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Whether Urban Development and Ecological Protection Can Achieve a Win-Win Situation—The Nonlinear Relationship between Urbanization and Ecosystem Service Value in China

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Abstract: Most of the existing research on urbanization suggests that urbanization leads to a decline in ecosystem services values (ESV). However, the impacts of industrial structure and changes in land use patterns on ESV have often been ignored. Using provincial data in China from 2003 to 2015, this study demonstrates the possibility of achieving a win-win situation regarding urbanization and ESV enhancement at the global and regional scales. The negative effect from production processes and the influence of residents' preferences are considered in the evaluation of ESV. The impact of urbanization on ESV is empirically analyzed by using a spatially adaptive semi-parametric model in order to mitigate both endogeneity of the parametric model and the curse of dimensionality in nonparametric model. The results show that there is a U-shaped curve relationship between urbanization and ESV for the whole country. However, most provinces of China are still located at the left side of the U-shaped curve where urbanization reduces the ESV per capita. Central and local governments should strengthen differentiated land use policies, environmental regulations, and finance and tax policies to transform the industrial structure, so that each province may achieve a win-win situation regarding urbanization and ESV enhancement. Such policy changes would promote sustainable development in China.

Keywords: urbanization; ecosystem service value; spatially adaptive semi-parametric model; win-win situation; China

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1. Introduction

With rapid economic development in many developing countries such as China, urbanization has placed pressures on ecosystem services [1]. Furthermore, these countries are still undergoing rapid urbanization [1]. Therefore, the coordination of economic development and ecological protection is very important for these regions [2]. The question of how to coordinate the relationship between urban development and ecosystem service values (ESV) enhancement, to realize a win-win situation for both, needs to be studied systematically.

Much of the existing literature has described negative relationships between urbanization and ESV [1–8]. These studies have indicated that urbanization leads to land use transition with a decline in ESV [1–3]. Land use transition results in a decrease in ESV that is primarily caused by the transition from cropland, wetland, grassland, forest, treed surfaces or water bodies into built-up land [4–10]. Urbanization reduces the value and function of ecosystem services by altering ecosystem structure, ecological habitat and ecosystem circulation processes [11,12]. However, ESV can be optimized by transforming the land use structure (land use structure refers to the proportion of agricultural land being converted into secondary industrial land or tertiary industrial land) [13,14]. The change in land use structure would lead to changes in ecosystem function structure, and affect the biogeochemical cycle, soil renewal, water cycle and other ecological processes, and thus cause changes in ESV [15–17]. ESV is influenced not only by the land use transition, but also by land use structure. Land use structure can cause changes in industrial structure and pollution emissions and further affect ESV. Few studies have investigated the impact of urbanization on ESV from the perspective of land use structure, land use transformation and industrial structure. This study explores the possible mutual coordination of urbanization and ESV enhancement from the perspective of land use structure. Land use transitions due to urban expansion lead to decreases in ecosystem service supply and the scarcity of ecosystem services, whereas residents' ecosystem service demand and willingness to pay (WTP) for ecosystem services increases with improvements in living standards [18,19]. Thus, this paper also considers residents' WTP for ESV.

Research methods in the existing literature on urbanization and ESV can be roughly divided into parametric and nonparametric models. Parametric models usually assume the form of the estimating function and some finite set of parameters in advance, while nonparametric models do not assume any form of estimating function and assume that the data distribution cannot be defined in terms of a finite set of parameters [20,21]. However, parametric models suffer from model setting errors and endogeneity [20]. Reverse causality and omitted variables lead to endogeneity between urbanization and ESV [8,21]. Traditional econometric models resolve endogeneity by using instrumental variables. However, effective instrumental variables are difficult to identify and cannot address endogeneity very well, especially when there is heterogeneity [22]. Moreover, pure nonparametric techniques are decreasingly valid as the dimension of the regression function increases [23]. This study utilizes a semi-parametric model to mitigate the curse of dimensionality. The penalty parameter of penalized splines mediates the trade-off between bias and variance (bias reflects the accuracy of the model, whereas variance reflects the stability of the model). The spatially adaptive semi-parametric model is a method for fitting penalized splines wherein the penalty parameter varies spatially in order to accommodate possible spatial heterogeneity of the regression model [24,25]. Also, spatial heterogeneity refers to the spatial heterogeneity and complexity of ecological processes and patterns. The spatially adaptive semi-parametric model is suitable for this study.

To comprehensively analyze the tradeoff between urbanization and ecosystem services, this paper systematically explores the possible win-win situation of both economic development and ecological protection. First, the ESV per capita was calculated based on the negative effects of pollution emissions from production processes and the WTP by residents for ecosystem services. Second, the relationship between urbanization and ESV per capita was analyzed quantitatively using the spatially adaptive semi-parametric model. Additionally, the specific path of mutual improvement for urbanization and ecosystem service values is discussed at the regional scale. The results of this study could inform the optimization of policy formulation in terms of achieving urban sustainable development.

2. Models and Data Processing

2.1. Theoretical Model

ESV mainly depends on the following three aspects. (1) The area of land with ecological benefits (AEB). Agricultural land (such as cultivated land, garden land and forest land) and unused land (such as rivers, lakes and wetland) all have positive ESV. (2) Negative effects of pollution (NEP) generated from production processes. Waste water, waste gas, and industrial dust discharged during industrial production have negative impacts on ESV because of the pollution and impacts on air and soil quality. It is worth noting that urbanization has many other negative effects on the ESV, such as UHI, flash flooding, carbon sequestration, bio-diversity, etc. [9,10]. However, this paper mainly discusses the impact of land use structure on the ESV by changing the industrial structure, because of the differences in pollution emission of different industries. Therefore, this paper only focuses on measuring the negative impact of pollution emissions on the ESV during urbanization. (3) Residents' willingness to pay (WTP) for ecosystem service. The demand of residents for environmental amenities and ecological products increases with economic development levels and income. Increased WTP for consumption of ecosystem services would result in the enhancement in ESV.

Rapid economic development has incentivized the conversion of large areas of land from agricultural use into industrial use. The land conversion leads to decreases in ESV, because the total amount of land that provides ecosystem services declines and ecosystem functions are damaged by pollution. However, the land use structure changes when pollution becomes restrictive to economic development. Agricultural land will be mostly converted into tertiary land or high-tech industrial land. The effect of pollution emission from tertiary land or high-tech industrial land is relatively slighter than the secondary industrial land, causing less damage to ecosystem function. Furthermore, residents' WTP for consumption of ecosystem services increases with improvements in living standards.

The influence mechanism between urbanization and ESV is shown in Figure 1. In the initial stage of economic development, agricultural land in ecological system is mainly transformed to the secondary industrial land because of industrial policies, financial and tax policies issued by the government. Pollution emission generated from production process of the secondary industries causes a larger negative effect on the ecological system. When it is in the advanced stage of economic development, agricultural land or unused land in an ecological system will be mainly transformed into the tertiary industrial land because of new industrial policies, financial and tax policies changed by the government. The tertiary land causes less negative effect on the ecological system. Moreover, ecosystem will also benefit from the government's environmental regulation policies and residents' increasing WTP for ecosystem service.

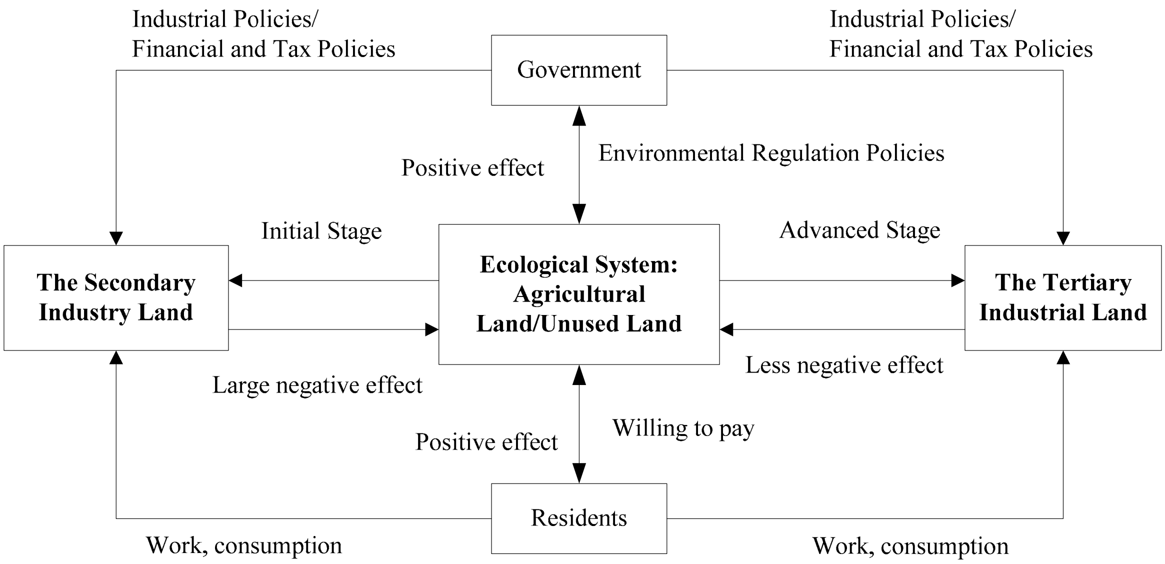

Figure 1. Influence mechanism diagram of urbanization and ESV.

When the negative effect of pollution generated by production processes exceeds the sum of the ESV generated by the ecologically beneficial land and the residents' WTP, i.e., NEP > AEB + WTP, the impact of urbanization on ESV per capita is negative. When the sum of the ESV and the residents'

WTP exceeds the negative effect of the pollution, i.e., AEB + WTP > NEP, the impact of urbanization on ESV per capita is positive. Furthermore, we hypothesize that a U-shaped relationship exists between urbanization and ESV (Figure 2). The curve ramps up again at higher land urbanization in Figure 2 which is corresponding to the situation AEB + WTP > NEP. On one hand, the damage to the ecological environment caused by the production process can be reduced by promoting tertiary industries or high-tech industries; on the other hand, the rapid development of urban economy can provide sufficient funds for eco-environmental protection through the construction of forests, parks, green areas, etc. In addition, the residents' WTP for the ESV will increase with improvements in living standards.

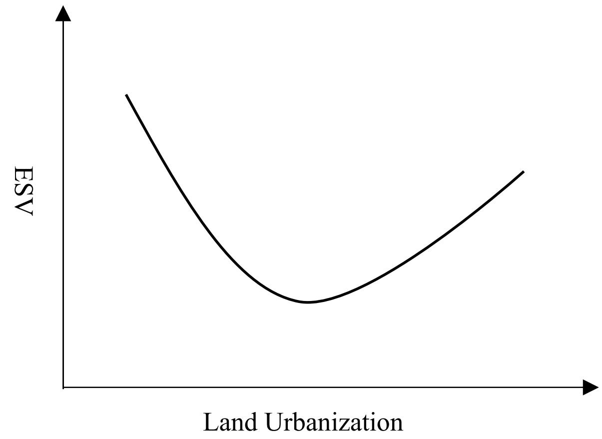

Figure 2. The hypothesized U-shaped curve between urbanization and ESV.

2.2. Econometrical Model: Spatially Adaptive Semi-Parametric Model

To avoid endogeneity in the parametric model and the curse of dimensionality in the nonparametric model, we applied a spatially adaptive semi-parametric model to analyze the impact of urbanization on ESV.

Due to the different geographical scope of each province, land areas with ESV are quite variable. The use of ESV per capita can more appropriately reflect the effect of ecosystem services supply in distinct provinces. To empirically analyze the relationship between the urbanization rate and ESV per capita, this study takes the net ESV per capita (y) as the dependent variable and the urbanization rate (x_1) as the independent variable. Variables influencing urbanization rates generally include the economic development level, industrial structure, local public financial expenditure, urban public service facilities level, education, medical resources, and transportation infrastructure [26–28]. Therefore, the control variables selected in this study are gross regional product per capita (x_2), the sum of industrial output value as a proportion of GDP (x_3), local fiscal expenditure (x_4), number of full-time teachers per 1000 people (x_5), and the number of hospital beds per 1000 people (x_6). The spatially adaptive semi-parametric model is as follows:

$$\ln y = \beta_0 + \beta_1 x_2 + \beta_2 x_3 + \beta_3 x_4 + \beta_4 x_5 + \beta_5 x_6 + f(x_1) + \sum_{k=1}^{K_m} b_k \left(x_1 - \kappa_k^m\right)_+^p \tag{1}$$

where β_0 is a constant; $\beta_i (i = 1, 2, \cdots, 6)$ are the coefficients for each linear variable; $f(x_1)$ is the nonparametric form; $\kappa_k^m (k = 1, 2, \cdots, K_m)$ are knots; K_m is the dimension of knots; $\left(x_1 - \kappa_k^m\right)_+^p$ is equal to $\left(x_1 - \kappa_k^m\right)^p$ if $\left(x_1 - \kappa_k^m\right) > 0$ and b_k is its coefficient; m is the type of knot; and p is the exponential power of the k-th knot.

2.3. Data Source and Descriptive Statistics

The urbanization rate of each province from 2003 to 2015 was calculated by dividing the total built-up area in 30 provinces and municipalities in mainland China—excluding Hong Kong, Macao, Taiwan, and Tibet due to missing data—by the total area under municipal jurisdiction. The data comes from the annual statistical yearbook of China's cities. Outliers with urbanization rates greater than 18% or lower than 1% are removed from the dataset. This study separately analyzes the whole country, the Eastern region, and the Midwest region. The Eastern region includes the province of Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan. The Midwest region includes all other provinces except those in the Eastern region.

Descriptive statistics of each variable are shown in Table 1.

Table 1. Descriptive statistics of each variable.

Variable (Abbreviation)	Notation	Mean
Regional GDP per capita (RGDP)	x_2	31,651.2
The total output of secondary and tertiary industries as a proportion of regional GDP (PST)	x_3	0.9
The number of full-time teachers per 1000 people (NFT)	x_4	10.3
Local fiscal expenditure (LFE)	x_5	2324.3
The number of hospital beds per 1000 people (NHB)	x_6	3.7

Data Source: Chinese Statistical Yearbook (2004-2016). http://www.stats.gov.cn/.

2.4. Calculation of ESV

Net ESV is calculated considering not only the positive ESV generated by cultivated land, garden land, grassland, wetland, forest, and water bodies, but also the negative effects of pollution. Furthermore, the WTP for ESV by residents is enhanced by rising income and increasing demands for ecosystem services.

This study calculates the total ESV for each of China's 30 provinces based on the ESV per unit area of each land type reported by Xie et al. (2008) [29] and the total area of each land type. The total ESV is divided by the total population of each province to obtain the ESV per capita. To consider the effect of residents' increasing WTP due to increases in income, the ESV per capita of each province in 2007 was converted into its value from 2003 to 2015, according to the regional GDP per capita. The calculation is as follows:

$$y_{1it} = \frac{\sum_{j=1}^{5} k_j A_{ij}}{P_i} \cdot \frac{AGDP_{it}}{AGDP_{i,2007}},\ i = 1, 2, \cdots, 30 \tag{2}$$

where k_j represents the ESV from a unit area of land type j; A_{ij} represents the area of land type j in province i; P_i is the population of province i; $AGDP_{it}$ and $AGDP_{i,2007}$ represents the gross regional product per capita of province i in year t and in 2007, respectively; and y_{1it} is the gross ESV of province i in year t.

The ESV per unit area of each land type is shown in Table 2. The calculation above only accounts for the positive effect of ESV. Because the waste water discharged by industrial production processes has a negative impact on soil quality, accounting for this negative effect on the ESV of land is necessary. The natural logarithm of net ESV per capita is obtained by subtracting the logarithm of total waste water per capita from the logarithm of gross ESV per capita. The calculation is as follows:

$$\ln y_{it} = \ln y_{1it} - \ln y_{2it} \tag{3}$$

where ln y_{it} is the logarithm of net ESV per capita of province i in year t; ln y_{1it} is the logarithm of gross ESV per capita of province i in the year t; and ln y_{2it} is the logarithm of the total waste water per capita of province i in year t.

Table 2. The ESV per unit area of China's ecosystem (unit: yuan*ha^{-1}*a^{-1}.

Land Type	Cultivated Land	Pasture Land/Garden Land	Forest/Afforestation	Wetland	Water Body
The ESV per unit area	3547.89	5241.00	12,628.69	24,597.21	20,366.69

3. Results

3.1. Spatial Pattern of ESV Per Capita

The ESV per capita of each province in 2003, 2007, and 2015 are shown in Table 3. The ESV per capita of the Midwest provinces is greater than those of Eastern regions (Table 3). The spatial distribution of ESV per capita slightly changes between 2003 and 2015. The provinces with higher ESV per capita are concentrated in the Midwest region, while the ESV per capita is lower in the Eastern region. In the Eastern region, the economic development is faster and the level of urbanization is higher than that in Midwest regions, while its ESV per capita is lower. Therefore, how to coordinate the relationship between economic development, urbanization and ecological protection is a very important issue.

Table 3. The ESV per capita and its growth rate for each province in 2003, 2007 and 2015.

Province	Region	ESV Per Capita		
		2003	2007	2015
Qinghai	Midwest	260.46	255.39	8050.95
Xinjiang	Midwest	30.09	55.02	802.79
Hainan	Eastern	48.63	133.26	218.41
Inner Mongolia	Midwest	7.88	23.36	194.79
Ningxia	Midwest	3.84	3.70	53.42
Gansu	Midwest	3.37	8.28	45.80
Heilongjiang	Midwest	2.28	5.32	15.93
Guizhou	Midwest	1.17	4.15	10.65
Shaanxi	Midwest	0.76	1.24	10.61
Yunnan	Midwest	2.32	5.31	10.30
Jilin	Midwest	1.87	2.84	8.70
Sichuan	Midwest	0.28	0.65	7.21
Guangxi	Midwest	0.26	0.37	3.85
Chongqing	Midwest	0.06	0.31	3.26
Jiangxi	Midwest	0.66	0.93	2.47
Beijing	Eastern	0.47	1.02	2.03
Fujian	Eastern	0.34	0.46	1.10
Hubei	Midwest	0.20	0.42	1.98
Hunan	Midwest	0.18	0.45	1.89
Liaoning	Eastern	0.29	0.50	1.65
Tianjin	Eastern	0.44	0.63	1.62
Shanxi	Midwest	0.51	0.78	1.48
Anhui	Midwest	0.21	0.36	1.31
Hebei	Eastern	0.15	0. 32	0.75
Zhejiang	Eastern	0.13	0.20	0.60
Guangdong	Eastern	0.13	0.12	0.41
Shanghai	Eastern	0.12	0.21	0.40
Henan	Midwest	0.06	0.13	0.37
Jiangsu	Eastern	0.04	0.07	0.34
Shandong	Eastern	0.10	0.13	0.27

The spatial distribution of growth rates of ESV per capita from 2003 to 2007, from 2007 to 2015 and from 2003 to 2015 are shown in Figure 3. The growth rates of ESV per capita in the Midwest provinces are also greater than those in the Eastern region. The growth rates of all regions from 2007 to 2015 are greater than those from 2003 to 2007.

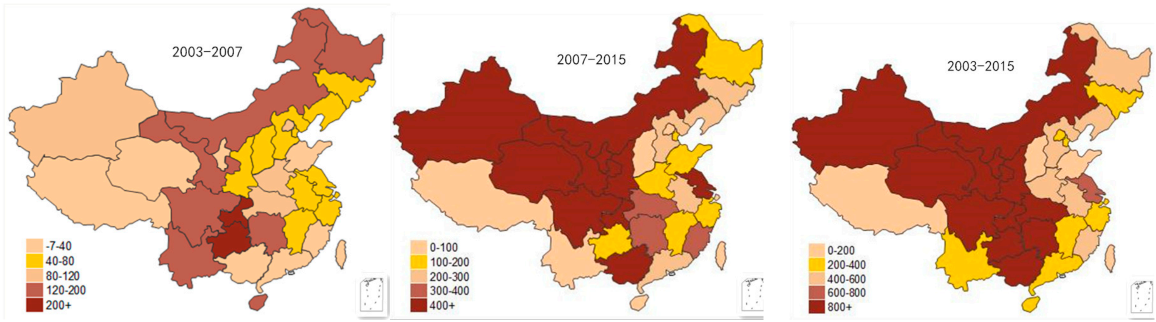

Figure 3. Spatial distribution of growth rate of ESV per capita from 2003 to 2007, from 2007 to 2015, and from 2003 to 2015

3.2. Urbanization and ESV Per Capita for the Whole Country

Net ESV per capita was quantitatively analyzed using the spatially adaptive semi-parametric model. The fitted curve for the urbanization rate and net ESV per capita is shown in Figure 4. The regression results of the spatially adaptive semi-parametric model are shown in Table 4. Nonparametric results, including degrees of freedom, nodes, and the value of spar statistics, indicate that the model fits the data well.

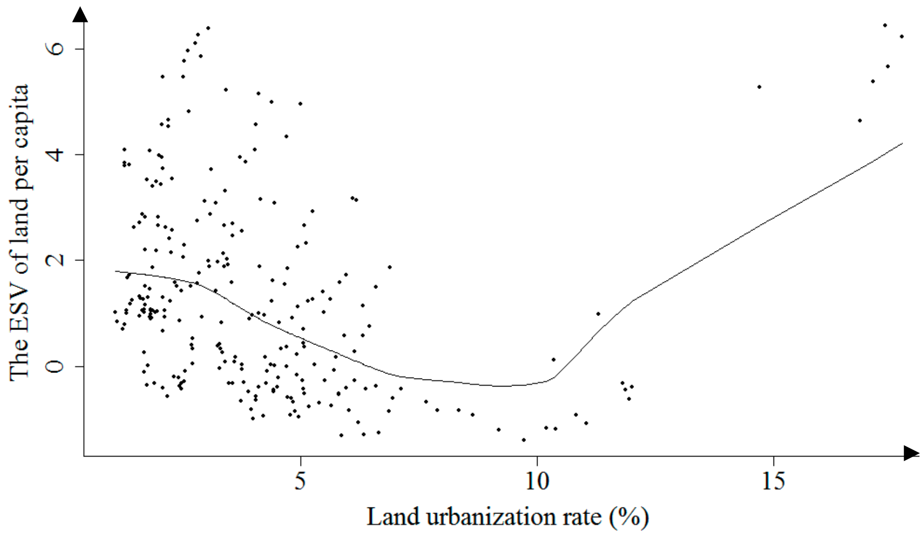

Figure 4. The fitted curve of urbanization rate and net ESV per capita.

Table 4. The ESV per capita based on the spatial adaptive semi-parametric regression model.

.	Notation	Variables (Abbreviation)	Coefficient
Parametric Results	x_2	Regional GDP per capita (RGDP)	4.31×10^{-5} *** (0.000)
	x_3	Total output of secondary and tertiary industries as a proportion of regional GDP (PST)	−11.16 *** (0.000)
	x_4	The number of full-time teachers per thousand people (NFT)	−0.15 *** (0.000)
	x_5	Local fiscal expenditure (LFE)	-5.25×10^{-4} *** (0.000)
	x_6	The number of hospital beds per thousand people (NHB)	1.39 *** (0.000)
Nonparametric Results		df	5.94
		spar	5.89
		knots	36

The value in parentheses below each coefficient is its corresponding p-value; *** represents statistical significance levels of 1%.

3.2.1. Nonlinear Relationship between Urbanization and ESV

The relationship between ESV per capita and the urbanization rate can be characterized as a U-shaped curve (Figure 4). This result indicates that the urbanization rate and ESV per capita have a negative relationship when the level of economic development is not high. At greater levels of economic development, the ESV per capita increases with increasing urbanization rate. Because the level of economic development in most regions of China is still not high, most of the observations are located at the left and middle bottom stages of the U-shaped curve, and only a small number of observations are located at the right side of the U-shaped curve.

This outcome suggests that most provinces in China are still undergoing urbanization such that ESV per capita is declining. Some regions are at a stage where the decline in ESV per capita has ceased. Very few regions are in the stage of urbanization where ESV per capita rises. The central government should strengthen environmental regulations and reform construction land reduction policy, as well as adjust the industrial structure, in order to incentivize each local government to achieve the win-win situation of promoting both urbanization and ESV enhancement. The minimum of the U-shaped curve occurs at an urbanization rate of approximately 8%, indicating that the urbanization rate and ESV per capita may have a positive relationship where the urbanization rate exceeds 8%. The provinces that are mainly economically developed coastal provinces, such as Beijing, Shanghai, Tianjin, Hebei, Guangdong, Zhejiang, Jiangsu, Shandong, and Henan, are located on the right side of the U-shaped curve.

3.2.2. The Linear Effect of Control Variables on ESV

In Table 4, regional GDP per capita and ESV per capita are positively related. This result indicates that the improvement of economic development level and the increase of residents' income are correlated with increases in ESV per capita. The total output value of secondary and tertiary industries as a proportion of regional GDP is negatively correlated with ESV per capita. This result is related to the fact that secondary and tertiary industries still account for a large proportion of total pollution. The government should further increase the proportion of tertiary industries and high-tech industries, increase the efficiency of economic development, and reduce the pollution caused by industrial development. Local fiscal expenditure and ESV per capita are negatively correlated. This result indicates that presently, the proportion of local finance invested in education, medical treatment, urban park green space, water conservancy facilities, and other livelihood projects in China is small, and the proportion of urban public goods investment needs to be increased in the future. NFT and ESV per capita are negatively correlated, suggesting that ESV is not great in areas with abundant education resources. NHB and ESV per capita are positively correlated, indicating that the areas with abundant medical facilities have a high ESV per capita.

3.2.3. Urbanization and ESV Per Capita for Subregions

The fitted curve between urbanization rate and net ESV per capita for the Eastern region is shown in Figure 5. ESV per capita declines sharply with urbanization where the urbanization rate is relatively low. With greater urbanization rates, the ESV per capita tends to be stable, or else shows signs of a slow rise.

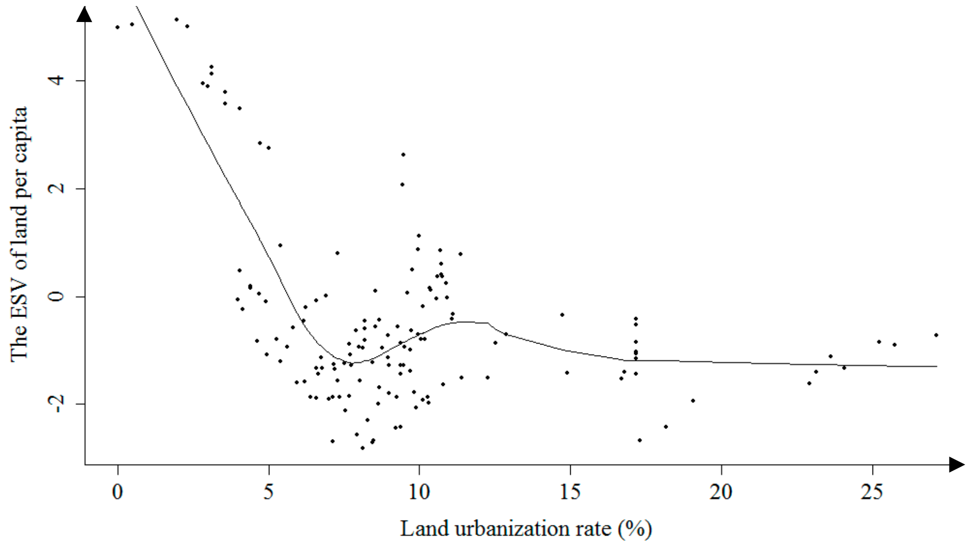

Figure 5. The relationship between urbanization rate and net ESV per capita in the Eastern region.

The results of the spatially adaptive semi-parametric regression model for the Eastern region are shown in Table 5. Regional GDP per capita is positively correlated with ESV. Thus, increases in economic development correspond to increases in ESV. Additionally, the total output of secondary and tertiary industries as a proportion of regional GDP is negatively correlated with ESV, which suggests that industrial structure needs to be reformed to further develop tertiary industry in order to reduce impacts ecosystem services. The number of full-time teachers per 1000 people and local fiscal expenditure are each negatively correlated with ESV, whereas the number of hospital beds per 1000 people is positively correlated with ESV. The directions for the coefficients in the Eastern region are the same as those for the whole country. Compared to results for the whole country, RGDP has a greater positive relationship with ESV per capita; PST has a greater negative relationship with ESV per capita. Compared to the results for the whole country, the negative coefficients for NFT and LFE are smaller and the positive coefficient for NHB is greater in the Eastern region. These results suggest that economic development, public expenditure, and public service supply in the Eastern region have a greater relationship with ESV per capita in comparison to the whole country. However, the negative relationship between industrial structure and ESV is also greater than that of the whole country. The Eastern region should further adjust its industrial structure and vigorously develop tertiary industries and high-tech industries to reduce the negative impact of production processes on ESV.

Table 5. The ESV per capita based on the spatial adaptive semi-parametric regression model for the Eastern region.

	Notation	Variables (Abbreviation)	Coefficient
Parametric Results	x_2	Regional GDP per capita (RGDP)	5.24×10^{-5} *** (0.000)
	x_3	Total output of secondary and tertiary industries as a proportion of regional GDP(PST)	−13.33 *** (0.000)
	x_4	The number of full-time teachers per thousand people (NFT)	-4.51×10^{-3} (0.816)
	x_5	Local fiscal expenditure (LFE)	-2.23×10^{-4} *** (0.000)
	x_6	The number of hospital beds per thousand people (NHB)	0.39 *** (0.003)
Nonparametric Results		df	5.97
		spar	3.86
		knots	33

The value in parentheses below each variable coefficient is its corresponding p-value; *** represents statistical significance levels of 1%.

The fitted curve between urbanization rate and ESV per capita for the Midwest region is shown in Figure 6.

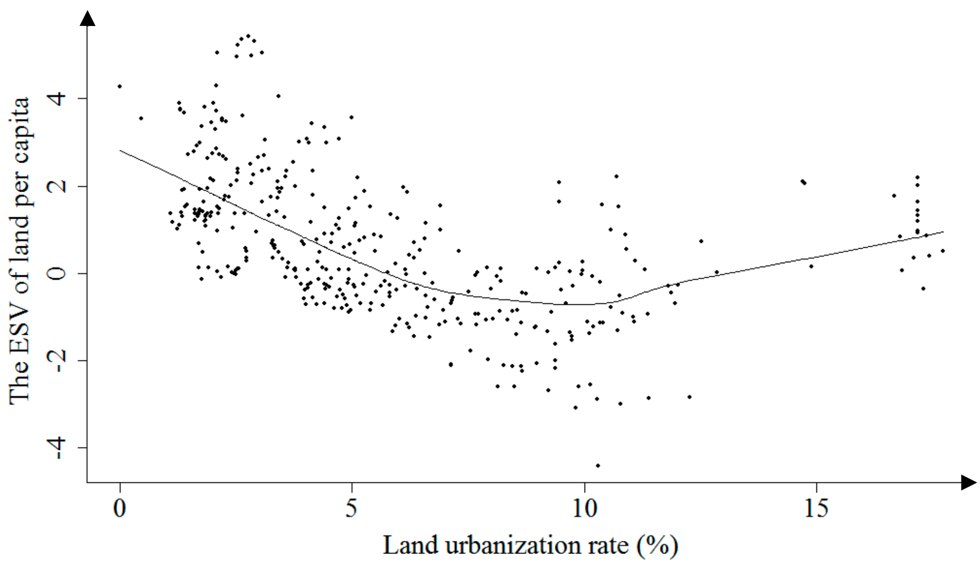

Figure 6. The fitted curve between urbanization rate and ESV per capita for the Midwest region.

In Figure 6, there is a U-shaped relationship between urbanization rate and ESV per capita for the Midwest region. The ESV per capita is declining with further increases in the urbanization rate for most provinces in the Midwest region. This result indicates that the promotion of urbanization has not comprehensively affected the function of ecosystem services in the Midwest region. The government should strengthen environmental regulations, land policy, and finance and tax policies in order to help the Midwest regions to simultaneously enhance urbanization and ESV per capita.

The regression results of the spatial adaptive semi-parametric regression model for the Midwest region are shown in Table 6. The results showed the following: (1) regional GDP per capita is positively correlated with ESV, so increases in the economic development level correspond to enhancement in ESV. (2) Total output of secondary and tertiary industries as a proportion of regional GDP also positively correlates with ESV. (3) The number of full-time teachers per 1000 people and local fiscal expenditure are each negatively correlated with ESV, whereas the number of hospital beds per 1000 people is positively correlated with ESV. In contrast with the results for the Eastern region, the relationship between the industrial structure and ESV per capita is positive for the Midwest region.

Table 6. The results of the spatial adaptive semi-parametric regression model for the Midwest region.

	Notation	Variables (Abbreviation)	Coefficient
Parametric Results	x_2	Regional GDP per capita (RGDP)	8.35×10^{-3} (0.127)
	x_3	Total output of secondary and tertiary industries as a proportion of regional GDP (PST)	771.20 (0.443)
	x_4	The number of full-time teachers per thousand people (NFT)	−79.89 *** (0.000)
	x_5	Local fiscal expenditure (LFE)	−0.23 *** (0.000)
	x_6	The number of hospital beds per thousand people (NHB)	368.7 *** (0.000)
Nonparametric Results		df	2.00
		spar	35.15
		knots	35

The value in parentheses below each variable coefficient is its corresponding p-value; *** represents statistical significance levels of 1%.

4. Discussion

4.1. The Improvement in ESV Evaluation

This study expands upon the traditional method for calculating ESV per capita. Calculations of ESV in most studies are based on Costanza et al. (1997; 2014) [30,31] and Xie et al. (2008) [29], and some studies also consider the impact of residents' WTP [32]. However, few studies consider the negative impact of pollution on ESV. Environmental pollution causes direct damage and indirect impacts on ecosystem function and structure. Such impacts include desertification, forest destruction, acid rain, smog, changes to habitats, and biomeshifts that could result from increased atmospheric concentrations of greenhouse gases [33–35]. Since the pollution discharged by production processes has a substantial impact on ecosystems, the negative impact should be included in the analysis when calculating ESV, which is precisely the point systematically analyzed in this paper. The estimates of the ESV per capita in previous studies are overestimated because the negative effect of pollution has not been accounted for [34]. The ESV per capita estimates from this study are lower than those in the existing literature [34]. After taking into account the negative effects of environmental pollution, the ESV per capita of a particular region depends not only on the land area providing ecosystem services, but also on the degree of environmental pollution, the investment and effort in environmental pollution abatement, and the adjustment of industrial structure by the local government. Therefore, the spatial distribution of ESV per capita calculated in this study is also distinct from the existing literature [3,36].

4.2. The Spatial Heterogeneity in the Relationship between Urbanization and ESV

This paper applies the spatially adaptive semi-parametric model to address the shortcomings of other models, while resolving the problem of spatial heterogeneity. The results in Section 3 indicate that the model is robust. The critical point is easily identified, as are the proportions of observations on the left and right sides of the U-shaped curve. For the whole country, the minimum point of the U-shaped curve occurs at an urbanization rate of approximately 8%, and approximately 80% of the observations lie on the left side of the U-shaped curve. For the Midwest region, the minimum point of the U-shaped curve occurs at an urbanization rate of approximately 10%. Nearly 90% of the sample lies on the left side of the U-shaped curve for the Midwest region. The downward trend in ESV per capita in the Eastern region becomes stable when urbanization rate has reached 8%. The decline in ESV per capita in the Eastern region becomes stable and the ESV per capita in the Midwest region changes from a decline to an upward trend, resulting in a U-shaped curve relationship. Urbanization and ESV enhancement can occur simultaneously with mutual coordination and promotion. The sub-regional analyses illustrate the distinction between the Eastern and the Midwest regions. Key mediating variables can promote both urbanization and ESV per capita to achieve a win-win situation. A positive relationship between urbanization and ESV per capita is not apparent in Eastern China, because the impact of industrial structure on ESV per capita is negative. A positive relationship between urbanization and ESV per capita is apparent in the Midwest region, due to the positive impact of industrial structure on ESV per capita.

4.3. Time Series Analysis of the Relationship between Urbanization and ESV

The initial stage of economic development is dominated by extensive development due to objective conditions, the technical level, and the human capital level. Most agricultural land or unused land is mainly converted into secondary industrial land due to the central government's GDP and tax assessment [37,38]. Waste water, waste gas, industrial dust, and other contaminants discharged by industrial production pollute the air, soil, and vegetation [15–17]. At the same time, areas that generate ESV and have positive effects on the ecological environment —such as cultivated land, garden land, woodland, grassland, wetland, and water bodies—, are rapidly reduced. Generally, most of the land used in secondary industry is inefficient land [38,39]. The sum of the marginal output of secondary industrial land and agricultural land is less than the marginal input of pollution abatement [2,27]. When the urbanization rate increases gradually, the marginal output of land in the secondary industry diminishes, while its marginal pollution level and the marginal investment into pollution abatement increase. At this stage, the ESV of land per capita decreases.

Environmental pollution becomes more restrictive to economic development when economic development reaches a certain level. The government is aware of the need to control environmental pollution, implement environmental regulations, and directly invest in ecological restoration projects to enhance the sustainability of economic development [39]. The central government issues corresponding industrial policies, as well as fiscal and taxation policies, to prompt local governments to shift more land to tertiary industry [40]. Additionally, the central government, through the implementation of construction land reduction policy, also requires the local government to remediate inefficient and highly polluted industrial land [13]. The policy of reducing the quantity of construction land can enhance land use efficiency without increasing the total amount of construction land. These policies facilitate a decrease in environmental damage caused by production processes. Agricultural land and unused land that can generate ESV also decline at a slower rate. At the same time, residents' demand for ecological amenities and services increases with economic development and improvement in living standard. Increases in residents' WTP for ESV results in increased ESV of land [32]. At this stage, the relationship between urban expansion and ESV is positive.

The government should promote further industrial upgrading and industrial clean production through land use policies and environmental regulation policies. It reduces the impact of pollution emission generated from production processes on the ESV by promoting technological progress. The government should gradually increase the proportion of the tertiary industry and high-tech industries. The high polluting industries can also be promoted to further upgrade and reduce their pollution emissions through technological progress. Sustainable development can be achieved by promoting the coordination of urbanization and environmental protection.

5. Conclusions and Policy Implications

Urbanization has promoted changes in land use patterns and structure. The disorder of land use and the irrationality of land use structure lead to declines in ESV. This study empirically analyzes the relationship between urbanization and ESV using a spatially adaptive semi-parametric model. Through theoretical analysis and empirical analysis, this study promotes strategies to realize the win-win situation of simultaneously enhancing urbanization and ESV.

Quantitative results verify the hypothesis that the relationship between urbanization rate and ecological value of land per capita is a U-shaped curve. Most observations are on the left and middle bottom of the U-shaped curve. Only a very small number of observations are on the right of the U-shaped curve. This outcome indicates that most of China is still at a development stage where urbanization reduces the ecological value of land per capita. The central government should introduce, as soon as possible, environmental regulations and other measures to adjust the industrial structure, so that each province may experience urbanization that is positively correlated with the ecological value of land per capita.

After demonstrating that urbanization can promote ESV per capita and achieve a win-win situation, the key question regards which policies issued by the central and local governments will further enhance this effect. The Chinese central government has issued a lot of land use policies and environmental regulation policies to regulate the behavior of land use of local governments and enterprises, and to promote the implementation of environmental responsibilities. However, most of these political measures are mainly administrative orders, and the market-based policies that will be more effective with economic development are inadequate. This paper proposes policy suggestions to realize the win-win situation between urbanization and ESV from two aspects, namely, land use policy and environmental regulation policy.

(1) Land use policy. First, the Chinese government should formulate differentiated land supply policies that tilt land use towards tertiary and high-tech industries and reduce the land supply for backwards and high-energy consuming industries. Second, the Chinese government should implement construction land reduction policies that curb the expansion of construction land space. Finally, the government should promote the protection of ecological spaces and farmland through cross-regional land development rights transactions.

(2) Environmental regulation policies. First, the government should strengthen the implementation of strict environmental regulations to protect the ecological environment. Second, the government should gradually strengthen the implementation of market-oriented environmental policies, such as environmental taxes and emission trading systems. For example, the government should impose an optimized environmental tax on pollution emissions and provide subsidies for ecologically beneficial technologies. The government is exploring the establishment of a trading system for pollutant discharge rights in protected areas. Finally, an interregional and interbasin ecological compensation mechanism should be established.

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