



An empirical study on energy utilization efficiency, economic development, and sustainable management

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Abstract

Based on the premise of sustainable development of the environment, how to achieve the balance of energy utilization, economic development, and sustainable management of the environment is becoming increasingly important in the process of stable economic development. This paper analyzes the concept of environmental Kuznets curve, taking 35 European countries as the research objects, first discusses the trend of energy utilization efficiency from 1990 to 2013, and then analyzes the relationship between energy efficiency and economic development. Empirical results show that labor has a significant negative impact on energy efficiency and the increase in labor input will reduce energy efficiency. If the added value of national manufacturing accounts for a higher percentage in GDP, it will have a negative impact on the effectiveness of energy utilization. In addition, when the national price level is high, price fluctuation will increase the price of energy utilization, or the cost of energy input in economic activities, which will further reduce the country's energy efficiency performance. Lastly, the empirical study also found that energy efficiency and economic development showed a quadratic U-shaped relationship, indicating that the long-term energy efficiency of the country will first decline and then rise during economic activities.

Keywords Economic growth · Energy usage efficiency · Environmental Kuznets curve

Introduction

With the deterioration of environmental quality, environmental problems have affected public health. More and more people participate in environmental protection activities. Some scholars have also pointed out that in environmental affairs management, in addition to relying on government regulation and market mechanism, we should strengthen environmental awareness of society and achieve environmental quality improvement through public participation in environmental protection activities (Xepapadeas and de Zeeuw 1999).

Meanwhile, some government officials (Fang 2000) also pointed out that officials should pay attention to enhancing public participation in environmental protection and improving environmental quality by increasing public participation.

On the theoretical side, developed countries started researches on public participation in pollution governance earlier. Concerning the impact of public participation in environmental protection on industrial emissions, most studies have been divided into three categories. First is direct negotiation or litigation between the public and the polluting industry (Stroup and Goodman 1992). Second, the public appeals to the government, provides pollution information, and exerts pressure to the government in order to safeguard the public interest. Third, when negotiations between the public and the polluting industries fail, or government inaction occurs, the public expels the polluting industries by demonstrating or violence (Pargal and Mani 2000).

In terms of empirical evidence, scholars in developed countries mainly use indicators, such as the number of public complaints and the level of urbanization to measure public participation in environmental protection, while scholars in developing countries use the total number of letters for

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environmental visits to measure public participation. Pargal and Wheeler (1996) examined the impact of public participation in pollution management, using Indonesian factories as the subjects of research. They measure public participation by indicators, such as per capita income and the proportion of local employment. The results show that the emission of pollutants from factories is relatively low in areas with high per capita income. Zeng and Hu (2015) conducted a study about 1500 factories in China in 1994 and measured the level of public participation by the pressure of public opinion in surrounding communities. It was found that higher public opinion pressure makes lower air pollution. Dasgupta (2001) points out that public complaints about environmental issues can influence government supervision and inspection, and thus can influence pollution governance. Kathuria (2007) uses information from four Indian monitoring stations in 1996–2000 to measure public participation in terms of the number of environmental pollution articles published in local newspapers. The study found a negative correlation between the number of environmental pollution articles published in local newspapers and the pollution behavior of enterprises, and news media coverage can effectively restrict the pollution behavior of enterprises.

The influence of greenhouse gas emission

The use of fossil fuels is the main source of greenhouse gas emissions, while the use of energy is the main driving force for social and economic developments for all countries in the world. However, at the same time, global warming has been exacerbated by the cumulative emissions of greenhouse gases during the energy conversion process, especially carbon dioxide (dioxide, CO₂), which has, directly and indirectly, led to ecological imbalance and economic and social impacts as well as other adverse consequences. It is common knowledge for all countries that countries around the world will shoulder varying degrees of emission reduction responsibilities, which also means that it is necessary to control or reduce the use of fossil fuels in order to further reduce the world's total greenhouse gas emissions. However, sustainable economic development is still the primary goal of the world; how to balance the emission reduction responsibility and economic development becomes the guidelines for improving the relevant policies. In terms of the input-output production structure, energy can be regarded as a factor input, while economic development and carbon dioxide emissions can be considered as desired outcome and undesired outcome, respectively. In this production structure relationship, in order to maintain economically sustainable development on the premise of commitment reduction, there are two decision-making objectives for the relevant decision-making units from the perspective of energy use. The first is to create more units of economic output with less energy input, that is, to improve energy

efficiency. The second is to replace fossil energy with less-polluting energy sources, or to upgrade energy technology to reduce pollution emissions in the conversion process, that is, enhancing energy emission efficiency.

The ways in which these two decision-making objectives are achieved, that is, the ways that affect energy utilization efficiency and energy emission efficiency, can be broadly divided into three categories. The first category is that increased people's awareness of environmental protection promotes the policy direction of the decision-making units to change. The second category is that the introduction of new energy conversion technologies promotes efficiency improvements. The third category is caused by the transformation process of national industrial structure from high energy consumption to low energy consumption. According to past studies, the first type of impact is that when people's environmental protection awareness increases, energy consumption preference patterns will change, and the relevant decision-making units will be urged to adopt more stringent regulations and policies to regulate or encourage producers to use less harmful measures to the environmental quality (Suri and Chapman 1998; Vaninsky 2008; Adom et al. 2018). This will also further impact on energy utilization efficiency and energy emission efficiency by changing the input-output structure of energy. The second category is that, with the development of pollution control and energy conversion technologies, it is possible to achieve the same level of output as the past with less input than the past by reducing the rate of energy conversion and consumption, or by reducing the non-decomposition rate in order to reduce greenhouse gas emissions in the production process during the process of converting energy into usable power (Mielnik and Goldemberg 1999; Richmond and Kaufmann 2006). Lastly, the third category of impact is when the national industrial structure changes from the initial large amount of energy-consuming industries and manufacturing-oriented industries to high output value and low energy consumption industries such as service industry and high-tech industries, the increase in total output is not necessarily accompanied by a large amount of greenhouse gas emissions, but rather by the transfer between different industrial sectors, which is the so-called composition effect. This process of industrial structure transformation has also changed the relationship between total output and energy input and between total output and carbon dioxide emissions, forming the relationship between different energy utilization efficiency and energy emission efficiency.

The trade-off and the relation of energy utilization efficiency and energy emission efficiency

In the course of economic development, although the two efficiency values, energy utilization efficiency and energy emission efficiency, can be provided through the above ways, the performance of these efficiency values should be

complemented by policy instruments. In other words, it requires human intervention and management execution, rather than natural change (Grossman and Krueger 1995; Panayotou 1997; Borghesi 1999; Schmalensee et al. 1998; Unruh and Moomaw 1998; Ravallion et al. 2000; Chen 2001; Heerink et al. 2001; Heil and Selden 2001; Lindmark 2002; Fridel and Getzner 2003; Dinda 2004). For example, since the utilization of new technologies comes at a price, even when economic development brings environmental technology development, decision-making units do not necessarily adopt new technologies, taking into account the minimal cost of profit-making. In other cases, policymakers may have misestimated market conditions, resulting in a failure to produce on the right scale, which will further affect the performance of energy utilization efficiency and energy emission efficiency values. Even under the same type of economic development environment, different decision-making units may have different performance of efficiency values for the above reasons.

On the other hand, improving energy utilization efficiency and energy emission efficiency can be regarded as two different policy directions. Since the performance of efficiency values has to rely on the intervention and intervention of decision-making, thus as the focus of the decision-making unit is different, the two efficiency values have a replacement relationship that one increases and one decreases, or a complementary relationship that they increase and decrease at the same time in the process of sustainable economic development. However, in terms of normative attitude, it would be the ideal policy objective to improve the performance of the two efficiency values in the process of economic development, under the premise of achieving their respective commitments to reductions.

In addition, a country will attach increasing importance to environmental quality as its economy progresses. The traditional literature applies the environmental Kuznets curve (hereinafter referred to as EKC) as an important analysis tool to describe the environmental quality and its horizontal interactive trajectory. However, in the existing empirical studies of EKC, few pieces of literature directly explore the relationship between energy utilization efficiency and economic development, or between energy emission efficiency and economic development. Instead, it focuses more on capturing the negative output of energy consumption, such as the empirical relationship between CO₂ emissions and economic development (Schmalensee et al. 1998; Unruh and Moomaw 1998; Ravallion et al. 2000; Dijkaraaf and Vollebergh 2005; Rezek and Rogers 2008).

Under the goal of maintaining stable economic growth, reducing greenhouse gas emissions, and promoting sustainable environmental development, renewable energy can be considered as a substitute for fossil fuels. This is vital for social development from the aspects of environmental benefits, climate change, and clean production (Azapagic 2004;

Akella et al. 2009; Ren et al. 2014, 2015; Wang et al. 2018). In these traditional EKC-related research documents, many choose a single environmental pollution index, such as the emission of CO₂ and SO₂ in a certain period of time, coupled with the reduced form of empirical function setting, to capture the trajectory between the income level and these environmental indicators. However, it is clear from the foregoing that the focus variables, emission indicators, and income levels discussed in these kinds of literature are in fact linked to the input-output production structure, not just the seeming interaction between the two variables. Therefore, we can only see the current state of environmental quality from these single indicators using the traditional analysis framework, yet there is no way to know how much energy consumption is responsible for the current environmental quality. The literature also fails to take into account the fact that this process also brings momentum to economic development, which in turn boosts overall productivity.

In other words, the traditional EKC empirical literature can only capture the trajectory of environmental quality and economic development in the same period, but cannot provide a more detailed explanation of the impact path behind these tracks. The researchers believe that although EKC can be used to describe the interaction between the income level and environmental quality, the empirical studies are difficult to propose more in-depth policy implications using a single environmental quality indicator as the response variable rate. Therefore, it is suggested to replace the use of the traditional single environmental quality index with the efficiency measurement index, which can consider the multiple input-output relationships in the production structure (Zaim and Taskin 2000; Färe et al. 2004). Based on the above reasons, the empirical models of the relationship between energy utilization efficiency and economic development are constructed by replacing the traditional single environmental quality index with the constructed energy utilization efficiency index and assisted by EKC as the empirical analysis model, to verify the interaction between the two efficiencies and economic development. Lastly, combined with the above empirical results, it indirectly discusses the interaction between energy emissions and utilization under the premise of economic development and analyzes how to further achieve sustainable development of the environment in the process of energy utilization and economic development.

This paper mainly pre-determines the relationship between economic development and energy emissions and use through the model setting of EKC. The national energy efficiency estimated by the application efficiency model is used as the explanatory variable to discuss the impact of economic development characteristic variables on it. The full text is structured as follows. The subsection describes the empirical model, followed by the analysis of the data and empirical results.

Methodology

In the empirical model setting of energy utilization efficiency, Zhou et al. (2012) deduced the total factor energy production efficiency using the stochastic frontier production function model. This paper follows the theories of Zhou et al. (2012); the estimation model is set as follows (formula (1)):

$$\begin{aligned} \ln(1/E_i) = & \beta_0 + \beta_K \ln(K_i) + \beta_L \ln(L_i) + \beta_Y \ln(Y_i) \\ & + \beta_{KL} \ln(K_i) \ln(L_i) + \beta_{KY} \ln(K_i) \ln(Y_i) \\ & + \beta_{LY} \ln(L_i) \ln(Y_i) + v_i - u_i \end{aligned} \quad (1)$$

E represents the energy emission amount of the research object, K and L represent the capital and labor input, respectively, and Y represents the gross value of GDP. u_i represents an inefficiency term of a non-negative statistical distribution and v_i represents error combination of random production boundaries.

In the empirical framework of the relationship between economic development and energy utilization efficiency, the latter is mainly regarded as the response variable, and the former and other related factors are regarded as the self-variable. In conjunction with the EKC model, a framework that presents a high quadratic relationship between the self-variables and the response variables is set to capture the interactive trajectories between each other. We can set a generalized conceptual model of the relationship between the abovementioned efficiency indicators and economic development, as shown in formula (2):

$$EE_i = f(Y, Z) \quad (2)$$

In the formula, EE_i is the estimated value of energy efficiency, variable Y represents economic development, and Z represents other variables. In the interpretation of variables, this paper selects per capita GDP and GDP as the representative variables of economic development, referring to the integration of the relevant literature in the past. On the other hand, it is generally believed that economic activities are more frequent in areas with higher population density, while energy utilization and consumption are relatively high in terms of both supply and demand, which is also regarded as one factor influencing energy utilization efficiency (Cropper and Griffiths 1994; Selden and Song 1994; Scruggs 1998). Therefore, we take the labor force of each country as a response to population density. Lastly, the use of energy is also affected by the industrial structure. In general, countries with higher industrial proportions also consume more energy. In order to capture the effect of this factor on each efficiency value, this paper uses “The proportion of a country’s manufacturing value added in GDP (referred to as MVA)” as the representative factor and brings it into the analysis (Grossman and Krueger 1995; Borghesi 1999). Under the

above variable selection, three efficiency indexes can be set, corresponding to the linear of the first power, the U-type (quadratic) of the second power, and the N-shaped (cubic) of the third power, respectively. Coupled with other explanatory variants, the relevant empirical model can be set as follows:

$$\begin{aligned} EE_i = & \gamma_0 + \gamma_1 \log(\text{Labor}) + \gamma_2 MVA_i + \gamma_3 \log(\text{GDP}_i) \\ & + \gamma_4 \text{Price level}_i + \varepsilon_i \end{aligned} \quad (3)$$

$$\begin{aligned} EE_i = & \gamma_0 + \gamma_1 \log(\text{Labor}) + \gamma_2 MVA_i + \gamma_3 \log(\text{GDP}_i) \\ & + \gamma_4 \log[(\text{GDP}_i)^2] + \gamma_5 \text{Price level}_i + \varepsilon_i \end{aligned} \quad (4)$$

$$\begin{aligned} EE_i = & \gamma_0 + \gamma_1 \log(\text{Labor}) + \gamma_2 MVA_i + \gamma_3 \log(\text{GDP}_i) \\ & + \gamma_4 \log[(\text{GDP}_i)^2] + \gamma_5 \log[(\text{GDP}_i)^3] \\ & + \gamma_6 \text{Price level}_i + \varepsilon_i \end{aligned} \quad (5)$$

$$\begin{aligned} EE_i = & \gamma_0 + \gamma_1 \log(\text{Labor}) + \gamma_2 MVA_i + \gamma_3 \log(\text{Capita}_i) \\ & + \gamma_4 \text{Price level}_i + \varepsilon_i \end{aligned} \quad (6)$$

$$\begin{aligned} EE_i = & \gamma_0 + \gamma_1 \log(\text{Labor}) + \gamma_2 MVA_i + \gamma_3 \log(\text{Capita}_i) \\ & + \gamma_4 \log[(\text{Capita}_i)^2] + \gamma_5 \text{Price level}_i + \varepsilon_i \end{aligned} \quad (7)$$

$$\begin{aligned} EE_i = & \gamma_0 + \gamma_1 \log(\text{Labor}) + \gamma_2 MVA_i + \gamma_3 \log(\text{Capita}_i) \\ & + \gamma_4 \log[(\text{Capita}_i)^2] + \gamma_5 \log[(\text{Capita}_i)^3] \\ & + \gamma_6 \text{Price level}_i + \varepsilon_i \end{aligned} \quad (8)$$

Results and discussion

The relevant energy and economic indicators in this paper are cited from the WBI database of the World Bank, which aggregates the statistics of 35 European countries from 1990 to 2013. Table 1 shows the descriptive statistics for our variable. Table 2 collates the correlation coefficient matrix of the variables. We can find that most of the correlations between the variables are a low correlation, which can better avoid the collinearity problem in the process of empirical response.

Figure 1 estimates the energy efficiency value of the sample according to formula (1) and collates changes in energy efficiency in different periods of different regions. Figure 1 shows that Southern Europe has the highest energy efficiency, Central Europe is the second, and Eastern Europe has the lowest energy efficiency. Among these, energy efficiency in Southern Europe has been in the high-efficiency group over years, while Eastern Europe has been relatively inefficient. Southern Europe showed a downward trend since 1998 and increased only after 2001. In addition, it can be found that the

Table 1 Descriptive statistics

Variable	Definition	Mean	Std. dev.
Labor force	Total labor force (unit: ten thousand)	983.938	137.287
Capital formation	Gross capital formation (constant 2010 US\$, unit: on hundred million dollar)	1212.682	1709.642
GDP	GDP at market prices (constant 2010 US\$, unit: on hundred million dollar)	5629.275	8183.469
Energy	Energy use (kg of oil equivalent) per \$1000 GDP	143.790	79.697
MVA	The proportion of a country's manufacturing value added in GDP	17.806	5.384
Capita	GDP per capita (constant 2010 US\$, unit: dollar)	30,658	22,784
Price level	Price level ratio of PPP conversion factor (GDP) to market exchange rate	0.863	0.359
Energy efficiency	Energy efficiency of countries derived from formula (1)	0.643	0.201
Countries ($N = 35$)	Albania, Austria, Belarus, Belgium, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Moldova, Netherlands, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, UK		

Data source: World Development indicators; Freedom House, ICRG, Polity IV project

energy efficiency of each region shows an increasing trend year by year.

According to the estimation of Table 3, the efficiency value of energy utilization is significantly affected by economic development, the proportion of industrial value in GDP, and population density. As industry accounts for a larger share in output, the lower the efficiency value of energy utilization will be. Similarly, the size of the labor force (or population density) decreases with an increase in energy efficiency for each additional unit. After controlling the effect of other explanatory variables other than economic development on energy efficiency value, a quadratic U-shaped relationship between energy utilization efficiency and economic development is obtained, which means that energy efficiency will decline first and then rise with economic growth.

In order to ensure the estimation stability, Table 4 uses the alternative variable per capita income of GDP as the explanatory variable and discusses the influence of the changes in individual income on national energy efficiency. First of all, you can see that the empirical results are very similar to those of Table 3. Taking the estimation result (3) of Table 4 as an example, the estimation results of each explanatory variable have a significant impact on the energy efficiency, while the labor force has a significant negative impact on energy efficiency. It reflects that higher labor input will reduce energy

efficiency. The estimated value of variable MVA is -0.0882 , indicating that when the added value of national manufacturing accounts for a higher proportion in GDP of the country, it will have a negative impact on the effectiveness of energy utilization. In addition, the estimated value of the price variable is -0.120 , indicating that a higher price level in the country will increase the price of energy utilization or increase the cost of energy input in economic activities, and further reduce the country's energy efficiency performance. In the estimation of the per capita income, the coefficients' influence of the variable $\log(\text{capita})$ and its square term and cubic term are positive, negative, and positive, respectively, indicating that the relationship between energy utilization efficiency and the economic development shows a quadratic U-shaped relationship. It can be seen that the country's energy efficiency will decline first and then rise in the long run during economic activities.

Table 5 performs the white test for multicollinearity and heteroscedasticity, checking the estimation results of Tables 3 and 4. According to Nerlove (1963), if the variance inflation factor (VIF) is greater than 10, the estimated variable has a higher impact. The results show that the VIF values of the other variables are less than 10, except for variables " $\log(\text{GDP}_i)$, $\log[(\text{GDP}_i)^2]$, and $\log[(\text{GDP}_i)^3]$ " in column (2) and column (3). However, it can be found that collinearity does not affect the importance of variables. Besides, except for the VIF in Table 3 (2) and (3), all results reject the null hypothesis that the model has homoscedasticity.

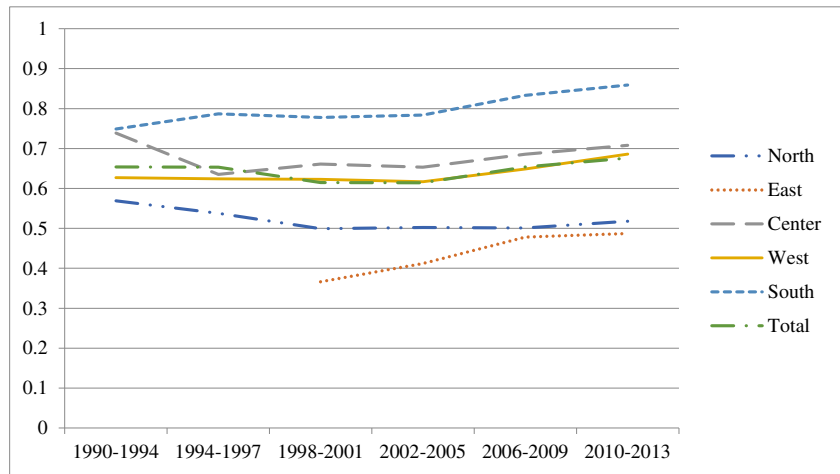
Table 2 Variable correlation coefficient matrix

	A	B	C	D	E	F	
EE_i	A	1					
Labor force	B	0.1901	1				
MVA	C	-0.2328	0.211	1			
GDP	D	0.3047	0.8142	0.0472	1		
Capita	E	0.2232	-0.03	-0.2117	0.5534	1	
Price level	F	0.156	-0.0077	-0.2652	0.5028	0.8864	1

Conclusion

Through combing the traditional EKC empirical literature, this paper finds that, in the past, it can only capture the change trajectory of environmental quality and economic development in the same period, but cannot provide a more detailed

Fig. 1 Changes in energy utilization efficiency in Europe and across the regions over years



explanation of the impact path behind these tracks. Therefore, this paper analyzes the concept of environmental Kuznets curve, taking 35 European countries as the research objects, discusses the trend of energy utilization efficiency from 1990 to 2013, and then analyzes the relationship between energy efficiency and economic development. The empirical results show that labor has a significant negative impact on energy efficiency. If the added value of national manufacturing accounts for a higher percentage in GDP, it will have a negative impact on the effectiveness of energy utilization. In addition, when the national price level is high, price fluctuation will

increase the price of energy utilization, or the cost of energy input in economic activities, which will further reduce the country’s energy efficiency performance. Lastly, the empirical study also found that energy efficiency and economic development showed a quadratic U-shaped relationship, indicating that the long-term energy efficiency of the country will first decline and then rise during economic activities.

As time goes on, with the global average temperature rising year by year, the international emphasis on environmental protection will increase. In the pursuit of economic development and growth, more emphasis should be placed on

Table 3 Estimated results of empirical study on the relationship between energy efficiency and economic development 1

	(1) EE_i	(2) EE_i	(3) EE_i
log(labor)	0.0736*** (0.0154)	0.0749*** (0.0155)	0.641*** (0.0778)
MVA	-0.0101*** (0.00138)	-0.0103*** (0.00138)	-0.00882*** (0.00134)
log(GDP _i)	0.111*** (0.0149)	0.0456 (0.0344)	0.0682** (0.0333)
log[(GDP _i) ²]		-0.0338* (0.0180)	-0.305*** (0.0405)
log[(GDP _i) ³]			0.193*** (0.0260)
Price level	-0.217*** (0.0410)	-0.220*** (0.0410)	-0.120*** (0.0417)
cons	-0.752*** (0.154)	-0.713*** (0.157)	-1.082*** (0.159)
N	680	680	680
R ²	0.189	0.191	0.252

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4 Estimated results of empirical study on the relationship between energy efficiency and economic development 2

	(1) EE_i	(2) EE_i	(3) EE_i
log(labor)	-0.0654*** (0.0146)	-0.624*** (0.0775)	-0.641*** (0.0778)
MVA	-0.0104*** (0.00138)	-0.00865*** (0.00135)	-0.00882*** (0.00134)
log(Capita _i)	0.105*** (0.0142)	0.661*** (0.0774)	0.0682** (0.0333)
log[(Capita _i) ²]		-0.1407 (1.3241)	-0.611*** (0.0810)
log[(Capita _i) ³]			0.289*** (0.0390)
Price level	-0.195*** (0.0390)	-0.118*** (0.0418)	-0.120*** (0.0417)
cons	-0.560*** (0.134)	-1.131*** (0.157)	-1.082*** (0.159)
N	680	680	680
R ²	0.182	0.247	0.252

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5 Robust check, multicollinearity check for variance inflation factor (VIF), and heteroscedasticity check for White test

EE_i	VIF in Table 3 (1)	VIF in Table 3 (2)	VIF in Table 3 (3)	VIF in Table 4 (1)	VIF in Table 4 (2)	VIF in Table 4 (3)
log(labor)	1.088	1.013	1.014	1.014	1.030	1.021
MVA	1.009		4.860	1.021	1.991	1.355
log(GDP _{<i>i</i>})	1.017	15.896	7.880			
log[(GDP _{<i>i</i>}) ²]		15.913	11.979			
log[(GDP _{<i>i</i>}) ³]			13.976			
log(Capita _{<i>i</i>})				1.026	1.025	1.242
log[(Capita _{<i>i</i>}) ²]					1.608	1.608
log[(Capita _{<i>i</i>}) ³]						4.994
Price level	1.043	1.016	1.607	1.114	1.113	1.244
Mean VIF	1.011	5.991	6.030	5.547	5.551	4.551
<i>p</i> value for White's test (H ₀ : homoscedasticity)	0.122	0.000	0.000	0.035	0.000	0.052

Note: the standard error value in parentheses, *, **, *** means 10%, 5%, 1% statistical significant level

sustainable management of the environment. Sustainable development is based on three foundations, economic development, environmental protection, and social justice. It is necessary to seek new models of economic development, not overlooking long-term sustainability and economic development in the long run due to the pursuit of short-term benefits. At the same time, economic development needs to coordinate with the carrying capacity of the earth environment. People should protect the natural resources and environment on which human beings depend, instead of taking whatever we want from the environment. Moreover, social justice must be taken into account during the development process. Therefore, it is necessary to seek a dynamic and sustainable balance between the seemingly conflicting economic, environmental, and social aspects, so as to achieve sustainable development of human beings.

At present, the environmental protection issue has moved from local to the global area and from group recognition to citizen cognition, and further emphasizes actual actions of the government and the non-governmental sectors. Policy measures have also changed from passive pollution control to a positive environmental-friendly and sustainable use of resources. Such a trend is bound to have a certain impact on the industrial development of all countries. The impact of countries on the economic aspects can be divided into two aspects: one is to face international pressure, to share international responsibility, and to avoid international economic and trade sanctions. Another is that the sustainable development of countries requires adjustment of their industrial and energy policies. In other words, sustainable operations should not only emphasize economic activities but also be concerned about the coordination of the natural environment and the social

environment. Moreover, sustainable development is not only a matter within countries but also involves international and interregional cooperation. Only multi-faceted efforts can effectively enhance the integrity of sustainable management.

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