A Case Study of Driving Factors of Beijing's Ecosystem Service Value Changes Based on Spatial Durbin Model

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Abstract

Since the "the 13th Five-Year Plan for Economic and Social Development of the People's Republic of China" in Beijing, the overall environmental planning has been carried out. Research on the driving factors of ecosystem service value can reflect the important factors affecting the area and surrounding areas, and provide focus for future policies. In order to study the driving factors of changes of Beijing's ecosystem service value (ESV), this paper selects data from 16 counties and districts in Beijing in the four phases of 2010, 2013, 2015, and 2018, and analyzes ecological services by constructing the spatial Durbin model (SDM). The influence of time and space factors in the area of value change. Research shows that: (1) On the whole, the improvement of the economic environment of all counties and districts in Beijing has a spatial spillover effect on the ecosystem service value. Changes in economic and environmental factors in each region will affect changes in the value of ecological services in the surrounding areas. (2) Social security, energy consumption ratio and gross domestic product are all important factors for the changes in the ecosystem service value in the region, while the industrial structure, greening rate, social security, arable land area, energy consumption ratio, and environmental expenditure can radiate ecosystem service value in the surrounding area and also are key elements to enhance the ecosystem service value. In the future, a systematic framework of influencing factors should be established, and related variables should be handled more refined.

Keywords: *Spatialdurbin model, spatial spillover effects, ecosystem service value, driving factors*

I. Region Overview and Literature Review

Beijing is located in the northern part of the North China Plain, between 115.7°-117.4°E east longitude and 39.4°-41.6°N north latitude, backed by the Taihang Mountains, with a total area of 16,410 square kilometers. The value of Beijing as a research area is based on its complex and diverse topographical and climatic conditions, the different development levels of various internal regionsand the research value of the capital's strategic center. The complexity of its topography and climate is reflected in the fact that Beijing borders the Taihang Mountains in the west and the Yanshan Mountains in the north. The height difference between mountains and plains is nearly one thousand meters. It runs through five water systems from west to east. The rich topography and landform affect the regional distribution and radiation of precipitation.The difference makes Yanqing and Huairou become radiation-rich areas. At the same time, there are significant development differences between the various regions within Beijing: the total output value of the four core development zones of Dongcheng District, Xicheng District, Chaoyang District, and Haidian District in the inner ring exceeds the total output value of other districts. In the planning of the 19th National Congress of the Communist Party of China to build a road map for ecological civilization construction and green development, combined with the comprehensive analysis of environmental conditions and economic conditions, it is necessary to find out the driving factors for the improvement of Beijing's ecological environment and to find the right direction for policies and the important path of economic development with ecological construction as its role as a model in the capital.

In fact, since the concept of "Global Ecosystem Service Value and Natural Capital" published by Costanza in Nature in 1997, a large number of domestic scholars have conducted research on it. In 2015, XieGaodi [1] used the sown area of rice, wheat and corn to measure the value equivalent factor per unit area based on the classification of his research, and successfully realized the value of 14 ecosystem types and 11 types of ecological service functions in China through the equivalent factor method with dynamic comprehensive assessment on time (monthly scale) and space (provincial scale); Zheng Defeng [2] used the two perspectives of total and intensity to improve the calculation of the ESV conversion factors, and re-derived the service value equilibrium factors of cultivated land, woodland, grassland, wetland, water area and unused land, and constructed green GDP; Wei Xiaojian [3] added the interference effect of urban expansion into the original calculation model, and successfully calculated that the change in the ecosystem service value caused by urban expansion would be greater than the calculation result of the change in the ecosystem service value before the improvement. Guo Aijun [4] analyzed the consistency of ecosystem service value and economic growth at the same time and space scale with the ecological economic coordination model, and concluded that the change of total ecosystem service value and unit ecosystem service value of the Yellow River Basin showed a "U" pattern. Li Xiang [5] discusses the differences between different groups of people in the cultural services of the green space ecosystem in the form of payment cards. A large number of studies have shown that the ecosystem service value calculation method based on the improvement equivalent factor has been mature, and the method has been appropriately improved according to the local reality, and the change of the ecosystem service value can be measured in different research backgrounds.

The spatial Durbin model is widely used in finance, infrastructure, industrial structure and environmental research. Huang Jianhuan [6] analyzed the four mechanisms by which financial development affects regional green development through the combination of green development measurement and spatial Durbin model; Zhu Yuxin [7] analyzed the temporal and spatial evolution characteristics and driving factors of the environmental and economic coordination index by constructing an economic environment coordination degree between the value of ecological services and per capita GDP; Hu Peiqi [8] studied the spatial Durbin model of the degree of air pollution by the three industrial agglomeration levels in Beijing, Tianjin and Hebei, and made it clear that industrial agglomeration has obvious direct and spatial effects on urban air quality; Ran Qiying [9] used the spatial Durbin model and the Moran index to prove the "V" characteristics of the competition of local governments at all levels in environmental pollution governance under environmental decentralization; Ma Bingying [10], Hao Shushuang [11], and Jin Fang [12] all applied the spatial Durbin model to environmental analysis, observing the changes in agricultural industrial structure and human activities and other factors to analyze the changes in environmental factors in their regions. At the same time, Federico Belotti [13] believes that the method of comparing fixed effects and random effects in the spatial weight matrix in Stata will cause the test to be inconsistent. It is more credible to compare the models by generating coefficients in the random effects. As can be seen from this, the application range of the spatial Durbin model is extremely wide, and it can explore the element connections within the spatial range under various themes, and find important driving factors through analysis and comparison between the local and the whole.

At present, exploring the spatial spillover effect of ecological service value through spatial measurement model is a kind of research idea, which aims to explore the influencing factors of ecological service value changes, especially the driving factors, from the perspective of holistic regional cooperation. Based on this point, this article makes further refinement and classification of variables, especially enriching the types of variables, selecting a variety of different economic entities, including industry and agriculture, population, finance, and so on. A system of economic influence variables has been initially constructed.

II. Research Design

2.1 Index selection

The research samples in this paper are 16 districts (counties) in Beijing, and the time periods are 2010, 2015 and 2018. Among them, land use data and other economic data are derived from the *Beijing Statistical Yearbook* and *Beijing Regional Statistical Yearbook.* The variables are shown in Table 1.

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Table 1 Variable

Variable type	Variable code	Variable name	Unit
Dependent variable	ESV	Ecosystem service value	Yuan per square kilometer
Independent variable	GDP	Gross domestic product	100 million yuan
	Pop	Population	Ten thousand people
	IndPer	Proportion of industrial output	percentage
	BP	Medical beds per thousand people	Piece
	DI	Urban disposable income	Yuan
	GR	Greening rate	percentage
	PA	Agricultural planted area	Hectares
	DE	Decrease rate of energy consumption	percentage
	EI	Environmental Investment	Ten thousand Yuan

Among them, ecosystem service value (ESV) refers to the benefits that humans obtain directly or indirectly from the ecosystem in order to survive or improve the quality of life [14]. The calculation of its value can reflect the situation of the regional ecological environment and has important guiding significance for maintaining the regional ecological security. Agricultural planting area, greening rate, energy consumption reduction rate and environmental fiscal expenditure are important factors that directly affect the overall environmental level [15].

2.2 Model design

This paper combines the treatment methods of Xie Gaodi [16] and others, and draws on the existing research results, and calculates the net profit of food production per unit area of farmland ecosystem as ESV of a standard equivalent factor. Based on 2010 data, ESV (yuan/hm^2) of a standard equivalent factor is 3406.5 yuan/hm2, and the ratio of the grain output per unit area of the study area to the national grain output per unit area is adopted, which is a relatively mature method to determine Beijing's correction factor. The formula is as (1), where f is the grain output per unit area of Beijing, and F is the national grain output during the same period. The correction coefficient for calculating Beijing is 1.034.

$$\alpha = \frac{f}{F} \tag{1}$$

$$\mathrm{ESV} = \sum_{K=1}^{6} A_K \times VC_K, K = 1,2,3 \cdots \tag{2}$$

$$\mathrm{ESV}_N = \sum_{K=1}^{6} (A_i \times VC_{NK}), K = 1,2,3 \cdots \tag{3}$$

In formula (2), ESV is the ecosystem service value; A_K is the area of land use type K; VC_K is the ecosystem service value coefficient of land use type K; ESV_N is the value of the Nth service function of the ecosystem; formula (3)VC_{Nk} is the value coefficient of the Nth service function of land use type K.ESV calculation results are shown in Table 2.

Table 2 Shows the calculation results of ESV of each district in Beijing

district	Year	ESV	Year	ESV	Year	ESV	Year	ESV
Dongcheng District	2010	60269682181	2013	0	2015	0	2018	0
Westcheng District	2010	7502603.914	2013	0	2015	0	2018	0
Chaoyang District	2010	2138055083	2013	1.82E+08	2015	1.92E+11	2018	2.08E+11
Fengtai District	2010	0	2013	1.54E+08	2015	1.75E+11	2018	1.82E+11
Shijingshan District	2010	40712780756	2013	62785902	2015	7.94E+10	2018	7.9E+10
Haidian	2010	1013184481	2013	3.03E+08	2015	3.64E+11	2018	3.66E+11

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District								
Mentougou District	2010	6773586913	2013	2.04E+09	2015	2.61E+12	2018	3.15E+12
Fangshan District	2010	87162407161	2013	7.35E+08	2015	6.45E+11	2018	2.62E+12
Tongzhou District	2010	42556117117	2013	8.62E+08	2015	8.28E+11	2018	6.47E+11
Shunyi District	2010	98479690234	2013	1.59E+09	2015	1.97E+12	2018	8.64E+11
Changping District	2010	16625528150	2013	6.72E+08	2015	5.31E+11	2018	2.02E+12
Daxing District	2010	1957764194	2013	2.34E+09	2015	3.15E+12	2018	5.45E+11
Huairou District	2010	9165630601	2013	3.7E+09	2015	4.76E+12	2018	4.77E+12
Pinggu District	2010	2385971127	2013	1.02E+09	2015	1.24E+12	2018	1.24E+12
Miyun District	2010	0	2013	3.77E+09	2015	4.65E+12	2018	4.67E+12
Yanqing District	2010	66199752738	2013	3.31E+09	2015	4.12E+12	2018	4.11E+12

The spatial weight matrix depicts the spatial correlation of each variable, and its distance will affect the degree of mutual influence of the variables. The spatial weight matrix W of is a standardized 16×16 (0-1) geographic adjacency matrix, that is, if there is a border between two regions, it is 1, and the opposite is 0. Its matrix elements are as follows:

$$W_{ab} = f(x) = \begin{cases} 1, a\ is\ adjacent\ to\ b \\ 0, a\ isn't\ adjacent\ to\ b \end{cases} \quad (4)$$

In order to eliminate the influence of different dimensions on the results of the spatial Doberman model, this paper preliminarily adopts logarithmic standardization for the four years of 2010, 2013, 2015, and 2018, and introduces a spatial measurement model. The selection of these four time points is based on the “Twelfth Five-Year Plan” of Beijing’s environmental planning, and the period to the “Nineteenth National Congress” is the main time period. Through the four nodes of pre-implementation, pre-implementation, mid-implementation, and the new period, the impact of the "Twelfth Five-Year Plan" on Beijing's environmental planning and the causes of environmental changes are analyzed. In terms of policy orientation, the 2011 "Beijing’s Environmental Protection and Construction Plan for the Twelfth Five-Year Plan" began to require all counties and districts to implement the environmental protection and construction in the Twelfth Five-Year Plan. In the same year, Beijing accelerated the transformation of its economic development mode, carried out self-inspection of the implementation of nine environmental protection measures, and focused on the investigation of various pollution treatments. In 2018, the *Opinions of the Beijing Municipal People's Government of the Beijing Municipal Committee of the Communist Party of China on Comprehensively Strengthening Ecological Environmental Protection and Resolutely Fighting Beijing's Pollution Prevention and Control Strategy* put forward a guiding outline, expounding the measures that should be taken for ecological environmental protection from various angles such as norms, principles and methods. By observing the relevant policies before, during and after the implementation of the three times, it can be analyzed which factors have the greatest impact on ecological protection and construction under the policy guidance. The difference between the spatial measurement model and the ordinary measurement model is whether spatial effects are introduced. Compared with the latter, the former emphasizes the regional difference of data and the regional dependence of cross-sectional dimensions, and conducts sequential analysis in each time and space dimension, which include Spatial Durbin Model(SDM), Spatial Autoregressive Model(SAR) and Spatial Error Model(SEM).

$$Y_{it} = \delta W \ln Y_{it} + \alpha \ln X_{it} + \mu W \ln X_{it} + \varepsilon_{it} \quad (5)$$
$$\varepsilon_{it} = \theta W \varepsilon_{it} + \varphi_{it} \quad (6)$$

In the formula(5), Y_{it} is the explained variable in the spatial measurement model, representing the ESV of the i district (county) in year t; $\ln X_{it}$ is the dimensionless explanatory variable; *W* is the spatial weight matrix established based on the distance function, α is the regression coefficient of the explanatory variable, μ is the spatial overflow coefficient, and ε_{it} is the random error term. φ_{it} is the random error term of the normal distribution, and θ is the spatial autocorrelation coefficient of the random error term. $W \ln Y_{it}$ is the intersection of spatial weight and dimensionless explanatory variable, $W \ln X_{it}$ is the intersection of spatial weight and dimensionless explanatory variable, $W\varepsilon_{it}$ is the intersection of space weight and random error term.

Among them, when θ=0, δ and μ are all non-zero, formula (5) is the SDM model; when δ≠0 and μ=0, formula (5) is the SAR model; When θ≠0 and δ=0, formula (5) is the SEM model.

The test results are shown in Table 3.In both the LR test and the Wald test, the model passed the 1% significance level test, proving that the SDM model will not degenerate into the SAR model and the SEM model. The Hausman test passed the 1% significance level test.

Table 3 LR test, Wald test and Hausman test results

LR Test		Wald Test	Hausman Test
Likelihood-ratio test	LR chi2(8) =41.80	chi2(8) =66.12	chi2(9) = (b-B)'[(V_b-V_B)^(-1)](b-B)=461.84
(Assumption: sar_a nested in sdm_a)	Prob > chi2 = 0.0000	Prob > chi2 = 0.0000	Prob>chi2 =0.0000
Likelihood-ratio test	LR chi2(8) = 41.85		
(Assumption: sem_a nested in sdm_a)	Prob > chi2 = 0.0000		

III. Regression Analysis

This paper uses the SDM model to analyze the driving factors of the change of ESV based on the stata15.0 measurement software. The results are shown in Table 4 and calculates the OLS regression model for comparison (Table 5).

Table 4 Regression results of SDM model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variables	Main	Wx	Spatial	Variance	LR_Direct	LR_Indirect	LR_Total
Ln_GDP	5.834*	-14.969			7.658**	-13.499*	-5.841
	(0.07)	(0.12)			(0.02)	(0.06)	(0.46)
Ln_IndPer	1.987	-78.240***			9.604	-63.866***	-54.263***
	(0.81)	(0.00)			(0.24)	(0.00)	(0.01)
Ln_DI	10.879	-74.331***			20.144	-63.505***	-43.361***
	(0.28)	(0.00)			(0.10)	(0.00)	(0.00)
Ln_BP	7.060**	19.728***			5.492*	12.861***	18.353***
	(0.01)	(0.00)			(0.05)	(0.01)	(0.00)
Ln_Pop	-1.393	-5.037			-0.933	-3.734	-4.667
	(0.61)	(0.55)			(0.75)	(0.59)	(0.47)
Ln_PA	-0.389	27.800***			-3.014	22.390***	19.376***
	(0.88)	(0.00)			(0.20)	(0.00)	(0.00)
Ln_GR	-2.956	75.588***			-10.162	62.386***	52.225**
	(0.71)	(0.00)			(0.18)	(0.00)	(0.01)
Ln_DE	-4.174***	-19.487***			-2.528*	-13.667***	-16.196***
	(0.01)	(0.00)			(0.10)	(0.00)	(0.00)
Ln_EI	-0.043	-5.264**			0.588	-4.165*	-3.577*
	(0.97)	(0.05)			(0.60)	(0.06)	(0.06)

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rho			-0.472**				
			(0.02)				
sigma2_e				9.210***			
				(0.00)			
Observations	64	64	64	64	64	64	64
R-squared	0.114	0.114	0.114	0.114	0.114	0.114	0.114
Number of code	16	16	16	16	16	16	16

Robust pval in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5 Regression results of OLS model

	(1)
Variables	Ln_ESV
Ln_GDP	2.113
	(0.17)
Ln_IndPer	2.827
	(0.33)
Ln_DI	0.463
	(0.94)
Ln_BP	2.710
	(0.29)
Ln_Pop	-0.740
	(0.77)
Ln_PA	0.666
	(0.11)
Ln_GR	7.746**
	(0.01)
Ln_DE	0.244
	(0.88)
Ln_EI	0.618
	(0.57)
Constant	-42.487
	(0.42)
P	0.00***
Observations	64
R-squared	0.446

Robust pval in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In Table 4, the estimated value of the spatial autocorrelation coefficient is -0.472, and its estimated value has passed the 5% significance level test, indicating that the improvement of the economic environment in a single county will not only affect the change of ESV of the county, but also at the same time, its effect will generate radiation to surrounding counties, and the spatial spillover effect is obvious.

In SDM Model, among the variable coefficients that directly affect the region, GDP, the number of beds per 10 thousand people and the reduction rate of energy consumption per 10,000 yuan have passed the significance level tests of 10%, 5%, and 1% in turn. Among them, the correlation coefficient between GDP and the number of beds per capita is positive, and the average marginal contribution rate is 5.834 and 7.06 respectively. That is to say, under the circumstance that other conditions remain unchanged, an average increase of 100 million yuan in GDP can increase the ESV of the county by 5.834 units; an average increase of one bed per 10,000 people can increase the ESV of the county by 7.06 units. For each region in Beijing, the gross product value and social security can play a significant role in the construction of ecological protection. Economic production has become an important basic condition for ecological construction. A reasonable production model and structure can better balance the needs of economic development and green development, and social security can effectively upgrade consumption patterns, which means the way of consumption tends to be more rational, and more consideration is given to the harmony between humans and ecology. On the contrary, the decrease in energy consumption has caused a decrease in ESV. An average increase in the rate of decrease in energy consumption per 10,000 yuan will result in a decrease in the ESV of the county by 4.174 units. This is a relatively special phenomenon, and its possible explanation is the lag of investment benefits and the improvement and upgrading of industrial structure. The hysteresis of investment benefits means that the investment benefits of energy consumption reduction cannot be quickly highlighted under the influence of many factors, and the main body of its direct effect is not the land but the atmosphere. The impact on ESV often requires years of continuous effective investment to achieve significant results, and these impacts on changes in the value of ecological services are more indirect, and it is difficult to have extremely significant benefits in a relatively short period of time. However, it is obviously unreasonable to deny that investment in this area has an effect on ecological improvement.

Regarding the second point, since China is in the stage of changing development thinking to the implementation of development mode during this period, the adjustment of the original industrial structure cannot be realized in the short term, and the original industrial structure has a strong inertia. This can be proved especially after observing that the proportion of the secondary industry has an inhibitory effect on ESV in surrounding areas.

Among the variable coefficients that directly affect the surrounding area, the proportion of the secondary industry, the urban per capita disposable income, the number of beds per capita, the agricultural planting area, the urban greening rate, and the reduction rate of energy consumption per 10,000 yuan all pass the 1% significance level test, environmental fiscal expenditures pass the 5% significance level test. Judging from the positive and negative values of the coefficients, the increase in the number of beds per capita, agricultural planting area, and urban greening rate will increase the ESV of surrounding counties and districts. It means that the increase in social security, greening rate and planting area can effectively radiate to surrounding counties and districts, improving the value of ecological services in surrounding counties and districts, especially the efficiency of improving greening rate, whose average increase of one percentage point can increase the ESV of surrounding counties by 75.588 units. The increase in the proportion of the secondary industry, environmental expenditure, urban per capita disposable income and energy consumption per 10,000 yuan in this county will inhibit the increase in ESV in surrounding counties. The impact of the proportion of the secondary industry and the decline in energy consumption is the same as mentioned above. The negative effects of the original industrial structure on the environment cannot be achieved from negative to positive in a short-term adjustment of the industrial structure due to strong inertia. Among them, what we need to focus on is that the inhibitory effect of environmental investment on the surrounding area and the effect of the region are not obvious. The increase in environmental investment in this county will cause a decline in the value of ecological services in surrounding counties. There are also two possible explanations-insufficient coordination and diversification of investment entities. The lack of coordination is that the perspective of environmental investment in the county is focused on the environmental improvement of the county, lacking a holistic vision, and lack of interaction and communication with the ecological protection actions of the surrounding counties. The effect of the protection action is reversed to the surrounding counties and districts; The diversification of investment subjects makes environmental expenditures lack of targeted investment direction. The subjects of governance include forest land, air, etc., and governance activities include pollution control, environmental publicity, infrastructure construction, and so on. Too much consideration and lack of concentration can lead to governance results that may not be obvious.

If the overall spatial spillover effects of the SDM model are decomposed into direct effects and indirect effects, the direct effects reflect the impact of each explanatory variable on the changes in the ecological service value of the county, and the indirect effects reflect their impact on the ESV changes in the surrounding counties. From the point of

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view of the coefficients, the direct effect and the indirect effect are consistent with the two coefficients of each variable. The more particular one is that the effect of GDP is not significant on the whole. The indirect effect is inconsistent with the significance of the indirect coefficient. It can be considered that to a certain extent, the gross product value can affect the ecological service value of the county and surrounding counties, but when the threshold is exceeded, the impact will be more concentrated in the county, and the impact on surrounding counties and districts can be ignored.

IV. Conclusions and Recommendations

Based on the above analysis results, it can be concluded that the major driving factors that affect the increase of Beijing's ESV are social security level, urban greening rate, and cultivated land protection. The development level can also increase the ESV to a certain extent and become the driving factors. At the same time, the governments of counties and districts in Beijing need to realize that the development method of the county and district will not only affect the environment of the region, but also affect the surrounding counties and districts. On this basis, each government needs to coordinate the development policies of the surrounding counties and districts under the overall framework while concentrating the main forces in their own construction, and formulate development policies based on the actual economic and ecological conditions of the county and district. In terms of policy details, it is necessary to focus on the development of agriculture and forestry, increase the greening rate, protect the lives of the people, adhere to the development concept of "green water and green mountains are golden mountains and silver mountains", and achieve regional cooperation for ecological improvement through industrial transformation; [17] At the same time, it is necessary to pay attention to the balance of short-term environmental investment benefits and long-term environmental investment benefits, accelerate structural transformation, concentrate on environmental governance, and provide sufficient support to the elements that may have an important impact on ecological protection and construction in the future. Eventually realize the harmonious symbiosis between man and nature. At the same time, due to the limitation of data and time period, the corresponding variables cannot fully describe the motivational mechanism and long-term influence of environmental development. At the same time, the different measurement methods make it impossible to determine which measurement method is better. It is necessary to build a multi-dimensional systematic framework of influencing factors in future research, and make more refined treatment of related variables.

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