10,000 designed models.

Table 2. Weighted averaging of coefficients

Variables	Weighted averaging of posterior coefficients	Standard deviation averaging of posterior coefficients	posterior inclusion probability
Gross domestic production	-0/63781	0/37851	0/98
Square of gross domestic production	0/32836	0/09620	0/95
Financial development	-0/15285	0/13850	0/28
Square of financial development	0/11798	0/10670	0/19
Intersecting effect of financial development-economic growth	0/0947	0/0836	0/38
Energy consumption	-0/53813	0/66372	0/89
Gini coefficient index	-0/00430	0/00361	0/47
Corruption perceptions index	-0/01985	0/00930	0/08
Trade openness	0/09935	0/08123	0/13
Capital-labor ratio	-0/00285	0/02700	0/11
Square of capital-labor ratio	0/00104	0/00098	0/09
Capital-relative workforce ratio	-0/03624	0/00081	0/12
Square of capital-relative workforce ratio	0/05663	0/00680	0/10
Intersecting effect of trade openness - capital-relative workforce ratio	-0/00154	0/00101	0/06
Square intersecting effect of trade openness - capital-relative workforce ratio	-0/00121	0/00090	0/05
Value added of industrial sector	-0/02883	0/00691	0/85
The FDI percent of GDP (FDI Inward)	0/00039	0/00390	0/52
The FDI percent of GDO (FDI Outward)	-0/00039	0/00400	0/35
Per capita consumption of electricity	0/19210	0/14780	0/68
Democracy index	0/1081	0/00990	0/16
Regulatory quality	0/02860	0/02200	0/15
Government efficiency and effectiveness	0/08420	0/01080	0/18
Government size	-0/0096	0/00900	0/29
Human development index	0/0089	0/00790	0/21
Literacy rate	0/00680	0/00680	0/41
Population growth	-0/05430	0/02310	0/81
Urbanization rate	-0/00490	0/00049	0/78
Population density	-0/00398	0/03100	0/14

Source: research findings

Table 3. Optimum models

Models Variables	First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth	Ninth	Tenth
GDP	1	1	1	1	1	1	1	1	1	1
GDP^2	1	1	1	1	1	1	1	1	1	1
FD	0	0	0	1	0	0	0	1	0	0
FD^2	0	0	0	0	0	0	0	0	0	0
$\mathrm{FD} * \mathrm{GDP}$	0	0	0	1	0	0	0	0	1	0
GDPEU	1	1	1	0	1	1	1	1	0	1
GINI	0	1	0	0	0	1	0	0	1	0
CPI	0	0	0	1	0	0	0	0	0	0
TO	0	0	0	0	0	1	0	0	1	
K/L	0	0	0	0	0	0	0	0	0	0
$(K/\mathrm{L})^2$	0	0	0	0	0	0	0	0	0	0
RK/L	0	0	0	0	0	0	0	0	0	0
$(RK/\mathrm{L})^2$	0	0	0	0	0	0	0	0	0	0
$(RK/L)_{it}T_{it}$	0	0	0	0	0	0	0	0	0	0
$\left((RK/L)_{it}T_{it}\right)^2$	0	0	0	0	0	0	0	0	0	0
INVA	1	0	0	1	1	1	1	0	1	1
FDII	0	0	0	0	0	0	0	0	0	0
FDIO	0	0	0	0	0	0	0	0	0	0
ELC	1	0	1	1	0	1	1	1	0	1
DEMC	0	0	0	0	0	0	0	0	0	0
RQ	0	0	0	0	0	0	0	0	0	0
GE	0	0	0	0	0	0	0	1	0	0
GS	0	0	0	0	0	0	0	0	0	0
HHDI	0	0	0	0	1	0	0	1	0	0
LIT	1	1	1	1	0	1	1	0	1	1
POPG	0	0	0	0	1	0	0	0	0	0
URB	0	1	0	1	0	0	0	1	0	0
DP	0	0	0	0	1	0	0	1	0	0

Source: research findings

Table 4. Optimum models odds

models	Posterior Odds (Analytical)	Posterior Odds (Numerical)
1	38.23	37.91
2	19.66	21.18
3	8.59	5.86
4	6.89	7.23
5	6.69	8.16
6	5.62	8.24
7	4.78	3.21
8	4.56	3.12
9	4.29	10.18
10	3.91	4.65

Source: research findings

CONCLUSIONS

The issue of environmental pollution is a basic requirement for achieving sustainable development in any country. In addition, the prerequisite for effective measures to improve the quality of the environment is to be aware of its determinants' impact. Accordingly, reducing pollution in the community through adoption of rational and scientific policies would be a highly influential strategy; therefore, the present study used Bayesian econometric approach and Bayesian Model Averaging to investigate the effects of potentially-effective factors on environmental performance as one of the most important indicators of air pollution in developing countries during a 20-year period from 1996 to 2016. The most important effective variable turned out to be GDP (economic growth) with a positive and almost definitive impact. Energy consumption per unit of GDP was ranked second with the effectiveness probability of 0.89% and a negative impact on environmental performance. The value added of the industrial sector and population growth was ranked third and fourth respectively, but population growth had a greater impact on environmental performance. In this research, the square of capital-workforce ratio, the square of capital-relative workforce ratio, and intersecting effect of trade openness-capital-relative workforce ratio were also used to examine their relation with environmental performance. According to the results of BMA analyses, these variables had a negligible effect on environmental performance, having positive, positive, and negative effects, respectively, while effectiveness probability of them was equal to 0.09%, 0.10%, and 0.06%, respectively, indicating that there was a relatively weak relation between above variables and environmental quality index. In the end, issues such as considering more comprehensive measures of environmental quality, namely Ecological Footprint Index (EFI), Environmental Sustainability Index (ESI), and Environmental Vulnerability Index (EVI), as well as using two Bayesian Model Averaging (BMA) and Weighted Averaging Least Square (WALS) approaches to test and check the robustness of the results are recommended.

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