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СОЦИО-ЭКОЛОГО-ЭКОНОМИЧЕСКАЯ ОЦЕНКА УСТОЙЧИВОСТИ В УПРАВЛЕНИИ РАЗВИТИЕМ РЕГИОНА НА ОСНОВЕ ЭКОНОМЕТРИЧЕСКОГО МОДЕЛИРОВАНИЯ¹

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В данной статье описаны результаты эконометрического моделирования устойчивости развития китайских регионов. В последние десятилетия в Китае наблюдался быстрый экономический рост. Но быстрый темп роста экономики не означает, что рост является устойчивым. Напротив, серьезные социальные и экологические проблемы назрели и требуют быстрого решения во многих районах Китая. Устойчивое развитие провозглашено во всех странах мира как тип социально-экономического развития, к переходу на который следует стремиться. В данном исследовании выявлены и обоснованы индикаторы, характеризующие состояние трех секторов региональной социо-эколого-экономической системы: экономики, окружающей среды и социальной сферы. С использованием выбранных индикаторов на базе данных, характеризующих состояние социальной, экологической и экономической сфер 31 провинции Китая в 2008 и 2017 годах построены и эмпирически верифицированы три эконометрические (множественные регрессионные) модели. На основании результатов моделирования проанализированы взаимовлияния трех секторов и даны рекомендации по мероприятиям, способствующим выходу на траекторию устойчивого развития.

Ключевые слова: устойчивое развитие, социо-эколого-экономическая оценка, эконометрическое моделирование, индикатор устойчивости, управление развитием региона.

SOCIO-ECOLOGICAL-ECONOMIC EVALUATION OF SUSTAINABILITY IN MANAGING REGIONAL DEVELOPMENT BASED ON ECONOMETRIC MODELING

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This article describes the results of an econometric modeling of the sustainability of the development of the Chinese regions. In recent decades, China has experienced rapid economic growth. But a fast pace of economic growth does not mean that growth is sustainable. On the contrary, serious social and environmental problems are ripe and require quick solutions in many areas of China. Sustainable development is proclaimed in all countries of the world as a type of socio-economic development, the transition to which should be sought. In this study, indicators are identified and justified that characterize the state of three sectors of the regional socio-ecological-economic system: economy, environment and social sphere. Using the selected indicators on the basis of a database characterizing the state of the social, environmental, and economic spheres of 31 provinces of China, three econometric (multiple regression) models were constructed and empirically verified in 2008 and 2017. Based on the simulation results, the mutual influences of the three sectors are analyzed and recommendations are given on measures that contribute to entering the sustainable development trajectory.

Keywords: sustainable development, socio-ecological-economic evaluation, econometric modeling, sustainability indicator, management of the regional development.

Introduction

With the rapid economic development, population growth and depletion of natural resources in China, sustainable development has been focused by both government and researchers. In 1983, the Brundtland Report defined sustainable development with the key element – the relation between environment and development. Since that, the definitions of sustainable development were discussed for many years.

To measure sustainable development is becoming a complex question [1-4]. Choosing proper 'sustainability indicators' turned out to be the crucial part when considering the sustainable development questions. In 1996, IISD reported the Bellagio principle, which is the method to evaluate sustainable development [4, 5]. According to C. Turcu, the definition of sustainable development is not widely accepted by most researchers, especially in those years [6]. Some new concepts and approaches have been promoted in giving the definition of sustainable development. The reduction of industrial emission plays a central role in the sustainable development of the global system [7]. Huang et al. improved the sustainable development indicating from a landscape ecology perspective [8]; Dhahri and Omri investigate the ability of entrepreneurial activity to three pillars of sustainable development [9].

The aim of this study is to analyze the sustainable development of 31 provinces in China. Considering there are three sectors of sustainable development, we try to figure out the exact correlation among those three sectors. By doing this study, we at first attempt to find suitable indicators from environmental, economic, social parts to evaluate China's sustainability at a province level. Second, based on those indicators we found to build three models. Using those three models, we could have quantity-level understandings of the relationship between economic system and environment; the relationship between environment and society; and the relationship between social and economic systems of 31 provinces in China.

Research methodology

To develop a deep analysis of sustainable development, sustainability indicators are the most important tools, which will simplify the regional system information. Harger and Meyer suggest that to compare and correlate actions undertaken in the environment, a scale of indicators is proved to be identified. And different measurements should be considered. Such as: simplicity, scope, quantification, assessment, sensitivity, timeliness [10]. Ness et al. provide that indicators are simple measures to represent a state of economic, social and environmental development in a certain region [11]. Based on a different benchmark, indicator sets could be sorted into different categories. One of the categories is based on the spatial level. Even though the country level indicators have been broadly researched, it is still a deficit about the details of regional information. So, the regional level indicators including more detailed information help better evaluate regional sustainable development [12].

Indicators are the most important part when analyzing sustainable development. How to choose indicators becomes a crucial step. In this paper, we focused on three parts of sustainability development – the economic section; the environmental and the social section. What indicators to select? Six general principles are used in choosing indicators for sustainable development. They are existence; effectiveness; freedom of action; security; adaptability; coexistence; psychological needs. Existence represents that the indicator should be able to exist in the environment, economic, social state. Effectiveness represents that the indicators should be effective to secure information of the environment, economic, and social. Freedom of action means that the indicators should have the ability to cope in different ways. Security indicates that the some variables could protect themselves from variability. Adaptability shows that the indicators should have the ability to learn, adapt and self-organize. Coexistence represents that the indicators could be modified to account for other systems. Psychological needs mean that human beings have psychological needs that must be satisfied. These seven principles are shown in Figure 1. In our research, we consider the existence, effectiveness, adaptability and coexistence.

Fig. 1. Principles of choosing indicators

The study used the cross-sectional data of China 31 provinces including three main parts: economic data, environmental and social data. Table 1 shows the indicators' name and the unit of each indicator. All data was received from the China Statistical Yearbook, China Energy Statistical Yearbook, China Environmental Statistical Yearbook. All the indicators were based on data in 2008 and in 2017. Here are some reasons that we choose 2008 and 2017 as the sample data: first reason to choose 2008 is economic crisis happened in this year. And it has seriously affected the economy of China. Second reason is that in 2008 China held the Olympic Games. This huge event influenced the economy, environment, and society of China. And the reason for choosing 2017 data is because the latest data could give us more intuitions and suggestions about the future policy making.

In order to better understand the relationship between three pillars of sustainability, we built three models to analysis the relationships. These three models cover economic, environmental and social sectors.

The first model focused on economic sector. There are many indicators related to economics: GDP, per capita GDP, consumption, income, CPI, etc. Researchers have done some research about the connections between those economic indicators and sustainability. For R&D indicator, there are large number of researches analyzing the causal relationship between R&D and economic growth. Take an example of UK growth: even a temporary cut to R&D funding still has a long-lasting impact on UK economic growth [13]. Swedish economists Edquist and Henrekson, concluded that R&D capital contributes to the economy growth increasing from 0.9 to 1.5 percentage points in 2017 [14].

Table 1

Sustainability Indicators

Indicator/Variable	Unit	Code
Province GDP	trillion yuan	gdp
Investment in pollution control	10000 yuan	polinv
Number of workers in R&D	10000 person	RDpop
The income difference between urban and rural	10000 yuan	incdif
Total volume of pollutants	10000 tons	Pollut
Number of people with education	person	Pedu
Areas of construction	10000 m ²	constrspace
Usage of electricity	million watts	eletri
Industrial solid wastes utilized	10000 tons	solwasuse
Regional GDP of primary industry	million yuan	Agri
Regional GDP of secondary industry	million yuan	ind
Number of private cars	10000 units	carN
Production of the second industry	10000 tons	indusprodu
Human Development Index		HDI
Per capita GDP	yuan	pergdp
Number of urban population	10000 person	urbpop
Natural growth rate	percentage	NgrowR

For urbanization indicator, recently, Liang and Yang, built a urbanization economic growth model evaluating the urbanization, economic growth and environmental pollution [15]. Some other studies focused on different aspects of economic growth; income distribution is a crucial part of social sustainability. Environment can affect the economy and the income distribution can have influence for unemployment rate [16].

GDP was selected as a dependent variable to measure the situation in economic section. Figure 2 shows the difference of GDP between 2008 and 2017. We used different kinds of pollutants – SO_2 , CO_2 , PM , solid waste, and waste water as indicators to measure the environmental sector situation. After checking the correlation between those indicators with the GDP, we created one indicator to make the model easier. The new indicator consists of all the pollutants mentioned above. And we used this new indicator to evaluate the environmental conditions.

In the first model, four variables were selected to measure the social sustainability. They are urban population, number of workers in R&D, income difference between urban and rural area, and the number of people with high school and higher education. Three reasons were to choose these four variables. 1. Urbanization will promote the economical development, at the same time it will also bring some environmental problems and social affairs, so urbanization is a highly important indicator to check the relationship between economy, environmental, and social. And one remarkable problem caused by the urbanization is the inequality of income distribution between the urban and the rural area. So, besides the urbanization level variable, we also have chosen another related variable – income difference variable as an indicator to measure the social sector. 2. Industry structure is an important to both environment and economy (especially the rate of high-tech industry). Number of workers in R&D industry is a powerful indicator to announce the structure of the R&D industry in the economy. 3. Education level is another crucial indicator which would influence the economy, and increase people's awareness of environmental protection.

Fig. 2. The regional GDP of 2008 and 2017

Based on three reasons, we could assume that selected four variables could give a comprehensive estimation of the social and environmental sectors. The model represents as following:

$$GDP = \alpha + \beta_1 urbpop + \beta_2 polinv + \beta_3 RDpop + \beta_4 Incdif +$$

$$+ \beta_5 Pollut + \beta_6 Pedu + \varepsilon;$$

$$Pollut = SO_2 * 10 + CO_2 * 10 + \frac{WAT}{100} + \frac{SOL}{10} + \frac{PM}{100} \quad (1)$$

The second model focused on environmental sector. Previous studies give us a broad way to consider the indicators for environmental sustainability. Power industry has a dominant influence on the environment conditions [17]; Solid waste is a considerable part of pollution. Solid waste has complexity characteristics. Government and private organizations make efforts to control it and create comprehensive solid waste management program [18]. At a national scale, agricultural industry does not produce such great amount of pollutants as from other sectors [19]. But the pollutants produced by agricultural sector are usually ignored. Because of this the agricultural pollution will cause serious problems. Much more researches concerned with secondary industry. Industrial activities have negative effects on the environment, especially because the pollutant emission to the air. Study from China shows that optimizing industrial structure will reduce the pollutant emissions of CO_2 , SO_2 , NO_x significantly [20]. Another contributor to pollution is cars. Especially diesel cars have great effects on the NO_2 polluting emissions [21].

$$Pollt = \alpha + \beta_1 electi + \beta_2 solwasuse + \beta_3 Agri + \\ + \beta_4 ind + \beta_5 carN + \beta_6 indusprodu + \varepsilon \quad (2)$$

Fig. 3. The regional level of pollution of 2008 and 2017

Considering previous studies, pollutant indicator in model 1 as the second model's dependent variable to assess the environment sector has been used. And in the second model, we focused more on how the developing economy affects the environmental pollution. Therefore, we choose four variables to adjust the economy. They are total volume of electricity usage, the GDP of primary industry, the GDP of secondary industry, and the total number of cars. Besides, there are two environmental variables. The first one is the volume of the solid waste being used, and another one is the volume of industry production staffs. The industry production variable is calculated by two kinds of energy productions: coal, natural gas; and another two kinds of industry productions: cement and steel. So this variable is calculated by using data of coal, natural gas, cement and steel producing volume.

The third model targets to social sector. For social sustainability, the fundamental problem is the economic inequality. Because of the inequality, other social problems appear. Such as poverty and undernutrition, health, education, etc. [22]. Human development index (HDI) score was used as the dependent variable for the third model. Measuring social sustainability using this index implies a reflection of the situation in the fields of education and health. There are four indicators taken into considering: life expectancy at birth, expected and mean years of schooling, GNI per capita. Based on the dependent variable of HDI, the third model to measure the social section was created (formula (3)).

$$HDI = \alpha + \beta_1 pergdp + \beta_2 Pollut + \beta_3 polinv + \beta_4 urbpop + \beta_5 NgrowR + \varepsilon \quad (3)$$

Results and discussion

The OLS regression models were used to analyze the relationships among economic, environment, and social sectors.

For the first model, the results of modeling the situation in 2008 show that the process of urbanization, the number of workers employed in R&D, as well as the volume of environmental investments have a positive impact on the economy of the region. The indicator of the level of environmental pollution does not significantly affect the state of the economic system in the region.

Fig. 4. The Regional HDI score of 2008 and 2017

The results of the assessment of the regression model based on the 2017 information demonstrate a significant positive impact on the economy of the region of three explanatory variables – the number of urban population, the difference in incomes between the city and the village, the number of R&D employees, as well as the significant factor impact (10% significance level) of variables reflecting the state of the ecological sphere of the region (negative – the level of environmental pollution of various types of waste, positive – the volume of environmental investments). The obtained assessment of the dependence of GRP on the number of educated people needs explanation. The influence of this variable is negative (5% significance level), which can be explained by the not high enough return on a person's investment in higher education at its high cost, but it requires further research.

The results in Fig. 5 show that an increase in the level of urbanization will lead to an increase in GDP and will contribute to more sustainable economic development. We can also find that the environmental pollution shows a negative effect on the economy. And putting more investment in the pollution control will not only promote the environmental conditions, but also will establish economic growth.

Another important result is the assessment of the effect on the value of GDP of the difference in the distribution of income between urban and rural population. The result shows that the greater the difference in the distribution of income, the higher the level of development of the economy. This assessment reflects the actual situation. But, from the point of view of sustainability of socio-ecological-economic development, a policy of reducing income inequality is needed, the main effect of which should be considered to improve the quality of the social environment in the region.

VARIABLES	(1) m1 gdp	(2) m2 pollut	(3) m3 HDI
constrspace		0.00507 (0.00819)	
eletri		1.342* (0.764)	
solwasuse		0.0360 (0.103)	
Agri		0.774** (0.311)	
ind		0.00176 (0.120)	
carN		0.145 (1.318)	
indusprodu		-0.0127 (0.0659)	
urbpop	2.938** (1.102)		-2.57e-06 (8.30e-06)
polinv	0.0126** (0.00518)		-4.96e-10 (3.31e-08)
RDpop	0.0825*** (0.0211)		
incdif	0.395** (0.167)		
pollut	0.236 (0.566)		1.00e-05 (7.74e-06)
Pedu	1.04e-05 (0.00152)		
pergdp			0.0261*** (0.00673)
NgrowR			-0.00353 (0.00282)
Constant	-3.930** (1.731)	445.4 (300.2)	0.697*** (0.0207)
Observations	30	30	31
R-squared	0.978	0.880	0.709

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Fig. 5. The results of modeling 2008

A comparison of the modeling results on the information base of 2008 and 2017 years demonstrates that the level of urbanization, the volume of environmental investments and the number of people employed in R&D have a positive impact on economic growth. The biggest regression coefficient has an explaining variable, characterizing level of urbanization and, appropriately, the GRP value in the most degree depends on this indicator. As regards the level of environmental pollution, this variable is characterized by a negative influence on the GVP value (model on the 2017 information basis). Thus, this result indicates the need for state environmental policy, the purpose of which is to combat pollution of the natural environment.

According to the results of constructing a model reflecting the situation in the region's ecological sector in 2008 and 2017, one can see a positive effect on the level of environmental pollution (at a significance level of 10%) of such factor variables as electricity use, areas of construction, regional GDP of primary and secondary industry (the influence of the first significantly exceeds the influence of the second), as well as the number of private cars.

From the results presented in fig. 5 and 6, it can be seen that, firstly, the agricultural industry has a more serious impact on the level of environmental pollution than the secondary industry. Over the past few years, the Chinese leadership has recognized the need to solve serious problems associated with high levels of environmental pollution. Certain environment-friendly measures have been taken, for example, to transform the structure of industry; reducing the industrial use of fossil fuels and replacing it with environment-friendly energy sources; etc.

VARIABLES	(1) m1 gdp	(2) m2 pollut	(3) m3 HDI
constrspace		-0.0107*** (0.00241)	
eletri		1.119*** (0.355)	
solwasuse		0.538 (0.327)	
Agri		0.379** (0.165)	
ind		-0.0463 (0.0505)	
carN		1.733* (1.005)	
indusprodu		-0.0127 (0.0206)	
urbpop	8.815*** (1.376)		2.24e-06 (4.64e-06)
polinv	0.0103*** (0.00315)		2.32e-08 (1.92e-08)
RDpop	0.0782*** (0.0171)		
incdif	0.250** (0.108)		
pollut	-1.140* (0.565)		-4.18e-07 (5.06e-06)
Pedu	-0.000487** (0.000225)		
pergdp			0.0151*** (0.00172)
NgrowR			-0.00454*** (0.00196)
Constant	-3.199 (2.714)	471.2 (321.8)	0.674*** (0.0157)
Observations	31	31	31
R-squared	0.984	0.908	0.782

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Fig. 6. The results of modeling 2017

But most activities are concentrated in the secondary industry. From this study, we recognize that not only the development of the secondary industry will cause serious environmental pollution problem, the agricultural industry will have a more serious impact on the environment. Secondly, we can find that the regression coefficients for the factor variables "Usage of electricity" and "Number of private cars" characterize the rather significant influence of these indicators on the dependent variable. Thus, environment-friendly modernization of the electric power industry and the transport (automobile) industry are becoming central elements of the policy of sustainable spatial development of the Chinese economy. It is necessary, in particular, to use renewable energy sources for generating electricity, as well as to increase the efficiency of the existing level of electricity conversion.

Similar solutions are necessary for the transport system, in particular, the development of the public transport system, which may contribute to a certain reduction in the number of private cars, as well as stimulating the transition to the use of electric vehicles. Comparison of the modeling results according to the data of 2008 and 2017 also showed that if in 2008 the contribution of the variable "Number of private cars" to the level of environmental pollution was relatively small, then in 2017 it is quite significant, which once again confirms the relevance and importance of environment-friendly political measures.

An econometric assessment of the degree of dependence of the Human Development Index on factors influencing it revealed a significant effect of two explanatory variables – GDP per capita (according to both 2008 and 2017) and the number of urban population (as of 2017). Moreover, variables reflecting the state of the environmental sphere do not significantly affect the value of the human development index. You can indicate the reason for this result: the dependent variable that we selected – the human development index, mainly reflects the state of the socio-economic system of the region and, to a lesser extent, the state of the environmental sphere. Moreover, the indicator of the average life expectancy at birth, included in the calculation of the index, although it depends on the cleanliness (level of pollution) of the environment, however, with the development of technologies and the health care system, this dependence decreases.

Conclusion

Sustainable development is a development that not only satisfies the needs of the current generation, but also takes into account the well-being of future generations. Thirty years have passed since the first steps were taken to move the global society and individual countries to a sustainable development strategy. In recent years, Chinese President Xi Jinping and the Government have been targeting the People's Republic of China on a sustainable development strategy. However, just adopting the concept is not enough to maintain the sustainability of the socio-ecological-economic development of the country and its individual regions. We need real government adjustment to ensure the construction of a sustainable development society.

The results of this study, namely: the developed economic, environmental,

and social indicators and three econometric (correlation-regression) models allowed us to advance in understanding the relationships between three sectors (economic, environmental and social) on the path to transition to China's sustainable spatial development strategy.

The simulation results demonstrate a statistically significant effect of the level of urbanization, the difference in incomes between the city and the village, the number of R&D employees, not only on the level of economic development of the regions, but also on the state of spatial ecological systems. They also made it possible to quantify the degree of the inverse effect of indicators of the state of ecological regional systems on the economy.

Environmentally-oriented modernization of the electric power industry and the transport (automobile) industry are becoming central elements of the policy of sustainable spatial development of the Chinese economy. It is necessary, in particular, to use renewable energy sources for generating electricity, as well as to increase the efficiency of the existing level of electricity conversion.

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