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The establishment of the national key ecological functional zone and the county's ecological green development

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Ecological green development is the development of conforming to nature and promoting the harmonious coexistence of man and nature. As the most basic and supportive grassroots political unit, the county level occupies a special key position in the overall national green development strategy. How to evaluate the ecological green development of the county, protect the green earth, and respond to climate change, have become a new problem facing various countries around the world. To this end, China is determined to implement the establishment of a national key ecological functional zone pilot policy to study its ecological green development from the perspective of the county. Based on the literature review and theoretical mechanism, this paper selects 1997 county-level data indicators in mainland China from 2007 to 2019 to explore the role of the establishment of national key ecological function areas on the ecological green development of counties. The implementation of the national key ecological function zone policy can significantly increase the vegetation normalization index by about 0.035–0.037units. The implementation of the policy has greatly expanded the capacity and range of above-ground and below-ground biomass. The reduction of large-scale investment by the government, the improvement of quality and efficiency of enterprises in the region, and the increase artificial afforestation are important transmission mechanisms for the implementation of policies to affect the green development of counties. The implementation of the policy has a positive green spillover effect on adjacent areas, which can realize regional coordinated ecological governance. Each additional hectare of artificial afforestation can absorb about 134,800 tons of carbon emissions each year, bringing additional benefits of 730 million yuan. It releases about 98,000 tons of oxygen a year, which can be used for 1.312 billion people for oxygen respiration consumption every year.

KEYWORDS

green development, national key ecological function area, mechanism analysis, ecological benefits, policy evaluation

1. Introduction

Sustainable spatial development should consider the settlement between human-dominated land use and the protection of nature, landscapes, ecosystems, and biodiversity, in accordance with the current needs of the society considering the spatial levels and temporal horizons (Pătru-Stupariu and Nita, 2022). The construction of ecological civilization is a long-term plan related to the well-being of the people and the future of the nation. After entering the stage of industrial

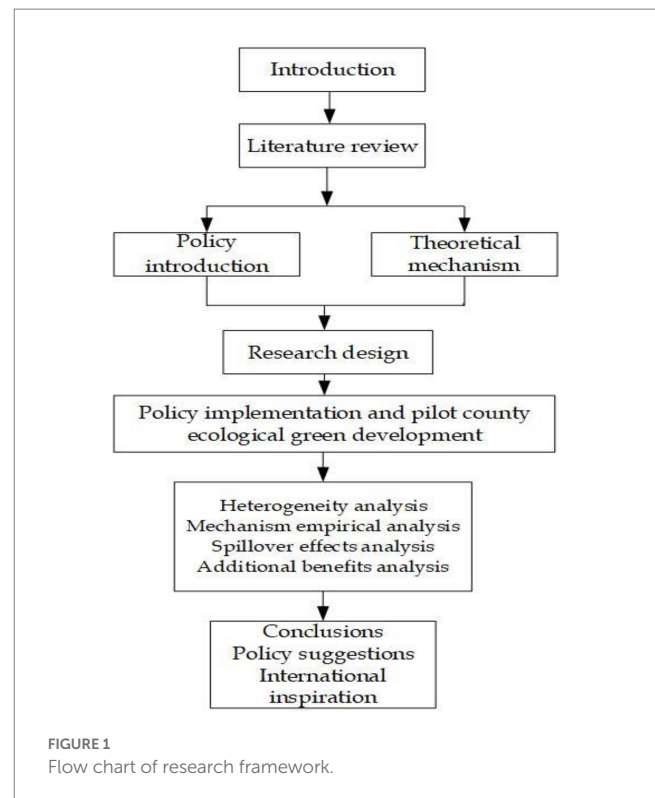
civilization, human beings have created unprecedented material wealth, and also produced irreversible and reparable ecological scars. As the main contradiction in society has transformed into the contradiction between the people's growing needs for a better life and unbalanced and inadequate development, the people's need for a beautiful Chinese ecological environment has become a key aspect of this contradiction. Under the new development situation, the national key ecological function area is an important measure to promote the construction of ecological civilization, an important path to implement the concept of green development, and an important task to optimize the spatial pattern of the country and build a beautiful China.

National key ecological function areas refer to the national ecological security-related areas responsible for water conservation, sand fixation and wind protection, soil and water restoration, and biodiversity maintenance. Its main function is to: (1) In the process of land and space development in this area, large-scale, high-density, high-intensity industrialization and urbanization development and construction are restricted. (2) On the basis of clarifying the direction of industrial development, strengthen ecological environment law enforcement supervision, testing and third-party evaluation. (3) Expand county-level ecological compensation and transfer expenditures. (4) Reduce and prevent disturbance and damage to ecosystems by setting environmental thresholds and negative lists. (5) Maintain and enhance the production and supply capacity of regional ecological products. (6) Expand the natural ecological living space.

Promoting the construction of key ecological function zones is a new requirement, new goal, and new measure proposed by the state to promote regional ecological civilization construction, green development, and improve the quality of the ecological environment from a strategic perspective. Its strategic significance and necessity are beyond doubt. How to keep the ecological environment red line and ensure that the ecological function system is not reduced, testing the wisdom and responsibility of the county-level government. How to actively explore the new ways of comprehensive governance of regional ecological functions, innovate regional protection and green development mechanisms, and explore the new model of the harmonious development of regional humanities and natural sciences is a new challenge facing the sustainable development of the county's ecological (Figure 1).

The marginal contribution of the article may lie in:

1. The first is to explore the impact of the ecological green development of the county with the help of the national key ecological functional zone policies. The mechanism that affects the implementation of the county's ecological green development by studying policies can actively explore and take the lead in implementing a new way to organically combine the county's ecology priority and green development.
2. The second is to study the green spillover effects of policy implementation on neighboring regions. This will help strengthen the co-governance and joint protection of ecological space and build a higher-level green collaborative governance mechanism.
3. The third is to conduct regional heterogeneity analysis of policy implementation. Under the circumstance of giving priority to ecology, seek the best balance between people's livelihood security and green development.



4. The fourth is to conduct additional benefits analysis. Green vegetation is an important economic and environmental asset. By giving full play to the carbon sink value and carbon sequestration capacity of green vegetation, this shows from the side that policy implementation can better serve the overall situation of China's carbon reduction.

2. Literature review and theoretical mechanism

2.1. Literature review

2.1.1. A review of foreign literature

Developed countries such as the United Kingdom, France and the United States continue to promote the reform of ecological and environmental policies and management organizations, improve the legislative and management capabilities of environmental policies, and comprehensively use a variety of policy tools to develop a green economy (Shaofu, 2016). Forest ecosystems play a key role in protecting water resources, with forest/water conservation programs delivering an average of \$154 million in clean water benefits annually, with a significant portion of this value tied to policy processes (Kreye et al., 2016). In order to achieve ecologically sustainable development goals and achieve balanced development among economic growth, social well-being and environmental protection, Asian countries have been trying various approaches to restore degraded natural resources and ecosystems (Hasan, 2020). Relevant governments should realize that the ultimate goal of environmental protection is to improve human livelihoods, not just restore vegetation, and poverty eradication

through the development of sustainable enterprises is a prerequisite for successful ecological restoration (Cao et al., 2010). The theory of ecological modernization has gradually evolved into a possible strategy for the developed industrial countries to solve the current ecological and environmental problems. This theory shows that strict government regulation can help solve ecological and environmental problems, and at the same time can promote the industry to be more competitive (Murphy and Gouldson, 2000). Agricultural development can still make progress in economic growth under the shadow of ecological crises, droughts, floods and humanitarian crises, because it requires arrangements in land management and the application of agricultural development technologies (Summase et al., 2019). The Environmental Impact Assessment have often been found to be of poor quality given the struggles that Romanian cities are facing in balancing economic, social, and environmental needs in terms of spatial land-use conflicts (Nita et al., 2022). The duty of leading the Environmental Impact Assessment procedure belongs to each county's Environmental Protection Agency (EPA), based on the project's location. All 42 counties in Romania have a regional EPA, which is responsible for the proper application of the Environmental Impact Assessment Directive. As a post-communist country, Romania has the same difficulties in Environmental Impact Assessment implementation as other developing countries resulting in a slowdown in the ongoing integration of EU directives. Considering the poor quality of the reports, especially in developing countries, there is an urgent need to analyze of the quality of EISs (Gavrilidis, 2019). The strategic interaction of inter-regional environmental regulation is a typical feature of local government behavior in China, which can affect the growth of local green productivity through the Potter effect and the pollution refuge effect (Peng, 2020). The government should continue to pay attention to the green innovation ecosystem to promote the green collaborative innovation activities of the government-university-industry alliance (Yang et al., 2021). Governments in the regions where the Danube flows are actively building a sustainable process of cooperation, information sharing and monitoring. As co-stakeholders, future actions follow a uniformly set development framework (Vucic, 2012).

In summary, most foreign literature only uses section data, case descriptions, case analysis, and enumeration of the region after the implementation of the policy. However, the above analysis methods did not consider the reverse causality in the process of empirical. To solve this problem, the article uses the DID method of the panel data for empirical estimates. DID method can eliminate the impact of mixed factors, and panel data can simply process multiple fluctuations.

2.1.2. A review of domestic literature

In terms of economic development, compared with the non-experimental group, the implementation of the national key ecological function zone policy can promote the treatment group's GDP growth rate and *per capita* GDP by about 6.9 and 7.1%. This helps to reduce the degree of labor space mismatch and accelerate the transformation and upgrading of the industrial structure (Fei and Guiyang, 2021). However, there is an economic disparity gap in this growth within each region, which is caused by the input of labor and capital factors, the output efficiency of input factors and the mode of production structure (Ying et al., 2020). From 2000 to 2010, the proportion of ecological land in the national key ecological function areas exceeded that of the non-key ecological function areas.

Compared with non-key ecological function areas, the degree of conversion of land vegetation cover types is smaller (Xu et al., 2019). The industrial base in the main ecological functional area is weak, the infrastructure and equipment are outdated, and the attractiveness of high-quality talents is not enough. There is still a considerable gap between the development of ecological and green industries in developed areas such as coastal areas in my country, but the development of low-carbon tourism can drive the economy (Junlin and Guosheng, 2018). While the implementation of the policy will increase the fiscal expenditure of the local government, it will also restrain the fiscal revenue of the local government and expand the fiscal revenue and expenditure gap of the local government. Counties with larger gaps in fiscal revenue and expenditure have stronger incentives for local governments to develop industries, thus facing the risk of further aggravated environmental pollution, and the level of basic public service supply has not been significantly improved (Shixian and Qi, 2021). Ecological compensation should internalize the costs and benefits of ecological protection. Considering from a longer time horizon, the county-level government can increase the horizontal compensation of other regions to the national key ecological function areas to control the imbalance of interests in adjacent regions (Wenfei, 2020). National key ecological function areas should promote the innovation of natural resource management system, scientifically care for the "mountain-water-forest-field-lake" ecological community, and build a diversified political performance assessment content and a negative list system for industrial access (Chengshu and Shifeng, 2017).

National key ecological function areas are conducive to the sustainable development of the ecological environment. The implementation of the policy can effectively control the spread of desertification, effectively curb soil erosion and soil wind erosion, effectively restore water bodies and wetlands, and greatly improve water conservation and soil conservation services. However, ecosystems and biodiversity have been degraded, and the windbreak and sand fixation services have declined as a whole (Liu et al., 2018). The implementation of ecological transfer payment has effectively improved the ecological environment of the counties and urban areas where the national key ecological function areas are located. The ecological environment status index of such areas has increased by about 3.4 units on average, and the comprehensive score of the ecological environment has increased significantly by about 4.5% (Yan and Honghua, 2020). The implementation of the national key ecological function zone policy has increased the afforestation area in the county by about 7%, but this effect also shows a downward trend over time (Dan, 2021). From a regional point of view, the proportion of ecological land in key ecological function zones in the central and eastern regions of my country with high population density and relatively developed economy is generally low, while the proportion of ecological land in western regions with less population is relatively high (Chen et al., 2018). After the Qinba Mountains in China were designated as key national ecological function zones, the average net primary productivity, total soil conservation and total water conservation were 2.595 g C/m², 581 million tons and 2.495 billion cubic meters higher than those in the non-designated group (Hanshou et al., 2022). The green poverty reduction effect of the biodiversity ecological function area in Qinba Mountains is significantly better than that of the hills and ravines of the Loess Plateau and the ecological function area of soil protection. The green

poverty reduction rate and intensity of the national-level poverty-stricken counties in the national key ecological function zones also significantly exceed those of the non-poor counties (Guoping and Shengzhi, 2018). Taking the key ecological functional areas of tropical rain forests in the central mountainous area of Hainan Island as a sample, it is found that the forest coverage ratio of the functional areas is about 85%, which is significantly higher than the expected average value of Hainan Island. The average human disturbance index of the functional area in the central mountainous area of Hainan Island is about 0.37, which is 0.12 lower than that outside the functional area, and the degree of biodiversity threat is significantly smaller, which can promote the protection of regional biodiversity (Peng et al., 2018). Although policy implementation has improved forest coverage to a certain extent, regional biodiversity has been continuously destroyed, soil erosion has become increasingly serious, and water quality has also deteriorated due to the application of pesticides and fertilizers (Ximing and Yang, 2018). County-level units should implement more diversified eco-environmental strategies to boost regional policy coordination and regional cooperative development, so as to achieve efficient green space governance as scheduled (Weiping et al., 2019).

In conclusion, policies such as ecological protection and green governance in national key ecological function areas can promote regional economic growth, but there are inconsistent views on the impact on ecological green sustainable development.

2.2. Theoretical mechanism

How to rationally use the advantages of ecological resources, deal with the environmental pollution caused by economic growth, and reduce the impact of the modernization process on the green ecology is an important challenge facing human beings today. As a strict environmental regulation policy, the construction of national key eco-industrial parks always adheres to the development concept of ecological dominance and protection priority, and adheres to the experience and practice of putting people first and restricting development.

2.2.1. Government investment in construction

First, the pilot counties obey relevant policy requirements and strictly control large-scale investment and development activities. The pilot counties will no longer invest in the construction of various types of development zones. Existing industrial development zones should reduce the intensity of resource consumption and pollution emissions, so as to realize the sustainable cycle of the park. The pilot counties resolutely put an end to the expansion of the original industrial development zone in the region to free up more space for maintaining a virtuous circle of green ecosystems (Casazza et al., 2021). Second, the government has greatly reduced investment and construction expenditures for unnecessary industries, efficiently utilized the stock construction land, and increased the area of ecological green coverage. The county actively cultivates an ecological industry network system, strictly implements the national energy conservation and emission reduction policy, and promotes the continuous reduction of the total pollutant discharge in the region. The pilot counties continue to optimize the industrial spatial structure within the region, make

overall planning for production, living and public service areas, and prohibit sprawling development and expansion (Chen et al., 2021).

2.2.2. Improve quality and efficiency of enterprises

First, the county government, in accordance with the principles of ecological function restoration and conservation and restoration, clarifies the industrial layout and future development direction, and implements more targeted policies and standards for industrial access and environmental access. The county-level government has continuously raised the industrial and environmental thresholds for various development projects, and projects that run counter to the construction goals of the main functional areas are not allowed to enter. The government implements the extension, expansion and reconstruction of the industrial chain to form the development advantages of industrial ecology and ecological industrialization. Second, for the original industries that do not meet the main function positioning, the county government should vigorously promote industrial gradient transfer, shut down and ban, integrate and relocate, rectify and upgrade, or eliminate and withdraw through means such as facility depreciation, financial loans, and land concessions. The government uses the vacated land to actively build ecological projects such as greenways, thereby reducing human disturbance to the natural ecosystem and preventing irreversible damage to the green ecosystem. Third, according to the carrying capacity of regional resources and environment, the government will support key ecological function areas to moderately develop and utilize characteristic resources, and develop suitable industries rationally, without affecting the positioning of main functions and without damaging ecological functions. The county-level government introduces and cultivates innovative talents, highlights the main position of enterprise innovation, enhances scientific and technological support capabilities, and strengthens the carrier of scientific and technological innovation of enterprises. The county-level government can accelerate the transformation of scientific and technological achievements, promote the pace of innovation and entrepreneurship, build a modern industrial innovation-driven system, and develop high-end emerging green and low-carbon industrial clusters (Zhuo and Deng, 2020). Fourth, the government vigorously promotes clean production and the development of circular economy, actively promotes the reduction, resource utilization and harmless treatment of industrial solid waste, strengthens the implementation of clean production audits of key enterprises in the region, and ensures that pollutant emissions standards (Hh et al., 2021).

2.2.3. Artificial afforestation area

First, the government has continuously formulated and issued policies and regulations on ecological compensation and green planting, comprehensively delineating ecological red lines and environmental quality bottom lines, and strengthening ecological protection supervision. The government strictly follows the regulations to transfer funds from financial transfer payments to protect the ecological environment and improve the level of basic public services. The government coordinated the implementation of ecological restoration and environmental governance projects, and actively explored the market-based governance model of abandoned land. By

linking land development and other ways, the government restores abandoned areas into a comprehensive ecosystem, and comprehensively expands the supply of high-quality ecological products.

Second, the county government constantly insists on taking ecological improvement as a guarantee for transformation and development, emphasizing that measures should be taken according to local conditions, scientific, rational and classified promotion of large-scale land greening actions. The government comprehensively controls soil erosion, promotes desertification and rocky desertification in an orderly manner, and implements comprehensive ecological protection and restoration projects in key areas. The implementation of the policy will help the county to continuously increase the forest accumulation area and continuously improve the carbon sink and purification function of the ecosystem (Littleton et al., 2021).

3. Experience analysis strategies

3.1. Methods and variables

DID method. The difference in difference method (DID method) is a policy assessment method. This method uses the county's county as a processing group. The county area that does not conduct a pilot is used as the control group. Compared with the control group, under the prerequisite for meeting the parallel trend in advance, the influence that the impact caused by the impact of the policy after the comparative processing group is regarded as a policy effect, that is, the estimation coefficient in the model. Based on the county name list of national key ecological function areas, the benchmark regression model is constructed as follows:

$$Y_{it} = \zeta + \gamma DID_{it} + \nu X_{it} + \vartheta_i + \psi_t + \mu_{it}$$

Among them, i represents the county individual, t represents the year; Y represents the explained variable. The key explanatory variables γ represent the impact of the national key ecological function zones on the green development of the county. The model adds a series of covariates X_{it} , controls for time and county fixed effects, adds random disturbance terms and estimates using county-level clustering robust standard errors.

3.2. Variable selection

Explained variable: The normalized index of vegetation (NDVI) was used as a proxy variable for green development ($Gredev$). Because of its wide monitoring range and high correlation with indicators such as biomass density, vegetation coverage, and leaf area index to quantify plant growth or physiological status, NDVI can be used in many aspects, all-round, wide-field and deep-level Comprehensive evaluation of vegetation cover and its growth vitality. NDVI reflects the radiation quantification value of the relative abundance and activity of green or vegetation, and has gradually become the main indicator to characterize the green development of surface vegetation. In addition, following the practice of Piao et al. (2004), the estimated aboveground biomass density ($Lndabio$) and

belowground biomass density ($Lndubio$) were used for robustness testing.

Control variable: economic development ($Lnpergdp$), measured by the logarithm of the ratio of the actual GDP of the county to the population of the county; Industrial structure ($Upais$), represented by the advanced index of county industrial structure; The education level ($Oeduc$) is represented by the ratio of the number of students in ordinary middle schools in the county to the population of the county. In the era of knowledge economy, the penetration rate and quality of education in a region determine the level of human capital efficiency and the level of civilizational literacy values in that region. Education has a reinforcing effect on environmental behavior. The scale and level of education can increase and publicize knowledge about ecological environmental protection and create a good atmosphere for protecting ecological vegetation and green space. Communication facilities ($Teleinst$), measured by the proportion of the county's fixed-line and mobile phone users in the county's population. Financial credit ($Ocredit$) is represented by the ratio of the balance of domestic and foreign currency loans of financial institutions in the county area to the actual GDP of the county area at the end of the year. Financial credit fund services form a strong support for the development of green economy. Financial credit can actively change the flow of credit funds, so that financial resources can better flow into clean and low-carbon or modern industries, and force the green transformation and transformation of polluting industries. The natural condition ($Sonat$) is represented by the county's average annual rainfall.

3.3. Samples and data

The data for the list of national key ecological function zones comes from the "Documents of the State Council" column on the official website of the Central People's Government of the People's Republic of China. The county-level normalized vegetation index (NDVI) data was obtained from MODIS¹ with a spatial resolution of 500 m. The value range of NDVI (Normalized difference vegetation index) is $-1 \sim 1$. Negative values indicate that the ground cover is cloud, rain, water, snow, etc., highly reflective to visible light. 0 means there is rock or bare soil. A positive value indicates that there is vegetation coverage, and it increases with the degree of vegetation coverage in the county. The area of artificial afforestation in the county comes from the afforestation section of counties in the "China Forestry Statistical Yearbook." The original precipitation data in the county area comes from the National Meteorological Science Data Sharing Service Platform – China's Surface Climate Data Daily Value Dataset (V3.0), and the county area is calculated using the Barnes method (using the IDW method to interpolate into grid point data, and then average across regions). annual average rainfall data. The county-level patent data comes from the website of the State Intellectual Property Office. Other data come from the "China County Statistical Yearbook" and the statistical yearbooks of various provinces (cities and autonomous regions) over the years. If there is a problem

1 <https://modis.gsfc.nasa.gov/>

of missing data, the CSMAR database and EPS database are used to fill in (Table 1).

4. Empirical analysis

4.1. Regression analysis

The problem considered in this article is the role of the construction of national key ecological function zones on the green development of the county. The benchmark regression in Table 2 estimation results show that the estimated coefficients of models (1)–(6) are positive numbers, and all pass the 1% confidence level test. The

empirical test preliminarily shows that the implementation of the national key ecological function zone policy can increase the coverage of regional ecological vegetation, expand the above and below biomass density, increase biodiversity, and improve the quality and stability of the ecosystem. No matter whether the control variable is added or not, and whether it is clustered at the county level or not, the positive significance of the core parameters still holds true.

After the implementation of the policy, the county government has continued to promote the transformation of the economic development model from extensive to intensive, improve the efficiency and output rate of production factor resources energy, realize the sharing of factor resources and industrial symbiosis. The government continuously implements the new development concept, gives play to regional industrial characteristics and location advantages, promotes industrial transformation and upgrading in the park, promotes the deep integration of innovation chain and industrial chain, and strengthens the close integration of ecologically advantageous industries. In summary, policy implementation effectively alleviates the resources and environmental pressures faced by the green development of the county.

The government has always adhered to the implementation of the overall management of the ecosystem, established and improved the regional ecological compensation mechanism, expanded the living space of ecological vegetation, explored a new path for the sustainable transformation and development of ecological green, improved the ecological quality and resilience of the county, and realized the inclusive development of man and nature.

In accordance with the principles of increasing carbon sinks and reducing carbon sources, county governments anchor biodiversity conservation within the region, improve biodiversity conservation policies regulations, and innovate mechanisms for sustainable use of biodiversity. The government has established a complete monitoring

TABLE 1 Descriptive statistics of variables.

Variable	Mean	SD	P50	Min	Max
<i>Gredev</i>	7.8971	0.5671	8.0045	0.0000	8.8961
<i>Lndabio</i>	18.0068	0.9202	18.1810	5.1913	19.6279
<i>Lndubio</i>	15.3325	0.6258	15.4510	6.6180	16.4348
<i>Lnpergdp</i>	10.0671	0.8003	10.0630	7.6036	13.0459
<i>Upais</i>	1.3624	0.1128	1.3543	0.3768	3.2708
<i>Oeduc</i>	0.7257	0.2483	0.6927	0.0047	2.7195
<i>Teleinst</i>	0.1338	0.1135	0.1067	0.0000	4.1245
<i>Ocredit</i>	0.6056	0.4195	0.5070	0.0002	7.5183
<i>Sonat</i>	9.0559	0.5454	9.0956	0.0000	10.3466

TABLE 2 Benchmark Results Estimation.

	(1) <i>Gredev</i>	(2) <i>Gredev</i>	(3) <i>Lndabio</i>	(4) <i>Lndabio</i>	(5) <i>Lndubio</i>	(6) <i>Lndubio</i>
<i>DID</i>	0.035*** (0.008)	0.035*** (0.008)	0.060*** (0.013)	0.056*** (0.013)	0.040*** (0.009)	0.038*** (0.009)
<i>Lnpergdp</i>		0.049*** (0.013)		0.080*** (0.021)		0.054*** (0.015)
<i>Upais</i>		0.023 (0.040)		0.038 (0.066)		0.026 (0.045)
<i>Oeduc</i>		0.046** (0.020)		0.075** (0.033)		0.051** (0.022)
<i>Teleinst</i>		0.059*** (0.021)		0.096*** (0.034)		0.065*** (0.023)
<i>Ocredit</i>		−0.025 (0.022)		−0.041 (0.036)		−0.028 (0.025)
<i>Sonat</i>		−0.094*** (0.011)		−0.153*** (0.018)		−0.104*** (0.012)
<i>_Cons</i>	7.891*** (0.001)	8.191*** (0.192)	17.997*** (0.002)	18.484*** (0.312)	15.326*** (0.001)	15.667*** (0.212)
Year fixed	Yes	Yes	Yes	Yes	Yes	Yes
County fixed	Yes	Yes	Yes	Yes	Yes	Yes
County-level clustering	Yes	Yes	Yes	Yes	Yes	Yes
<i>N</i>	25,961	25,961	25,961	25,961	25,961	25,961
<i>R2_a</i>	0.904	0.887	0.904	0.887	0.904	0.887

*, **, and *** indicate significance at the 10%, 5%, and 1% level.

system for biodiversity conservation, continuously increased the scale of regional biomass, effectively protected the types of animal and plant communities, and continued to optimize the spatial pattern of biodiversity conservation.

Economic development, educational scale and communication facilities have a positive effect on the green development of the county, significantly increasing the vegetation coverage in the region, while the natural conditions have a significant negative impact on the green vegetation coverage in the county. After the implementation of the policy, the county has stepped up efforts to eliminate outdated production capacity and accelerated the green transformation of production methods to provide good external conditions for the survival and development of ecological vegetation. The government continues to realize the greening of production methods, expand the space and scope of green development, and improve the mainstreaming level of biodiversity in ecological function areas. The county government has continuously incorporated green development into the middle and long-term planning of primary and secondary schools, higher education and vocational education systems and local environmental protection education, and firmly established the awareness that man and nature constitute a community. The government strengthens the role of role model and value leadership, and conducts extensive publicity and green life education activities to enhance the people's awareness of ecological civilization. The county-level government has implemented the ecological green national action in depth, accelerated the formation of a green and low-carbon lifestyle, and formed a benign green governance pattern (Tao and Jingyun, 2022). The improvement of communication facilities is beneficial to the transparency of information disclosure, improve public supervision and reporting and feedback mechanisms, improve the level of public participation in environmental decision-making, and enhance the effectiveness of public participation in green ecological governance. Natural factors such as effective rainfall can affect the change of green vegetation and the ecological environment, which play a certain role in maintaining the balance of the ecosystem. The government needs to comprehensively consider the rainfall conditions in its own area and pay attention to the distribution and configuration of vegetation types, which will help to improve and enhance the ecological environment of the county.

4.2. Robustness test

Results from the omitted variable test, the replacement variable test, the benchmark variable test, and the parallel trend test, are all consistent with the previous empirical results.²

4.3. Heterogeneity analysis

Due to the differences in geographical location, administrative level, social attributes, distance and infrastructure of counties, the impact of the implementation of the national key ecological function zone policy on the green development of pilot counties will also

be different. Therefore, the pilot counties are divided into eastern, central, western, northern and southern regions in terms of geographical location. On the administrative level, it is divided into three types of administrative units: city, county and district. In terms of social attributes, it is divided into revolutionary old districts and counties and non-revolutionary old districts and counties. In terms of distance, it is divided into 0–20 km, 20–50 km, 50–100 km and more than 100 km areas. In terms of infrastructure, it is divided into counties with high-speed rail and counties without high-speed rail. Finally, the sample is divided into different quantiles.

4.3.1. Geographic location

Compared with the eastern and central regions, after the implementation of the policy, the ecological green level of the counties in the western region has been significantly improved, which has significantly promoted the regional biological cycle system and the treasure house of ecological species.

The counties in the western region are constantly improving the green ecological network, jointly promoting the restoration of farmland to forests and grasslands and wetland restoration, and scientifically planning regional ecological corridors and ecological buffer zones. The government reduces the demand and destruction of ecological vegetation, taps the green potential of the watershed space, and walks out a green governance path for the high-quality development of regional ecological space. By building green vegetation such as oases in the western region, ecological desertification and fragmentation can be effectively suppressed, the environmental bearing pressure on ecologically fragile areas can be alleviated, and the green productivity of the county can be enhanced (Littleton et al., 2021).

4.3.2. Administrative level

The implementation of the national key ecological function zone policy has significantly improved the green vegetation coverage of administrative units in county-level cities, and protected ecological functions and biodiversity within the zone. The county-level city government is rooted in the concept of green development, and realizes innovation-driven development through structural adjustment, optimization and upgrading of traditional industries. County-level cities should make overall plans to explore the unique endowments and comparative advantages of the county, cultivate new suitable industrial growth points, and take the road of green economic development.

4.3.3. Social attributes

After the implementation of the policy, the old revolutionary counties have always practiced the concept of ecological priority, strengthened the monitoring, forecasting and early warning of ecological conditions, continuously maintained the diversity of species, and maintained the integrity of the ecosystem.

The old revolutionary base areas and counties actively extend the supply chain of ecological industries, promote the implementation of new measures of transfer payment and ecological compensation, build new advantages of green agricultural product brands, and expand the scope of green economic development. The counties can improve the green added value of processing links, and promote the ecological sustainable development of old revolutionary base areas (Yang et al., 2019).

² For details, please refer to the Appendix for details.

4.3.4. Distance

The closest (within 20 km) and farthest (more than 100 km) counties to the city center can greatly improve the green development level within the region. The reason is that the most distant counties can put ecological protection in an overwhelming position, clarify the boundaries of urban development, delineate the bottom line of ecological environment quality, strictly adhere to the red line of ecological protection, and create a green ecosystem. The nearest county is constantly building a long-term governance mechanism for the integration of ecological space, cultivating and optimizing the formation of a green industry development system, and exploring the green and sustainable development that interacts with the city center from the aspects of systematic.

4.3.5. Infrastructure

The opening of the high-speed rail will help the region to improve the green ecological network, guide the intensive and efficient green development mode, open up the green channel of watershed space governance, and use the free flow and optimal allocation of various resource elements in the watershed space to promote green transformation.

4.3.6. Different quantiles

The implementation of the national key ecological function zone policy is conducive to excavating the law of the future green development of the county. The county pursues an ecologically sustainable governance effect from the overall perspective of its own green governance. The county government cultivates new kinetic energy for green development, accurately implements ecological green space, expands new advantages of green development, and emphasizes the affordability of the ecological environment. The county-level government has solidly promoted land greening and ecological restoration projects, enhanced the quality and stability of the ecosystem, and improved the diversity index and richness of green vegetation species.

5. Expand the discussion

5.1. Mechanism path analysis

5.1.1. Government investment

This indicator is measured by the logarithm ($Lnctinvest$) of the social fixed asset investment in the county minus the urban fixed asset investment. The empirical results show that the estimated coefficients are statistically significantly negative (Table 3). This shows that the county-level government is constantly coordinating the industrial layout and ecological environmental protection within the region. According to its own environmental carrying capacity and ecological environment capacity, the county implements a holistic and linkage strategy of organically combining ecological vegetation protection and economic new normal development.

The government carries out the main function adaptability evaluation of the special industrial planning and the layout of major projects, implements the rigid constraints of the planning environmental impact assessment, and sets up early warning control lines and response lines. The county government restricts

or prohibits investment in development areas, strictly restricts the blind expansion of construction land in townships, controls the intensity of land construction and the order of development, and utilizes the existing space in built-up areas efficiently. The government has continuously strengthened the hard constraints of the ecological environment, effectively supported key tasks such as ecological environmental protection and vegetation restoration, and formed a new pattern of land space green development (Badiu et al., 2019).

5.1.2. Enterprises performance

This indicator is represented by the number of county-level industrial enterprises ($Lnqiye$), the output value of county-level industrial enterprises ($Lnqyvalue$), and the number of county-level patent applications ($zhuanli$). Empirical tests show that the implementation of the national key ecological function zone policy has significantly reduced the number of enterprises within the county, which can increase the output value of industrial enterprises and the number of patent applications in the county (Table 3).

The county government vigorously promotes the construction of the ecological and environmental protection technology innovation system, stimulates the green development of enterprises, and promotes the transformation of the regional industrial structure to high-end, emerging, high-efficiency, and high value-added. The government gives priority to supporting technological innovations in the fields of low-carbon energy saving, clean production and waste utilization. County government can use new technologies, new formats and new models to promote the upgrading and transformation of traditional industries, accelerate the transformation of scientific technological, and promote industrial enterprises to reduce quantity and improve quality and efficiency (Du et al., 2021). The government encourages the development of green and low-carbon industrial projects, fosters emerging industrial entities, promotes the development of low-carbon modern service industries, builds green industrial supply chains, and enhances the recycling level of industrial parks and industrial clusters.

5.1.3. Afforestation

This indicator is represented by the area of artificial afforestation in the county ($Zaolin$). The empirical results show that after the implementation of the policy, the relevant governments have continuously improved the vegetation coverage and relative biomass density, which can increase the output value of industrial enterprises and the number of patent applications in the county (Table 3).

The county-level government should enhance the awareness of the residents of the county on the protection of green vegetation and biodiversity, reduce the rate of biodiversity loss, speed up the containment of the trend of ecological degradation, and consolidate the foundation for the green development. One of the most important strengths of the ecological green development is that it should foster environmental awareness among actors at all levels, from the individuals to the organizations. Forest ecosystems are both carbon sources and carbon sinks. The county government continues to follow the internal mechanism of the ecosystem, and highlight important ecological locations and key governance areas. Ecological green vegetation as a carbon sink, enhance the carbon sequestration

TABLE 3 Mechanism Path Analysis.

	(1) <i>Lninvest</i>	(2) <i>Lnqiye</i>	(3) <i>Lnqyvalue</i>	(4) <i>Zaolin</i>	(5) <i>zhuanti</i>
<i>DiD</i>	−0.040*** (0.012)	−0.050*** (0.019)	0.022* (0.013)	369.316*** (95.937)	5.709*** (1.983)
<i>_Cons</i>	5.614*** (0.284)	−1.888*** (0.409)	−4.689*** (0.254)	−403.058 (1539.490)	0.742*** (169.166)
Year fixed	Yes	Yes	Yes	Yes	Yes
County fixed	Yes	Yes	Yes	Yes	Yes
County-level clustering	Yes	Yes	Yes	Yes	Yes
Control variable	Yes	Yes	Yes	Yes	Yes
<i>N</i>	25,961	25,961	25,961	25,594	25,594
<i>R2_a</i>	0.904	0.955	0.975	0.503	0.841

*, **, and *** indicate significance at the 10%, 5%, and 1% level.

capacity of the ecosystem, realize the transformation of forest resources from service flow to value flow, and create a new highland of ecological green value.

5.2. Analysis of spillover effects

Because the ecological environment has the attributes of spatial correlation, pollution continuity and inseparability, a single ecological environment governance model will be stretched, which determines the systematic nature of the ecological environment collaborative governance. Constrained by the limited degree of government's grasp of pollution information in different regions, and the lag of regulatory authorities in corporate pollution behavior, the overall regional environmental pollution control model needs to be innovated. From the perspective of the integrity of the ecosystem, the government should coordinate to promote the modernization of the environmental governance system, strengthen the linkage development with surrounding counties, and promote the formation of a larger development driving effect (Zhiren and Jiaqi, 2022).

The empirical test found that the policy implementation has obvious green spillover effect, which can promote the green effect of adjacent counties to increase by about 0.169 units. This shows that after the implementation of the national key ecological function zone policy, government departments in relevant regions have established a new concept of inter-governmental comprehensive strategic cooperation, highlighted the scientific, systematic and matching nature of the top-level design of coordinated progress. More county governments have participated in the formulation of joint strategies to overcome barriers to intergovernmental cooperation, so as to change the "separate" style of ecological environment governance and administrative management.

On a larger regional scale, adjacent county-level governments should establish the principles of ecological co-governance and ecological sharing, enhance the attraction of inter-governmental cooperation in cross-regional green governance, and establish a cross-regional ecological governance responsibility mechanism.

Adjacent county-level governments improve the accountability system and performance appraisal mechanism for regional environmental collaborative governance, improve the operational efficiency of collaborative ecological governance, and avoid the

spillover effect of pollution, which limits the regional collaborative governance model of the ecological environment (Zhuo et al., 2022).

5.3. Analysis of additional benefits

The United Nations Intergovernmental Panel on Climate Change (IPCC) estimates that terrestrial ecosystems have about 2.5 trillion tons of carbon storage, of which 1.2 trillion tons are stored in forest ecosystems. Research from Peking University also shows that for every cubic meter of forest growth, it absorbs more than 1.8 tons of carbon dioxide on average and releases about 1.6 tons of oxygen. Data from China's seventh forest resource inventory show that the total carbon storage in China's forest vegetation has reached 7.8 billion tons. According to the estimated data of the fourth and ninth national forest resources inventory, China's forest carbon sink capacity has increased from 18.55 billion tons of carbon dioxide in 1990 to 32.14 billion tons of carbon dioxide in 2020, a net increase of 13.59 billion tons of carbon. The proportion of the world's forest carbon accumulation increased from 1.8% in 1990 to 3.2% in 2020. According to research and estimates, the carbon dioxide equivalent emitted per ton of steel produced by domestic enterprises is about 1.83 tons, the carbon dioxide equivalent emitted per ton of aluminum production is about 11.2 tons, and the cement is about 0.8–0.9 tons. China's forests absorb more than 500 million tons of carbon dioxide each year, accounting for about 8–10% of industrial emissions in that year.

Forests are of special significance for achieving the "dual carbon" goals, especially carbon neutrality. According to data, during the growing season, 1 hectare of broad-leaved forest can absorb 1 ton of carbon dioxide per day and produce 730 kg of oxygen. An adult breathes 0.75 kg of oxygen and 0.9 kg of carbon dioxide per day. If the forest protection rate can be increased to 142% by 2050, the emission reduction of forest protection in 2050 will be reduced to 0.79GTC. Carbon prices are projected to rise on schedule, jumping from <\$18 in 2015 to \$51 in 2050, due to the potential contribution of protecting forests.

Based on the above research results, combined with the previous mechanism path analysis, compared with the control group sample, the implementation of the national key functional zone policy can increase the area of artificial afforestation in the pilot counties by an average of about 369.316 hectares. According to the calculation that 1

hectare of forest can absorb 1,000 kilograms of carbon dioxide per day, the artificial afforestation in the pilot counties can absorb about 134,800.34 tons of carbon dioxide every year. After calculation, artificial afforestation can release 269.6 tons of oxygen per day, which can provide 359,467 adults with respiratory consumption per day. If the average carbon dioxide shadow price in my country's industrial sector is 5,480 yuan/ton (Weijie and Shaohua, 2018), the implementation of the policy can bring about 738,705,863.2 yuan of carbon benefits.

6. Conclusions and policy recommendations

6.1. Conclusion

The county is the bottom administrative unit at the Chinese administrative level. Protecting the ecological environment and promoting the sustainable development of green is the unswerving responsibility of county governance. With the help of the national key ecological function zone policy, the county-level data in mainland China from 2007 to 2019 was selected to discuss its impact on the green development of the county, and the mechanism path, spillover effects and additional benefits were expanded analyzed.

The following conclusions are drawn:

First, the implementation of the policy has significantly increased the green vegetation coverage area in the county, ~ 0.035 units of the normalized index of increased vegetation. Policy implementation can significantly increase the total amount and density of above-ground and below-ground biomass in the region and maintain the biodiversity of county ecosystems. This result remains significant after a series of robustness tests, ensuring that the conclusions are reliable.

Second, the implementation of the national key ecological function zone policy can improve the green development level of the western regions, northern regions, old revolutionary bases, counties with high-speed railways, county-level cities, and counties closest/farthest to the cities.

Third, the green development effect of the pilot counties is achieved by reducing large-scale investment by the government, improving the quality and efficiency of enterprises in the region, and increasing the area of artificial afforestation.

Fourth, policy implementation brings a significant green space overflow effect. Policy implementation can promote the green development of neighboring counties in pilot counties.

Fifth, the implementation of the policy can increase the scale of forest carbon sinks in the pilot counties. Each hectare of artificial afforestation can absorb about 130,000 tons of carbon dioxide emissions and release 98,400 tons of oxygen, which can supply about 360,000 people for oxygen respiration consumption every day. Policy implementation can bring carbon revenue of 738.71 million yuan.

6.2. Policy suggestions

One is to anchor the ecological base to increase the green area. The government should fully coordinate the integrity and linkage of green planning, grasp the limit of ecological carrying capacity, follow the principles of ecological priority and green development, and "leave

white space and increase green" for county space governance. The government builds a scientific and reasonable ecosystem protection system and reduces human activities at important ecological nodes to maintain natural ecological functions. The government should focus on the requirements of achieving carbon peaking and carbon neutrality, increase forest carbon sink reserves, increase the coverage of green vegetation, and help achieve the carbon emission goal as scheduled.

The second is to cultivate ecological advantages and develop a green economy. The county government should clarify the direction of industrial agglomeration, generate new kinetic energy for green development, strengthen and optimize characteristic industries, and strictly control the threshold for enterprise access approval. The government should shift from "efficiency priority" to "promoting the all-round development of human beings," improve the supply level of public services in the ecosystem, and broaden the value conversion mechanism for multiple types of ecological products. County governments should strengthen explicit education and guidance, and translate green concepts into conscious actions of all people. The government should give full play to the role of communication infrastructure as a channel, actively encourage the public to participate in green co-governance, and continuously promote the development of a low-carbon economy from the perspective of green economy.

The third is to rely on the ecosystem to achieve green development. The governments of the pilot counties and neighboring counties should improve and strengthen the cross-regional environmental governance mechanism, coordinate the inter-government relations, cultivate the awareness of the overall ecological situation, and form a partnership of interests for joint construction and sharing. The governments of all parties should strengthen the motivation of environmental collaborative governance, unify regional environmental protection policy standards with higher standards, and improve the interregional benefit compensation mechanism for ecological environmental protection. The governments of all parties should optimize the performance evaluation mechanism of regional environmental collaborative governance, deepen the cooperation of regional legislation, judiciary and law enforcement, and promote the sustainable operation of the collaborative governance model among local governments.

6.3. Chinese contribution and international inspiration

Ecological green development is the symbol of life and the background of nature. Ecological green development is the development of the maximum economic and social benefits at the least resource and environmental cost. Under the guidance of Xi Jinping's new era of socialism with Chinese characteristics, China follows the path of ecological priority and green development, and has created the world's attention ecological miracles and green development miracles. Green has become the distinctive background of China in the new era, and green development has become a significant feature of Chinese -style modernization. As the world's largest developing country, China adheres to the concept of the community of human destiny, firmly implements multilateralism, proposes global development initiative, global security initiative,

deepen pragmatic cooperation, and actively participate in global environment and climate governance.

In promoting the green development of county ecology, China has the following experience to share with countries around the world.

The first is government support. Accelerating ecological priority and green development are a major responsibility of participating in global governance and establishing a major country with a common future. China has formulated long-term planning and development strategies in promoting the development of ecological green in the county, and has strictly implemented the implementation, which is worth promoting to other countries. China gives full play to and strictly implement the leading role of major regional strategies. The national key ecological function zone is an important national strategic policy implemented by the Chinese government in the county-level administrative unit. The Chinese government has focused on building a county's ecological green development, which can promote the overall improvement of the national ecological green level. The implementation of the policy at the county level can directly reflect the national intention to the county-level governments, reducing the degree of interference in the county-level cities and provinces to the county. Countries around the world should include the construction of ecological green development into an important agenda, and introduce specific provisions based on their own actual height. The government should also increase the support of fiscal funds and promote the improvement of enterprises to improve quality and efficiency to achieve the rapid development of the country's green economy.

The second is regional collaboration. The implementation of the national key ecological function zone policy can promote the ecological green development of adjacent counties in pilot areas. From an international perspective, various countries around the world should work together to achieve real ecological green sustainable development. The realization of global ecological green development is inseparable from the cooperation between countries. Protecting the global green ecological environment requires all countries to work together to come up with more practical actions. On the issue of global ecological green development, it is unrealistic to solve the use of technical means in one country or several countries. Solving problems requires cooperation between countries and ethnic groups to open up and cooperate. Only by letting go of prejudice, maintaining the ecological and biodiversity environment of other countries, and through technological integration and system optimization, can we jointly solve the current challenges facing the global ecological green development. For example, all world countries should actively contribute to the United Nations in 2030.

The third is people's response. The implementation of the policy to achieve ecological green development by increasing the area of artificial afforestation. While significantly increased the artificial forest-made area, it will also bring additional benefits to reduce regional carbon emissions. The government-led, regional collaboration and the participation of the people, the combination of natural restoration and artificial governance, the combination of legal constraints and policy incentives, so that China has taken a path to a county's ecological green sustainable development path. At present, global ecological and environmental issues are facing severe challenges, and humans are at the crossroads of sustainable development. Climate change, sharp decrease in biodiversity, desertification, sudden natural

disasters and pollution, threatened human survival and development. To solve worldwide ecological problems requires the wisdom and strength of the people of all countries. The state should actively practice the concept of green life of residents, actively practice and promote the green lifestyle of residents with practical actions, and guide people to become protectors and beneficiaries of ecological green development.

Data availability statement

The original contributions presented in the study are included in the article/[Supplementary materials](#), further inquiries can be directed to the corresponding author.

Author contributions

ZC-b: theoretical framework, project administration, funding acquisition, and supervision. ZC-b and ZR-b: revised the study. ZR-b: writing-review and editing and data and evaluated the results. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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