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Promotion Effect of Atmospheric Pollutants VOCs Emission Efficiency Considering Economic Growth Effect

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Coordinated development of economy and environment is the common responsibility and pursuit of the international community. In this context, China is beginning to transform and upgrade its economy in a new model of coordinated economic and environmental development. Taking the VOCs emissions of atmospheric pollutants as object of study, this paper studies the relationship between environmental governance of pollutants emission and economic growth in Hunan Province, its characteristics, and also the mechanism of the relationship between the two. Besides, it also studies the measurement of the coordinated development of environment and economy. The study found that after 2015, the pollutant emission index of Hunan Province showed a linear downward trend, and the coordination degree between the environment and economic system decreased first and then gradually increased in the defined interval of coordination degree. The source of economic growth in Hunan Province comes from capital investment and environmental consumption. The improvement of environmental performance in Hunan Province is mainly driven by technological progress, and the emission reduction effect restricts the further growth of environmental performance.

1. Introduction

Since the reform and opening up, China's economic development has made great achievements, but the economic development model of long-term "high investment, high consumption, high emissions, incoordination, difficulty to recycle, and low efficiency" has caused greater resource and environmental costs (Kukla- Gryz, 2009). At present, China's energy consumption accounts for 21.2% of the global total, making it the world's largest energy consumer (Orubu and Omotor, 2011). Under the severe environmental conditions and the economic development requirements of sustained high economic growth, the environmental cost of China's economic development is becoming explicit. Economic growth will inevitably lead to pollutant emissions, while the pollutant emissions will inevitably cause environmental problems and environmental governance; efficient environmental governance promotes better economic development (Lanzi et al., 2018). Some existing studies have found that under the constraint of atmospheric pollution, the main source of power for long-term sustained economic growth is human capital investment and R&D innovation. Environmental management plays an important role in optimal economic growth rate, environmental quality improvement and environmental carrying capacity (Li and Sun, 2016).
VOCs emissions of pollutants are mainly derived from industrial waste, diesel machinery, and architectural decoration; VOCs emissions increase with economic growth (Naqvi and Zwickl, 2017). In recent years, with the emergence of endogenous economic growth models, many researchers have used the environmental quality or pollution emissions as production factors, introduced environmental quality into utility functions, and included environmental and sustainable development issues in the basic framework of new growth theory (Liu et al., 2017; Adetutu et al., 2015). By constructing an economic growth model that considers sustainable energy use and pollution control, sustained economic growth is achievable under the dual constraints of energy and environment. Promoting pollutant emission efficiency can achieve sustainable development of economy, environment and energy (Li and Wu, 2011). Thus, in this paper, the studies were conducted about the mechanism of the relationship between the emission efficiency of VOCs of atmospheric pollutants and the

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economic growth in Hunan Province, and also the measurement of the coordinated development of environment and economy.

2. Pollutant emission efficiency and economic growth status

2.1 Research on the relationship between pollutant emissions and economic growth

Pollutant emissions are human wastes that directly or indirectly discharge to the ecological environment beyond their own purification capacity, affecting human health, destroying ecosystems and causing large property losses. Economic globalization continues to deliver environmental pollution to the rest of the world, and the catch-up and extensive development model at the expense of the environment is no longer applicable. Institutional factors arising from environmental problems in the process of economic growth include market failures and government regulatory failures, among which factors affecting market failure include externalities and information scarcity asymmetry. Fig.1 shows the negative externalities of the environment, where, A is the enterprise, B is the resident, and the intersection point F indicates that the pollutant emission enterprise can realize the maximum benefit; at this time, the additional cost brought to the residents by the enterprise pollution is MC_B, thus, the marginal cost should be the sum of MC_A and MC_B.

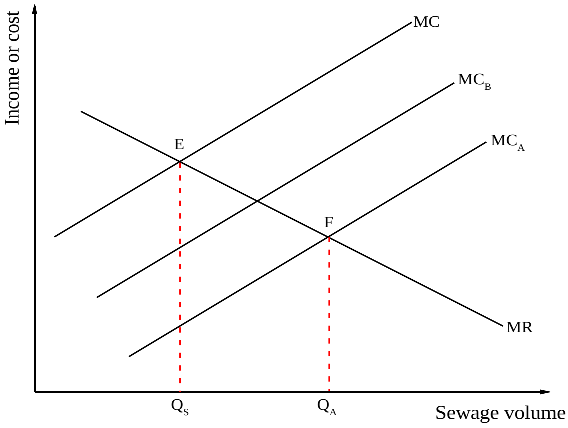


Figure 1: Negative externalities of the environment

2.2 Environmental and economic coordination measurement and results analysis

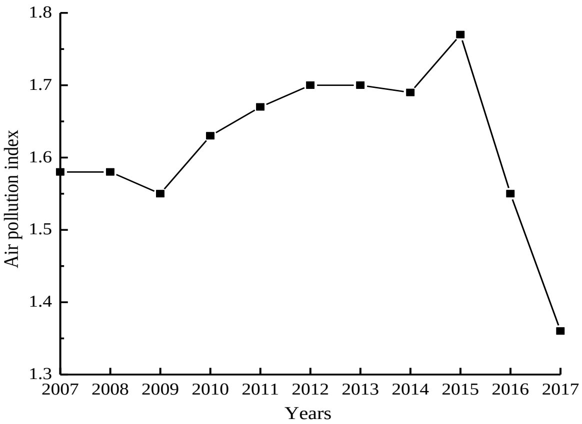
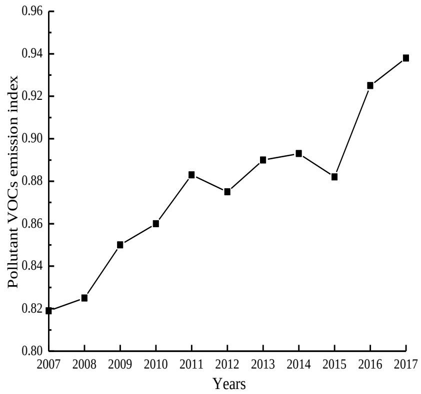


Figure 2: Hunan province average pollutant discharge index 2007-2017

At present, China's total pollutant emissions are high, e.g., the industrial waste, construction waste and motor vehicle emissions have been increasing, and the environmental situation is increasingly severe. Fig.2 shows the average pollutant emission index of Hunan Province from 2007 to 2017; it can be clearly seen that the pollutant emission index has decreased linearly after 2015, which is closely related to national policies. Fig.3 shows the average pollutant VOCs emission index of Hunan Province from 2007 to 2017; it can be seen that the pollutant VOCs emission index of Hunan Province is gradually expanding. Fig.4 shows the relationship between regional economic growth and VOCs emission measurement in Hunan Province. The coordination degree decreases first and then increases, indicating that the coordination degree between the environment and economic system in Hunan Province is gradually reduced and then gradually increased.



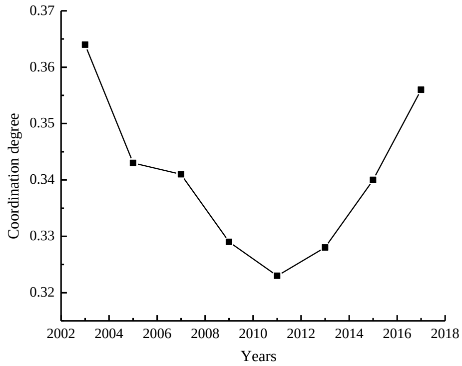
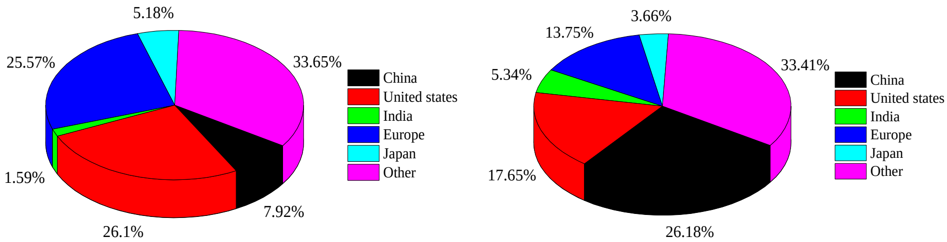


Figure 3: Hunan province average pollutant VOCs emission index 2007-2017

Figure 4: The relationship between regional economic growth and VOCs emission measurement in Hunan province

3. Decomposition of economic growth sources

3.1 EKC curve between VOCs emissions and economic growth



(a) 1997

(b) 2017

Figure 5: Proportion of VOCs emissions from major countries in the world in 1997 and 2017

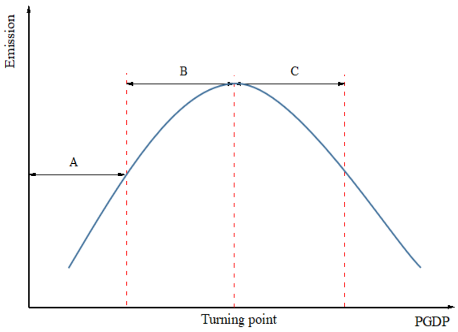


Figure 6: Environmental Kuznets curve

Fig.5 shows the proportion of VOCs emissions in the major countries across the world in 1997 and 2017. It can be clearly seen that the proportion of China's VOCs emissions has increased from 7.92% in 1997 to 26.18% in 2017, and the emissions of the United States and European countries have decreased. The famous environmental Kuznets curve hypothesis (EKC) describes the interaction mechanism between atmospheric pollutant emissions and economic growth. Fig.6 shows the environmental Kuznets curve. It can be seen that with the economic growth and resource consumption in the early stage, waste discharges also increase accordingly; when the economy grows to a certain stage, the industrial structural transformation is accelerated, people's awareness of environmental protection is enhanced, and waste emissions are reduced. The generation of EFK effect is related to market mechanism, international trade, scale effect and structural effect. The simplest detection model of atmospheric pollutant VOCs and economic growth is shown in formula 1:

$$\ln pvocs_{it}=\alpha+\gamma \ln pvocs_{it-1}+\rho W \ln pvocs_{it}+\beta_1 \ln pgdp_{it}+\beta_2(\ln pgdp_{it})^2+X\delta+\mu_i+\omega_{it} \quad (1)$$

$$\ln pvocs_{it}=\alpha+\rho \ln pvocs_{it-1}+\beta_1 \ln pgdp_{it}+\beta_2(\ln pgdp_{it})^2+X\delta+\mu_i+\varepsilon_{it} \quad (2)$$

$$\varepsilon_{it}=\lambda W\varepsilon_{it}+\omega_{it} \quad (3)$$

where, i is an individual unit, t is time, and μ_i is the fixed effect. Table 1 lists the basic statistical values of the corresponding raw data in Hunan Province.

Table 1: Basic statistical values of the corresponding indicators of Hunan Province

Variable	Unit	Indicator description	Mean value	Standard deviation	Minimum value	Maximum value
pvocs	Ton	Per capita VOCs emissions	5.106	3.229	1.226	22.814
pgdp	Yuan	Per capita GDP	16316	13150	2900	69346
intensity	—	Energy intensity	1.671	0.805	0.631	4.445
open	%	Openness to the outside world	34.999	42.777	3.606	179.815
sect	%	Industrial structure	46.064	7.602	23.007	60.022

3.2 Result analysis for decomposition of economic growth source

In the existing research, the economic growth mode has been divided into two types: extensive economic growth mode and intensive economic growth mode, which are measured by the input of production factors and the proportion of environmental consumption in the process of economic growth, involving five indicators such as output, labour input, domestic fixed asset stock, FDI stock and environmental consumption. Table 2 lists the statistical values of the five variables, where the environmental consumption proportion is based on the VOCs emissions; the FDI stock is estimated using the perpetual inventory method, namely:

$$fdi_t=fdi_{t}\text{-}1(1-\delta_t)+fdiflow_t \quad (4)$$

where: fdi is the FDI stock, and δt is the depreciation rate, taking the fixed value of 10.96%.

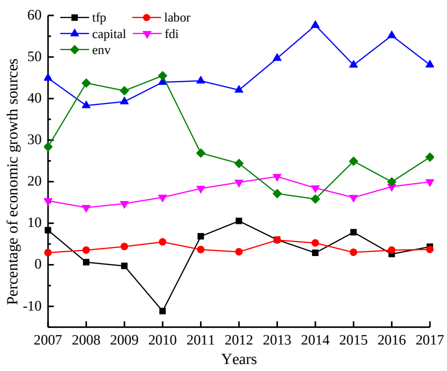


Figure 7: The trend of the source of economic growth in Hunan Province over time

Table 2: Descriptive statistics of each variable

Variable	Observations	Unit	Mean value	Standard deviation	Minimum value	Maximum value
GDP	500	Billion	613.68	605.661	22.277	3923.88
labor	500	Million	23.531	15.758	2.447	64.326
capaital	500	Billion	1113.726	1070.072	48.115	7040.14
fdi	500	Billion	109.052	164.06	0.755	844.838
VOCs	500	Thousand tons	729.31	460.66	20.13	2258.87

Fig.7 shows the trend chart for the decomposition of economic growth sources in Hunan Province over time. It can be seen that the growth rate of total factor productivity (tfp) to the economy is less than 10%, and the contribution rate of environmental consumption to economic growth is around 20%, also, the source of economic growth in Hunan Province comes from capital investment and environmental consumption.

4. Economic growth mode and pollutant emission control experiences

4.1 Environmental performance measurement

By establishing an environmental performance appraisal system to reduce the resource input and emission rate in the production process, environmental performance can be simply defined as the proportion of economic value added and environmental pressure value. The environmental performance over a period of time can be calculated by the following formula:

$$\text{Env-performance}' = \frac{v^t}{w_1 p_1^{'} + \cdots + w_n p_n^{'}} \quad (5)$$

Where v^t is the economic activity output increase over time, p' is environmental pressure, and w is weight.
The existing environmental performance measurement models include the traditional DEA model and the non-radial BML-DEA model. Considering the availability of data, the data of Hunan Province were used as the research samples, and the two indicators such as carbon dioxide emissions and industrial smoke dust emission were also included in the environmental pressure in addition to the VOCs emissions.

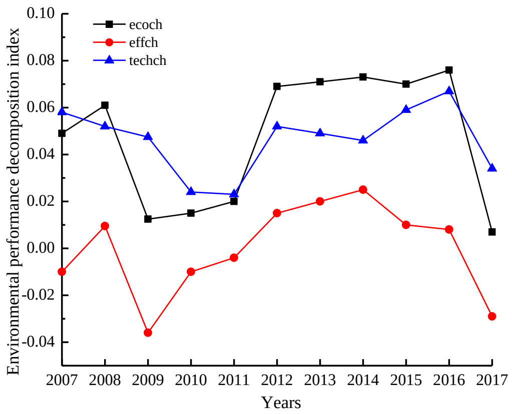


Figure 8: Industrial environment performance and decomposition index of Hunan Province from 2007 to 2017

Table 3: Each variable describes the statistical value

Variable	Unit	Mean value	Standard deviation	Minimum value	Maximum value
Industrial added value	Billion	293.336	3614.73	52.04	23032.04
VOCs	Ten thousand tons	59.10	38.80	1.68	175.09
CO_2	Billion tons	0.174	1.34	0.081	7.80
Smoker	Ten thousand tons	52.45	39.68	1.10	210.54

Table 4: The average environmental performance of Hunan Province

Traditional DEA model			Non-radial BML-DEA model		
ecoch	effch	techch	ecoch	effch	techch
0.024	0.003	0.021	0.025	0.006	0.018

Note: ecoch in the table represents the overall indicator of environmental performance; effch represents the efficiency change index; techch represents the technical change index

Table 3 shows description statistics of each variable; Table 4 is the average environmental performance of Hunan Province in two calculation models. By comparison, it is found that compared with the traditional EDA model, the non-radial BML-EDA model can solve the problem of no feasible solution. Fig. 8 shows the industrial environmental performance and its decomposition index of Hunan Province from 2007 to 2017. It can be seen that the improvement of environmental performance is mainly driven by technological progress.

The efficiency change index has shown a growth trend since 2009 and has become negative growth in 2017, indicating that emission reduction effect constrains the further growth of environmental performance.

4.2 Path selection for coordination Development between economic growth and pollutant VOCs emission control

Economic growth is not stereotypical. The developed countries such as the United States and the European Union are constantly adjusting their development models in the process of economic development, shifting from an extensive economic model to an intensive economic growth model. For China's economic growth model, we have been transforming traditional concepts and establishing a scientific growth concept; in addition, it's necessary to promote scientific and technological progress and independent innovation, and provide guarantees for transforming economic growth. The industrial structure should also be adjusted to achieve a fundamental change in the mode of economic growth, reduce the emission of pollutant VOCs, give full play to government functions, promote the scientific and green performance evaluation, and seek new channels for regional coordinated development according to local conditions.

5. Conclusions

This paper studies the mechanism of the relationship between the VOCs emission efficiency of atmospheric pollutants and the economic growth in Hunan Province, and also the measurement of the coordinated development of environment and economy. The specific conclusions are as follows:
(1) As the economy grows, resource consumption increases, and waste discharge increases accordingly; when the economy grows to a certain stage, the industrial structure transformation accelerates, people's awareness of environmental protection increases, and waste emissions decrease.
(2) The growth rate of total factor productivity (tfp) to the economy is less than 10%, and the contribution rate of environmental consumption to economic growth is around 20%. The source of economic growth in Hunan Province comes from capital investment and environmental consumption.
The improvement of environmental performance is mainly driven by technological progress. The efficiency change index has shown a growth trend since 2009 and has become negative growth in 2017, indicating that the emission reduction effect restricts the further growth of environmental performance.

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