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The Growth-Ecology Dilemma: How Land-Based Fiscal Expansion Suppresses Ecosystem Value

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Abstract Pursuing progress through land has served a prominent role in economic development. China aggressively exploits its land resources. The land ecosystem cycle is disrupted, posing a threat to sustainable land development and adversely affecting socioeconomic progress. This study employed the Heihe-Tengchong line as the demarcation for regional environmental carrying capacity. Utilizing panel data from 276 prefecture-level cities in China spanning 2005 to 2020, it empirically examined the correlation between land-based fiscal revenue and ecosystem service value from a policy-driven perspective. Ecosystem service value data were calculated using remote sensing datasets processed with ArcGIS 10.2 software. The results based on data analysis revealed that land finance had a remarkable inhibitory and negative effect on ecological value. Additionally, land finance had a prominent time-lag influence on ecological value, considering the policy standpoint. Furthermore, promotion pressure significantly affected land finance and ecological value. From the perspective of data science, it had the potential to distort officials' economic development behavior and adversely affect the ecosystem. Given the findings based on these data values, the state should actively explore the transfer of ecologically valuable state-owned land, improve the political promotion assessment system, and use environmental consideration as leading tools for performance assessment.

Index Terms Ecological value; Land finance; Remote sensing datasets; Promotion pressure; Political promotion

I. Introduction

Scholars consider "safety, green, environmental protection, and ecology" as the guiding principles for the high-quality development of Chinese society [1]. With the growingly popular concepts of ecology and environmental protection, China's economic development model has transitioned from being haphazard (i.e., characterized by unregulated practices) to being intensive (i.e., focuses on efficiency and sustainability). Social development has gradually transformed from "emphasizing quantity" to "improving quality" [2]. This involves abandoning activities that may be highly economically efficient but exceed environmental bearing capacity. The "ecological value of land" refers to the monetization of the ecological services and functions provided by land resources. It reflects the overall value of the benefits that humans can derive from land ecosystems directly or indirectly, such as clean air, pure water, biodiversity preservation, and climate regulation [3]. This ecological value is now considered a "new yardstick" for measuring high-quality economic growth and a "green baton" for guiding future sustainable development. Therefore, ecological value serves as a primary indicator for land management decisions, paving the way for sustainable land development [4]. This understanding helps raise awareness regarding the proper management and consideration of ecological value as a step toward devising strategies for conserving land ecological resources [5] and finding a nexus between sustainable economic development and ecosystems [6].

Land policy is an important tool for managing land conflicts in China, which is closely related to national conditions and productivity development. Meanwhile, the land finance model serves as an important financial instrument created by Chinese local governments as rational economic agents facing multiple trade-offs. It manifests through financial revenue, expenditure activities, and benefit distribution relationships associated with land mortgage financing. Since launching its reform and liberalization initiative, China has undergone remarkable industrialization and urbanization, and the government's engagement in "land finance" behavior has been indispensable in driving rapid economic growth [7]. At the national level (see Figure 1), the research findings indicate a continuous increase in China's land finance revenue. National land concession revenue increased from 0.06 trillion yuan to over 8 trillion yuan during the period from 2000 to 2021, with an average annual growth rate of

28.16%. Regarding prefecture-level municipalities, where tax data are available, the percentage of land concession revenue to financial revenue remained relatively stable at approximately 50% throughout the year (see Figure 1). Although the amount of land sales revenue reached a record high in 2021, increasing by $871 million from 2020 compared to previous years, the 3.5% increase represents a significant slowdown in the overall growth of land sales revenues, largely caused by the impact of the COVID-19 pandemic. Additionally, signs of a declining land market are apparent. Furthermore, in the context of promoting pilot property reform and fostering the development of an ecological civilization, there is a growing market consensus for the need for a transformation in land finance.

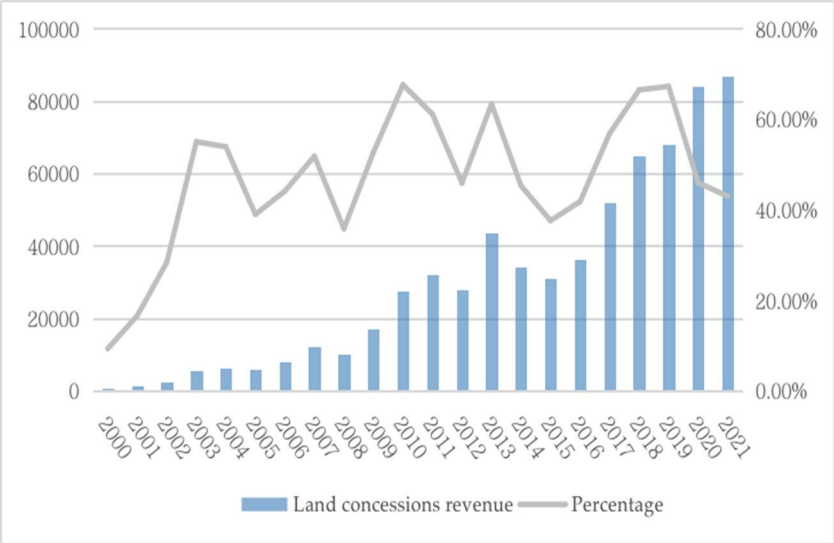

Figure 1: Trend of land concession revenue from 2000 to 2021

II. Literature review

In recent decades, scholars have closely monitored the ecological degradation brought about by human economic activities [8]. Changes in land use are a direct cause of changes in ecological value, which are conditioned by elements such as economic growth and population aggregation [9]. Sagoff (1998) linked ecological value with socioeconomic development and, following theoretical and practical studies, suggested that the two must be interconnected and influence each other [10]. Rapid regional economic development and increasing urbanization will invariably result in the spatial expansion of land resources. Subsequently, these phenomena will affect the efficiency and structure of regional land use and have far-reaching implications for economic structure and social development [11]. Scholars argue that globalization, urbanization, and the informal economy pose a great challenge to urban ecological security, affecting the ecological footprint [12]. In addition to urbanization, regional climate and anthropogenic land-use changes can alter the efficiency of ecosystem service delivery and functions, indirectly affecting the efficiency of regional ecological value [13], [14]. Changes in the ecological structure caused by expanding human activities have destructive effects on ecosystems [15] and threaten their ecological integrity [16]. Exploring the nexus between the value of ecological products and socioeconomic development can facilitate ecological sustainability [17]. Thus, research on the factors influencing ecological value has expanded in recent years [18]. Both natural and economic development factors cause land cover changes, which, in turn, affect ecological value [19]. While research has primarily focused on economic factors, this article seeks to address the research gap by exploring the often-neglected role of institutional factors, particularly local government behavior, in influencing ecological value. This approach recognizes the importance of governance and policy interventions in achieving sustainable land management.

Scholars have conducted analyses of land finance from the standpoint of the decentralization system, arguing that tax-sharing reform is the underlying factor [20], [21]. Following the 1994 tax-sharing reform, the financial revenue share of regional governments in China showed a significant downward trend and was significantly lower than the fiscal expenditure share. This resulted in a loss of revenue-generating capacity, hindering local governments' ability to meet economic and social advancement needs. However, under the economic growth-oriented promotion assessment system, the nationalization of land and rapid urbanization in China has closely tied the land finance model to the promotion mechanisms for officials. Studies suggest that competition in the promotion of officials is more directly influenced by local government behavior. This, in turn, significantly

promotes land capitalization [22], [23]. To achieve political promotion, local governments must choose the fastest and most profitable land financing model.

Under strong pressure to promote government officials, local governments are prone to making one-sided economic decisions, favoring short-term economic interests over ecological and environmental conservation and neglecting sustainable and balanced ecological development [24]. For some time now, the central administration has been willing to reward and penalize officials based on economic progress at the district level. The stronger the dynamics of regional economic development, the greater the likelihood of official promotion, which strongly motivates these officials to prioritize regional industrial development to inject new momentum into the economy at the expense of natural ecology [25]. However, blind land expansion threatens biodiversity and undermines the provision of essential services and functions by ecosystems. Studies have investigated the current association between political promotions and ecology. The excessive pursuit of GDP growth by local governments has caused environmental pollution and ecological damage [26]. Nevertheless, scholars also consider promotion tournaments to be an effective competitive mechanism to inspire local governments' ecological governance. Meng et al. (2022) believed that the myopic actions of district officials should be avoided, starting with extending environmental appraisal indicators and upgrading the rotational performance of officials to enhancing their environmental performance aspirations [27]. In response to the national appeal, the advancement mechanism of district government officials should be optimized, and ecological protection indices should become an important method for assessing cadres' performance [28] to guarantee the realization of ecological services and functions.

Both the land finance pattern and the realization of ecological value emerged as China urbanized and industrialized, acting as a pivotal force in China's economic progress. The literature on land finance and ecological value is extensive. However, few studies have further clarified the connection between the two. Social, economic, and environmental factors mainly drive ecological value. Few studies have focused on government actions, and almost no systematic theoretical analysis framework specifies the nexus between land finance and ecological value. Although land finance has provided substantial funds for economic development, driving urbanization [29], [30] and infrastructure construction [31], [32] under conditions of political promotion, it has also significantly undermined the supply of ecosystem services and functions, wasting land resources [33]. Therefore, when analyzing land finance behavior, it is necessary to consider both positive and negative effects and mitigate the negative effects on human life and activities through relevant policies. In light of this, our research adopts the ecologization of land finance as its research guide, studies the impact of land finance on ecological value from the standpoint of officials' promotion, unravels the "mystery" of the influence of land finance behavior on the ecological value of land, and analyzes the mechanism of influence between the two. The objective is to promote the natural ecological setting and enhance the efficiency of ecological value realization through land finance policies. In summary, the primary research question of this study is: How do different land finance patterns, influenced by local government behavior, affect ecological value? By answering this question, we aim to deepen our understanding of the complex dynamics between land finance, governance, and ecological sustainability.

III. Theoretical analysis and research hypothesis

III. A. Land finance and ecological value

Land use is intimately linked to the sustainable utilization of ecosystems and terrestrial ecosystems. Irrational land use interferes with land ecosystems, causes ecological damage, leads to a decline in ecological services and functions, and inhibits sustainable human progress. Currently, China's land finance model overlooks the potential ecological risks associated with blind economic development, inevitably resulting in certain ecological costs, specifically the loss of the ecological value of land. The ecological cost of China's land finance mainly includes the following stages: in the early stage, there is a loss of ecological land value when ecological land, such as agriculture, is converted into construction land; in the middle stage, there is ecological loss caused by resource consumption during exploitation; and in the later stage, there is a cost associated with investing in the ecological value of the land after realizing the importance of ecological resources and functions [34].

During an economic transition, land resources serve as spatial carriers and input factors for urbanization and economic development [35]. Therefore, expanding urban spaces becomes urgent from an economic and social development perspective. Local governments usually expand their fiscal revenue by changing the nature of the land, and land concessions are a source of retroactive funding for infrastructure development and urbanization construction [36], [37]. However, analyzing land market transactions reveals that urban construction land represents the maximum ratio of the total land supply [38]. The land finance model, which provides ample capital and land for accelerated urbanization, also exerts significant pressure on the environment [39]. From an ecology perspective, land finance behavior reduces the extent of ecological land in China. The harmful gases and substances produced during land development and industrial construction exacerbate ecological pollution, leading

to a decline in ecological diversity, increased air pollution, and the intensification of the urban heat island effect [40]. In the process of obtaining fiscal revenue through land concessions, local authorities generally employ differentiated land concession tactics, which inevitably hampers and creates a significant imbalance in the restructuring and upzoning of urban industrial structures. To attract investments and high-quality enterprises to form a “bloc economy” and secure market share, local governments provide low-cost industrial land as well as a series of tax incentives. This unfair land concession strategy, led by local governments, gives localities greater discretionary power, results in a land resource mismatch, and profoundly affects industrial upgrading and transformation [41], posing a serious threat to the environment and sustainability of regional lands [42]. From a social development perspective, the land finance model significantly increases the urban population and influences the urban spatial structure [43], [44]. Motivated by political and economic incentives, local governments use their power to extract value from land and gain economic benefits. The expanding scope of human activities affects the structure of land, which, in turn, changes ecosystem services and functions [45], degrading ecosystems. This shows that the “land finance” behavior results from the local government’s concern for immediate benefits and disregard for future social development, to the extent of pitting economic development against ecological environment to an unsustainable extent. Land finance is characterized by an “ecological paradox.” On the basis of the above theoretical assumptions, we present Hypothesis 1:

H1: Land finance has a remarkably negative inhibitory influence on ecological value.

III. B. Promotion pressure, land finance, and ecological value

In China, local governments are an important political force with a substantial role in facilitating economic progress, enhancing regional infrastructure, fostering foreign exchange and cooperation, and exerting greater influence on business management than Western governments. Chinese officials prepare more carefully for competitions than their foreign counterparts. When anticipating a potential promotion, government officials strive to enhance their promotion prospects by improving performance appraisal indicators, such as GDP growth, adopting a short-term and impetuous approach solely to provide satisfactory answers to higher-level authorities, while their successors suffer the adverse consequences [46]. Reflecting the assumption of the “economic man,” officials in other regions influence the government's decision-making behavior and economic agents within their jurisdictions upon learning about such events. This invisible pressure for promotion emerges through the pursuit of political promotion incentives, forcing local officials to conduct competitive tournaments centered on economic growth and rapid improvements in economic development to achieve political advancement [47].

The top-down GDP-based performance appraisal system is highly directive and, while promoting China’s rapid economic development, tends to overlook the importance of the ecological environment, with negative consequences. The government’s motivation distorts the pricing of land factors, which, although beneficial for capital accumulation in industries, reduces land-use efficiency. Traditional gross domestic product (GDP) accounting neglects natural resource consumption and ecosystem development. Local officials in China have long been under promotion pressure. Although this has boosted the local economy to some extent, it had negative effects on the ecosystem, severely damaging the ecological value of land. A prominent manifestation of this is that local governments and their officials have prioritized economic growth at the expense of environmental quality, resulting in continuous environmental degradation. Under the pressure for promotion, local authorities compete with each other to formulate policies and secure more resources. The above theoretical analyses define Hypothesis 2:

H2: Competition among local officials to secure promotion has a negative influence on the ecological value of land.

Since China implemented the reform and opening-up policy, the promotion and competition model of officials, centered on economic growth goals, has fostered rapid economic progress while leading to serious environmental problems (see Figure 2). In the short term, local officials are realists, and in the pre-political period, they prioritize visual infrastructure, including municipal roads, highways, and ports, to fulfill political performance expectations. In the long term, officials inevitably shift their focus toward livelihood projects and promote infrastructure development that benefits the people to maximize the well-being of residents. Urban infrastructure construction and regional economic development require significant financial support. However, faced with the increasing financial gap, local governments seek financing through various channels, including the land finance model [29]. During the development stage, land resources with ecological services and functions, such as agricultural land, are expropriated to establish cities and industrial parks to respond to the needs of urbanization and industrialization processes. This results in the loss of positive externalities and a decline in ecosystem functions [48].

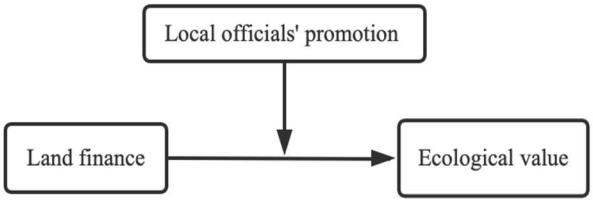

Figure 2: Analysis of the regulation of competition for political promotion.

Against the backdrop of the distinctive land system in China, the authorities hold exclusive monopoly rights over land transfer, which leads to forced expropriation practices. The behavior of “land finance” is not driven by fiscal pressure but reflects the pursuit of regional GDP [49]. In an effort to relieve the pressure of tax competition among governments and meet performance appraisal targets, local governments often choose the “tender, auction, and listing” method to sell land, generating substantial revenue for urban infrastructure construction and welfare projects aimed at promoting urbanization and improving livelihoods, which, in turn, enhances their performance [50]. However, the incentive-driven competition among local governments, which focuses on economic growth and scarce resource allocation, damages the environment people rely on and indirectly affects sustainable economic development. Therefore, maintaining a healthy competition framework is one of the secrets to sustained high-quality economic growth. Thus, the ecological issues arising from the land finance model under the influence of local political promotion incentives cannot be overlooked. Based on these observations, we propose Hypothesis 3:

H3: Competition for official promotion affects the nexus between land finance and ecological value. As the pressure for promotion increases, the adverse effect of land finance behavior on ecological value also increases.

IV. Explanation of variables and model description

IV. A. Data sources

Owing to significant data deficiencies in certain regions (e.g., Lhasa, Haidong, Bijie, Tongren, and other prefecture-level cities), this research uses panel data from 276 prefecture-level cities from 2005 to 2020; the sample distribution is shown in Figure 3. The remote sensing data were derived from the Resource and Environment Science Data Center of the Chinese Academy of Sciences (http://www.resdc.cn). These Data were obtained from the China City Statistical Yearbook, China Land Resources Statistical Yearbook, China Regional Economic Statistical Yearbook, prefectural cities’ budget tables, and data platforms such as the National Bureau of Statistics, EPS, and Land Market Network. To minimize the implications of heteroscedasticity and skewness on the empirical findings, this study uses the logarithms of land revenue, ecological value, and population density. To eliminate the effect of prices, the variables amounts were recalculated and deflated using the annual provincial Consumer Price Index (CPI), with 2005 as the base period. In addition, we performed a tailing process for each variable to avoid outliers interfering with the empirical results.

Figure 3: Sample distribution of prefecture-level cities.

IV. B. Variables description

IV. B. 1) Explained variables

This study employed land-use data to obtain statistical information on the area of various land categories in each municipality using ArcGIS 10.2 software. These data were combined with the equivalence factor table of ecological value [51] and the economic value per unit area equivalence factor. Different value amounts were assigned to ecological services and functions of different land types [52], [53]. Social development coefficients (The social development coefficient is a combination of the Peel growth curve model and the Engel coefficient to represent the willingness of the population to pay.) were applied to adjust these values as a measure of the ecological value. This approach provides a more visual and suitable way to assess the ecological value of large regional ecosystems [54], focusing on the value that the natural ecological environment can provide.

Figure 4 shows that the ecological value of land in China is unevenly spatially distributed, and the regional disparity is apparent. With the Heihe-Tengchong line as the boundary, the ecological value in the western region is clearly higher than that of the eastern region, and the overall ecological character is low in the East, high in the West, low in the South, and high in the North. The Heihe-Tengchong line serves as a distinction for population density comparison and also represents a boundary of regional environmental carrying capacity. From a spatial perspective, the area northwest of the Heihe-Tengchong line (such as Lhasa and Xinjiang) shows a higher ecological value despite lower ecological carrying capacity due to lower demographic density and a relatively low economic development level. Conversely, the area east of the Heihe-Tengchong line, especially the Beijing-Tianjin-Hebei, Sichuan-Chongqing, and Yangtze River Delta regions, bears a heavier ecological load and has higher economic and population density, resulting in significantly lower ecological value than the western regions. To promote high-quality economic growth, each region should consider local conditions and maximize potential development dividends by balancing economic development considerations with the ecological load.

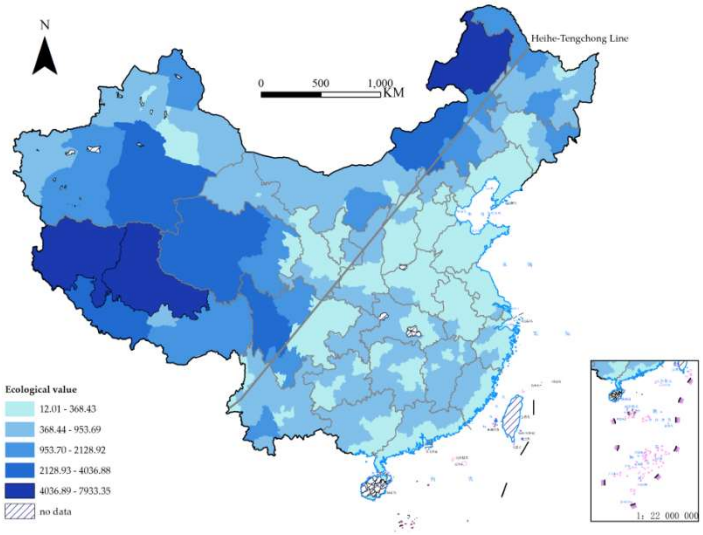

Figure 4: National ecological value map in 2020.

IV. B. 2) Explanatory variable

The explanatory variable we used was land finance, expressed as land concession revenue (Lf). Figure 5 shows that land finance revenue encompasses land concessions and also related tax and non-tax revenues, such as land value-added tax, deed tax, and land transfer fees [55]. On the basis of deficiencies and low share of land revenues in tax and non-tax revenue data of prefecture-level municipalities, this study uses land concession revenue at a narrow level as a measure of land finance [56]. To allow for comparisons in land finance revenue within the same time dimension, we deflate the size of land finance using the provincial CPI, with 2005 as the base period.

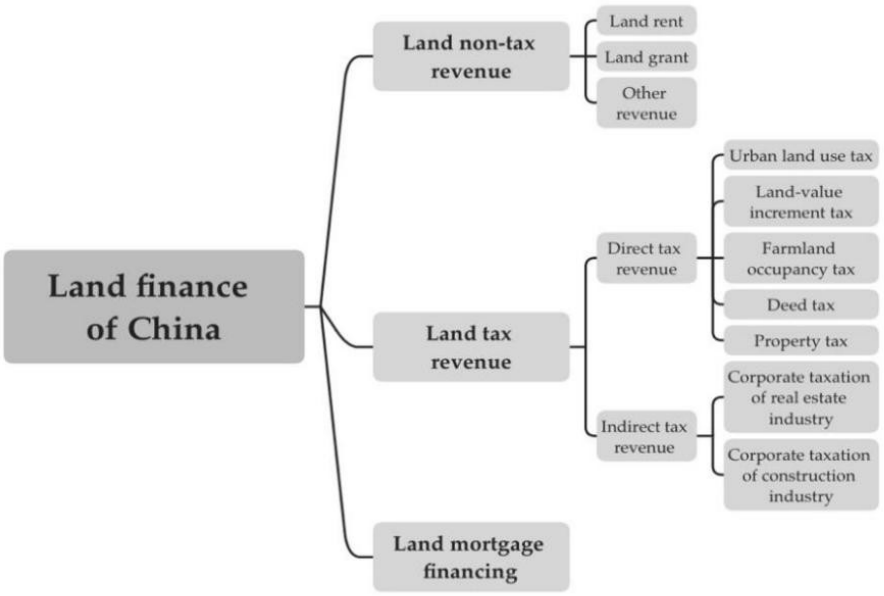

Figure 5: Map of the broad scope of land revenue.

IV. B. 3) Control variables

In relation to the selection of control variables, this study considers three aspects: economic activities, the spatial environment of human activities, and social development. For economic activities, the main selections were fixed-asset investments and industrial structures. The fixed-asset investment indicator (Invest) reflects the growth rate of capital investment in various types of physical infrastructure construction relative to regional GDP. The percentage of the tertiary industry relative to the secondary industry indicates the industrial structure (industry), which reflects the industrial composition of each region. For human activities, the indicators include the urban population growth rate (People), population density (Pd), and non-farm employment ratio (Nfp). The latter is determined using the ratio of non-farm employment to gross population because non-farm population data for each prefecture-level city has not been published since 2010; population growth rate and population density are obtained from statistical yearbooks. The spatial environment is primarily expressed using the area of roads per capita (Pr), which is an important factor reflecting urban expansion and affects the base preferences of residents within the jurisdiction. For social development, two main indicators are considered: the human capital level (Hum) and infrastructure education level (Edv). The human capital level is calculated based on the proportion of people with education at the general undergraduate level and above relative to the city's resident population. The infrastructure education level is illustrated by the number of books per 10,000 people.

IV. B. 4) Moderating variables

The promotion competition variable in this study is represented by the promotion incentive (Pro). The promotion pressure is expressed by the ratio of total real foreign investment to regional GDP as a proxy variable [57]. Under the vertical management of decentralization and centralization, local governments have sufficient initiative and motivation to attract foreign investment to develop the regional economy. Therefore, with GDP growth as the main objective, the larger the indicator, the stronger the lower-level government participation in the political competition.

IV. C. Model description

IV. C. 1) Baseline regression model

The proposed baseline regression model is as follows

$$\boldsymbol{LnEv}_{it} = \alpha_0 + \alpha_1 \boldsymbol{LnLf}_{it} + \gamma \boldsymbol{Control}_{it} + \mu_i + \vartheta_t + \tau_{it} \quad (1)$$

where $\boldsymbol{i}$ indicates prefecture-level cities, $\boldsymbol{t}$ stands for year, $\boldsymbol{LnEv}_{it}$ is the ecological value of land, $\boldsymbol{LnLf}_{it}$ represents the scale of land revenue, $\boldsymbol{Control}_{it}$ is a group of factors under control, μ_i and ϑ_t denote the fixed effects of prefecture-level cities and time-fixed effects added in the model to control for the city and time heterogeneity that is not represented in this study, and τ_{it} is the random error term. Descriptive statistics of the variables are presented in Table 1.

Table 1: Descriptive statistics for each variable.

Variables	Average value	Standard deviation	Mini value	Max value	Observations
LnEv	13.69952	0.909	11.443	15.757	4416
LnLf	12.6054	1.539	8.919	16.101	4416
Industr	0.940	0.520	0.094	5.348	4416
Invest	0.793	0.444	0.010	5.666	4416
People	5.598	5.207	−16.640	40.780	4416
Pd	5.753	0.904	1.609	7.882	4416
Nfp	0.380	0.202	0.058	1.926	4416
Pr	0.119	0.087	0.006	1.238	4416
Edv	0.652	2.382	0.010	94.490	4416
Hum	10.590	1.330	5.468	14.083	4416
Pro	1.785	1.899	0.015	9.015	4416

IV. C. 2) Moderating effects model

The above analysis indicates that official promotion competition moderates the effect of land financing on ecological value. To explore the moderation of ecological influences of land finance by promotion competition, we formulate the following model:

$$\boldsymbol{LnEv}_{it} = \beta_0 + \beta_1 \boldsymbol{LnLf}_{it} + \delta_0 \Pr \boldsymbol{o}_{it} + \delta_1 \boldsymbol{LnLf}_{it} * \Pr \boldsymbol{o}_{it} + \gamma \boldsymbol{Control}_{it} + \mu_i + \vartheta_t + \tau_{it} \quad (2)$$

where $\Pr \boldsymbol{o}_{it}$ denotes the officer's promotional competition. Decentralization was performed for better model comparison and coefficient interpretation. If β_1 and δ_1 have the same sign, then promotion competition strengthens the influence of land finance on ecological value. Conversely, if they have different signs, then promotion competition weakens the effect of land finance on ecological value.

V. Empirical results

V. A. Baseline regression

Table 2 presents the results of the regression of land finance on ecological values for the full sample. According to Models (1) and (2), we observed that the regression coefficients of land concession revenue indicators on ecological value are negative, which is significant at the 10% level. The finding demonstrates that land finance behavior negatively affects ecological value, confirming Hypothesis 1. It clearly illustrates that local governments' behavior in granting land-use rights is at the expense of ecological value. "Land finance" behavior results in the depletion of ecological resources and the "resource curse" effect. Simultaneously, the random effects Model (3) was added to the basic regression to confirm further the negative impact of "land finance" behavior on the ecological value of land. Furthermore, considering the possibility of a longer time-lag effect, the land finance variables and control variables are replaced with their lagged one-period terms, as shown in Model (4), where the results demonstrate a pronounced time-lag effect. This can be attributed to the considerable time gap between land acquisition by local governments and the completion of industrial enterprises or residential building sites. Consequently, the occurrence of "land finance" behavior and its ecological effects are not synchronized, underscoring the presence of a time lag in the ecological effects of land finance.

Table 2: Baseline regression results.

Variables	Model (1)	Model (2)	Model (3)	Model (4)
LnLf	−0.016** (0.005)	−0.014* (0.007)	−0.020** (0.008)	−0.016* (0.008)
Industr		0.046* (0.025)	0.049* (0.026)	0.043 (0.028)
Invest		0.014 (0.015)	0.021* (0.011)	0.005 (0.019)
Pd		−0.316*** (0.090)	−0.386** (0.174)	−0.307*** (0.101)
People		−0.002 (0.001)	−0.002 (0.002)	−0.002 (0.001)
Nfp		−0.195*** (0.062)	−0.199*** (0.054)	−0.242*** (0.073)

Pr		−0.185*** (0.060)	−0.269 (0.196)	−0.107*** (0.092)
Edv		0.006*** (0.001)	0.007*** (0.001)	0.007*** (0.002)
Hum		0.085** (0.030)	0.092*** (0.029)	0.106*** (0.035)
Time effect	Yes	Yes	Yes	Yes
Individual effects	Yes	Yes	NO	Yes
Constant	13.552*** (0.052)	14.492*** (0.295)	12.916*** (0.272)	15.054*** (0.362)
Hausman	P=0.000			
Observations	4416	4416	4416	4416
R2	0.2390	0.2470	0.2970	0.2072

Note: Robust standard errors are presented in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

With regards to the control variables, the coefficients of fixed-asset investment and industrial structure are positive, indicating that both positively affect the ecological value of land. While cities inevitably increase resource exploitation in their economic activities, they also exert positive ecological effects. For example, the rationalization and upgrading of industrial structures can reduce pollution, and financial support for ecological management can be strengthened, effectively promoting the continuous improvement of regional ecological services and functions.

Human activity differs from economic development status. Table 2 shows that both population density and the degree of non-farm employment have a remarkably negative influence on the ecological value. Human activities affect the ecological value of land in the region primarily by influencing land-type patterns, especially in areas with dense vegetation [58]. Urbanization leads to a large influx of migrant workers into cities. The influx of people from the rural areas provides sufficient labor for cities and drives the urbanization process. In addition to human activities, the loss of ecological value is mainly due to the reduction of ecological land use triggered by urban sprawl [59]. Hence, population urbanization can have a significantly detrimental influence on ecological value.

From a spatial environmental perspective, the per capita road area ownership exhibits a remarkably negative effect on the ecological value of land. One possible explanation is that the constant expansion and development of urban construction land, aimed at providing space for regional economic development, has a severe impact on ecosystems and the supply of ecological products. From the standpoint of social advancement, both infrastructure education facilities and the level of human capital have a significantly positive influence on the ecological value of land. Improvement in the level of urban basic education facilities allows citizens to enjoy education and cultural services equitably, promoting social welfare effects and resident satisfaction, and also further enhances the public ecological consciousness and the practical effectiveness of participation in environmental governance.

V. B. Robustness tests

V. B. 1) Substitution variables

Regarding the indicators of land finance, this study uses land concession revenue as a measure. However, other scholars have proposed other measures. The first is the proportion of land concession revenue to fiscal revenue, which reflects the drawing capacity of local governments. Another is the area of land concession, which partly indicates the scale of land finance; thus, the base regression also includes the natural logarithm variable of the land concession area. Because of missing data, the time span of the area of land concession runs from 2005 to 2017. Therefore, both were used as robustness tests in this study. Columns (5) and (6) show the share of land finance revenue in Table 3, while columns (7) and (8) represent the area of land concessions. Replacing the explanatory variables still yields similar results. Although the estimated coefficients of the core independent variable, land finance, have changed to some extent, the significance level does not change significantly. Hence, the outcomes of this study are highly robust and support Hypothesis 1. The study confirms that the behavior of “land finance” has a negative and pronounced lagging effect on ecological value.

Table 3: Robustness test.

Variables	Model (5)	Model (6)	Model (7)	Model (8)
LnLf	−0.091** (0.042)		−0.022*** (0.006)	
L. LnLf		−0.083**		−0.020***

		(0.036)		(0.005)
Control variables	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes
Individual effects	Yes	Yes	Yes	Yes
Constant	14.380*** (0.284)	14.229*** (0.553)	14.536*** (0.318)	14.809*** (0.320)
Observations	4416	4416	3588	3588
R2	0.2067	0.2072	0.2472	0.2070

Note: Robust standard errors are presented in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

V. B. 2) Endogeneity test

Due to the variable-setting problem, there may be an interaction between land finance and ecological value, which affects the stability of the empirical findings. To support the robustness of the regression test, this study employed a two-stage least squares test using instrumental factors to adjust for endogeneity. To satisfy the requirements of “relevance” and “exogeneity” of the instrumental variables, this research uses the interaction of the average slope value of each city and the transfer payment to fiscal revenue as the instrumental variables of land finance from the perspective of both the supply and demand sides of land finance [60]. On the supply side, each city's average slope is a descriptive variable that shows different levels of revenue from land financing at the individual level. The share of transfer payments in fiscal revenue is reflected as a time-level change from the demand side, which can effectively address the degree of fiscal imbalance, protect the financial resources of local governments, and alleviate local dependence on land finance to a certain degree. The specific regression findings are shown in Table 4.

In Table 4, the first column shows the first-stage regression and the second column shows the second-stage regression results. The results of model (9) show that it is logical to use the average urban land slope and the proportion of transfer revenue as instrumental variables. The instrumental variables are significantly negatively correlated with land fiscal revenues, and the F-value in the first stage is significantly greater than 10, implying that the instrumental variables are of a good nature and there is no problem with weak instrumental variables. The findings reveal that the land finance indicator maintains a good significance level, which is in accordance with the base regression results, confirming the accuracy of the empirical results. This result indicates that the “land finance” policy has a remarkably negative influence on the regional ecological value.

Table 4: Endogeneity test.

Variables	Model (9)	Model (10)
LnLf_IV	-0.009*** (0.003)	
LnLf		-0.518* (0.308)
Control variables	Yes	Yes
Time effect	Yes	Yes
Individual effects	Yes	Yes
Phase I F-value	77.58	

Note: Robust standard errors are presented in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

V. C. Heterogeneity analysis

According to Table 5, the estimated coefficients of land concession revenue in the eastern region are all in the negative and significant range, which is consistent with the national sample test results. The next column shows the test results in the remaining regions of China, where the estimated coefficients of land finance are no longer significant and are obviously lower than those in the eastern region. Owing to the context of economic evolution in China's eastern region, local governments often attract foreign capital, excellent talent, and a large amount of labor to improve regional economic capacity and compete for limited resources. Due to the high demand for urban space and additional financial resources, utilizing land resources for urban expansion has become the best choice for local governments. However, under relatively limited land resources, extensive urban expansion can easily damage the original ecosystem and generate more urban diseases, which can also result in environmental and ecological problems. The economic development intensity and population activity range of the central and western areas are far less than those of the eastern cities, their land resources are comparatively plentiful, and the actual

land fiscal revenue scale is relatively low. This is also the result of the difficulty for cities to develop in these regions. Therefore, the negative influence of increasing land fiscal revenue on the value of ecosystem services will be far less than that of the eastern region.

Table 5: heterogeneity test.

Variable	Eastern Region	Central and Western Region
	Model (11)	Model (12)
LnLf	−0.035** (0.014)	−0.003 (0.009)
Control variables	Yes	Yes
Time effect	Yes	Yes
Individual effects	Yes	Yes
Constant	18.983*** (0.807)	12.879*** (0.953)
Observations	1568	2848
R2	0.4168	0.1995

Note: Robust standard errors are presented in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

V. D. Moderating effect test

Table 6 represents the results of the regression with the inclusion of competition for promotion. The results show that competition for political promotion adversely affects ecological values, confirming Hypothesis 2, which suggests a strong negative relationship between the promotion competition variable and ecological values. The negative sign of the interaction term in Model (14) aligns with the main effect of baseline regression, indicating that higher promotion pressure among local officials intensifies the negative effect of “land finance” behavior on ecological value, thus supporting Hypothesis 3. At the same time, the interaction term's coefficient is significant, which implies that there is noticeable moderating effect.

To ascertain the robustness of the empirical findings, we conduct a further robustness estimation using a systematic generalized method of moments (GMM) based on a test of moderating effects through a fixed-effects model. In the systematic GMM estimation, the lagged one-period term and lagged two-period term of the independent variables are used as endogenous variables. The findings imply that the impact of land finance on ecological value is clearly negative, and the coefficient of the interaction term with promotion pressure is negative and significant. This is in accordance with the fixed-effects regression results. Therefore, it is unreasonable to disregard official promotion pressure's negative effect on ecological value realization and environmental pollution.

China’s governance structure has an important influence on the government’s economic behavior and shapes the underlying incentives for political promotion. Promotion incentives affect the behavior of officials during alternating periods, creating land finance behavior, which in turn influences the provision of regional environmental and ecological values. It is essential to optimize government officials' performance evaluation system continuously so as not to judge champions according to GDP; additionally, it is essential to increase the proportion of ecological appraisal indices, which will help localities determine a development model that is consistent with a green economy.

Table 6: Regression results of moderating effects.

Variable	FE		GMM	
	Model (13)	Model (14)	Model (15)	Model (146
L.LnEv			0.611*** (0.052)	0.577*** (0.056)
LnLf	−0.015** (0.007)	−0.016* (0.008)	−0.049* (0.026)	−0.059* (0.032)
Pro	−0.009** (0.004)	−0.008** (0.004)	−0.228*** (0.070)	−0.255*** (0.081)
LnLf* Pro		−0.004** (0.002)		−0.071* (0.038)
Control variables	Yes	Yes	Yes	Yes
Time effect	Yes	Yes	Yes	Yes
Individual effects	Yes	Yes	Yes	Yes

AR(1)			0.000	0.001
AR(2)			0.181	0.107
N	4416	4416	4416	4416

Note: Robust standard errors are presented in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

VI. Conclusions and policy implications

VI. A. Conclusions

Political promotion incentives are the main motivation for local officials to promote the land finance model; however, when local officials blindly engage in economic activities, it has serious implications for the region's ecological value. Based on analytical leads from both theory and empirical studies, this study drew two conclusions. First, land finance behavior has a significantly inhibitory effect on ecological value, and there is a temporal lag effect. Second, regarding the moderating effect of promotion competition, local officials' promotion pressure has significantly acted as a moderator between land finance and ecological value. Promotion pressure undeniably distorts officials' economic development behavior, harming the ecological environment, which, in turn, affects residents' overall quality of life.

VI. B. Policy implications

This study proposes three policy recommendations to realize the blueprint of "Lucid waters and lush mountains are invaluable assets."

First, it is essential to optimize the land transfer system. Local governments should avoid prioritizing short-term gains over long-term ecological and environmental protection. Green development should not replace genuine long-term policies and government tools for ecological and environmental protection with superficial landscape effects. Instead, ecological environment should be a cornerstone of people's well-being, while high-quality development is promoted through quality ecological products, public satisfaction and happiness, and a robust ecological barrier and sustainable circular economic development are effectively established.

Therefore, the state should innovate "green land" concessions, discourage "bottom-up competition," and foster fair and healthy competition in the land market. Localities should explore a model of state land concessions that integrates ecological value, continuously enhances ecological advantages, and enables neighboring residents to benefit from ecological dividends. This will gradually transform ecological advantages into developmental advantages. Such an approach reflects the collective ownership of natural resource assets, ensures the safety and preservation of natural resources, supports social and economic development, and promotes a green economic model of "taking from the ecology and using it for the ecology."

The second recommendation is to improve the political promotion appraisal system. Previous performance appraisals of local officials have tended to focus excessively on the growth rate of regional socioeconomic development, disregarding the cost to the occupied ecological environment and the implication for ecosystem services and functions due to environmental pollution. The deviation from the fundamental interests of the people neglects the natural environment and ecological satisfaction of the masses. In other words, the traditional economic model that excessively prioritizes immediate effects and resource consumption can no longer adapt to the needs of high-quality economic development. This is particularly evident in residents' quality of life and limited economic development. Therefore, China must embark on the path of sustainable development and gradually move away from the "GDP-only" theory.

Finally, the nexus between economic development and ecological conservation must be reconciled. A performance appraisal mechanism for local officials should be established, which reflects the requirements of ecological civilization. It should use environmental consideration as a leading tool for performance assessment. This means that the appraisal of local officials should place more emphasis on non-economic indicators such as ecological value and public satisfaction. Additionally, a green GDP assessment system should be established to highlight ecological protection and incorporate ecological and environmental performance into the performance appraisal system for local officials [61]. Under the adage "After the political voice is gone, public opinion is being talked about," officials who seek a favorable political reputation should be encouraged to adopt a correct view of "green" performance so that promotion incentives can develop in a positive direction. By strictly implementing accountability mechanisms, it is possible to effectively curb unhealthy competition among local officials, preventing excessive and blind exploitation of land resources and promoting a green and safe ecological environment. An assessment system for officials' ecological performance should be established to maximize people's fundamental interests and achieve tangible green accomplishments in line with the scientific concept of development.

Author contribution

All authors contributed the conception and design of this study.Conceptualization, Huilin Xia and Jia Ding; Data curation, Jia Ding; Formal analysis, Huilin Xia; Funding acquisition, Huilin Xia; Investigation, Yuchi Shen; Methodology, Jia Ding; Supervision, Yuchi Shen; Visualization, Yuchi Shen; Writing – original draft, Huilin Xia and Jia Ding; Writing – review & editing, Huilin Xia and Yuchi Shen.

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Data Sharing Agreement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethical Approval

No ethical approval was required as it did not involve the collection or analysis of data involving human or animal subjects.

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