

Fiscal Decentralization and the Spatial Convergence of Ecological Welfare Performance in China: Evidence from Informatics-Based Provincial Panel Analysis

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Abstract. This study explores how fiscal decentralization influences the spatial convergence of ecological welfare performance across China's provincial regions. Using panel data from 30 provinces covering 2000–2021, the study integrates a super-efficiency SBM model with undesirable outputs to measure provincial ecological welfare performance and applies a spatial β -convergence model to examine dynamic evolution patterns. Fiscal decentralization is quantified through the ratio of revenue and expenditure decentralization to capture the fiscal relationship between central and local governments. The empirical results reveal that China's provincial ecological welfare performance exhibits both absolute and relative spatial β -convergence. Fiscal decentralization significantly enhances ecological welfare performance and accelerates its spatial convergence, although this effect differs regionally. The eastern provinces show the highest improvement in performance but the weakest convergence, whereas the central and western provinces demonstrate faster convergence rates. Industrial structure upgrading and innovation capacity further reinforce convergence, while environmental regulation and foreign openness exert negative effects. The findings provide decision-support insights for optimizing intergovernmental fiscal structures, improving regional ecological coordination, and advancing informatization-based sustainable governance in China.

Keywords: Fiscal decentralization, Ecological welfare performance, Spatial convergence, Regional heterogeneity, Informatics-based governance

1. Introduction

Over the past three decades, China has experienced rapid economic growth; however, this growth has been accompanied by excessive resource consumption and severe environmental challenges. To address these issues, the Chinese government has implemented a sustainable development strategy, shifting the country's economic model from a high ecological-cost growth paradigm to an environmentally friendly and sustainable development approach. When examining China's current economic development trajectory, integrating sustainability as a core consideration aligns more closely with the nation's long-term societal goals. Daly (1974) first introduced the concept of ecological welfare performance, aiming to assess the sustainability of economic growth from the perspective of human welfare. Few (1993) and Moran (2008) further emphasized that economic development can only be considered sustainable if welfare levels improve within an ecologically sustainable framework. Since then, the use of ecological welfare performance as an indicator to measure the level and potential of sustainable development has become a dominant research trend.

Fiscal decentralization plays a crucial role in guiding China's provincial governments towards sustainable economic development. Yu, B., & Fan, C. (2018) argue that fiscal decentralization not only enhances the sense of responsibility and decision-making autonomy of local governments, but also significantly improves the efficiency of resource allocation and policy innovation capacity. Building on the mechanism of fiscal decentralization, Lin, M., & Xiao, Y. (2024) reveal that local governments can flexibly formulate and implement fiscal policies that are tailored to their local characteristics and needs. This approach precisely guides and supports key areas of economic development, promotes the innovation and growth of green technologies and industries, and provides a solid fiscal foundation for sustainable economic development.

Scholars such as Xue, H., & Kan, L. (2022) have conducted meaningful research on the impact of fiscal decentralization on ecological welfare performance. However, their study was limited to examining this impact alone, without delving into the broader issue of regional balanced development of ecological welfare performance, particularly its spatial convergence, which is influenced by fiscal decentralization. Based on this, the present study, using a longer time span of provincial panel data from 2000 to 2021, aims to further validate the research findings of Xue, H., & Kan, L. (2022) and, more importantly, to examine the spatial convergence pattern of the impact of provincial fiscal decentralization on ecological welfare performance in China.

2. Literature Review

2.1. Concept and Measurement of Ecological Welfare Performance

The concept of ecological welfare performance originates from the steady-state economic theory proposed by Daly (1974). Compared with traditional economic growth theories, steady-state economics places greater emphasis on social welfare, arguing that economic development is merely an intermediate outcome, while the ultimate goal of socioeconomic progress is the enhancement of societal well-being. This theory posits the existence of both a "welfare threshold" and an "ecological threshold," suggesting that sustainable economic development should balance ecological sustainability and social well-being by maximizing human welfare output with minimal ecological capital investment. In light of this perspective, Zhu et al. (2008) introduced the concept of ecological welfare performance to measure the level and potential of sustainable economic development.

Zhu, D., et al. (2008) measured the level of ecological welfare performance using the ratio of natural resource input to social welfare output. For the measurement of ecological capital input, they adopted indicators such as energy consumption, water consumption, and land resource consumption. The social welfare level was assessed using the Human Development Index (HDI) published by the United Nations Development Programme in 1990. With the evolution of welfare economics from traditional welfare economics to new welfare economics and then to modern welfare economics,

scholars such as Wang, Z., & Wang, Z. (2021), Zhu, J., & Pang, W. (2022), and Chen, D., & Liu, W. (2024) have further enriched the measurement of social welfare level based on the HDI. They have constructed specific indicator systems to measure social welfare level from four sub-dimensions: environmental welfare, economic development welfare, health welfare, and education welfare.

Scholars such as Guo, B., et al. (2022) and Li, C., et al. (2019) believe that the essential characteristic of ecological welfare performance lies in maximizing social welfare benefits with minimal ecological and environmental costs while ensuring efficient resource utilization. It requires simultaneous attention to ecological and environmental protection and minimization of pollution in the pursuit of maximizing social welfare. Therefore, when measuring ecological welfare performance, the output should not only include the improvement of social welfare level but also consider the undesired output of environmental pollution, which is measured by indicators such as wastewater discharge, waste gas emission, and solid waste discharge (Long, L., & Wang, X., 2017; Xu, Y., 2017; Deng, Y., 2020).

It is noted that when studying the impact of provincial fiscal decentralization on ecological welfare in China, scholars such as Guo, B., et al. (2022) and Li, L., et al. (2022) only used the Human Development Index as the measurement indicator for social welfare level. In this study, we will adopt the measurement indicator system for ecological welfare performance from the research by Chen, D., & Liu, W. (2024) and incorporate the undesired output measurement indicators from Deng, Y. (2020) to form a more comprehensive indicator system for measuring ecological welfare performance that reflects the sustainable economic development level of Chinese provinces. Based on this, we will use the Super-Efficiency Slack-Based Measure (SBM) model with undesired outputs to measure the ecological welfare performance of Chinese provinces (Guo, B., et al., 2022), in order to more comprehensively explore the impact of provincial fiscal decentralization on ecological welfare performance in China.

2.2. Concept and Measurement of Fiscal Decentralization

In the 1950s, American economists pioneeringly proposed the concept of fiscal decentralization based on the theory of fiscal federalism, emphasizing the autonomy of local finance. The core of this concept lies in the decentralization of fiscal power, advocating for greater fiscal autonomy for local governments. The aim is to promote the maximization of social welfare by enhancing local governments' ability to respond to residents' needs, optimize resource allocation, and improve the efficiency of public services (Chen, K., & Gu, Q., 2002). The second-generation fiscal decentralization, however, focuses more on the incentive and restraint mechanisms from a political economy perspective, highlighting that while local governments and their officials pursue public interests, they also have motives for personal gain and political promotion. Therefore, the central government needs to establish corresponding institutional constraints to ensure that the actions of local governments align with overall interests and policy orientations. Since 1984, China's fiscal decentralization reform has been further deepened, clarifying the division of central and local fiscal revenues. While strengthening the central government's fiscal control capabilities, it has granted local governments a certain degree of fiscal autonomy, ensuring the relative independence and stability of fiscal revenues (Ma, E., et al., 2024).

Regarding the measurement of fiscal decentralization in Chinese provinces, Li, L., et al. (2022) selected the ratio of local general budget revenue to local general budget expenditure as an indicator of fiscal decentralization when examining its impact on ecological welfare performance. This study argues that this measurement indicator does not reflect the decentralization relationship between provincial governments and the central government in terms of fiscal expenditure and revenue, thus having certain limitations in measurement. This study adopts the specific approach of scholars such as Tian, H., & He, B. (2021) for measuring fiscal decentralization: using the ratio of fiscal revenue decentralization to fiscal expenditure decentralization as the measurement indicator of fiscal

decentralization. Fiscal revenue decentralization is measured by the ratio of provincial per capita fiscal revenue to the sum of provincial per capita fiscal revenue and central per capita fiscal revenue. Fiscal expenditure decentralization is measured by the ratio of provincial per capita fiscal expenditure to the sum of provincial per capita fiscal expenditure and central per capita fiscal expenditure. This study believes that this measurement method for fiscal decentralization takes into account both the central and provincial dimensions, considering both fiscal expenditure and fiscal revenue.

2.3.Relevant Studies on Ecological Welfare Performance and Fiscal Decentralization

Guo, B., et al. (2022) argue that existing research primarily approaches the topic from the perspective of fiscal decentralization, discussing it through the two pathways of economic development and environmental governance separately. A systematic analytical framework for the relationship between fiscal decentralization and ecological welfare performance has yet to be established. Based on panel data from 30 provinces spanning from 2005 to 2020, they conduct empirical analyses using both static and dynamic panel models. The empirical results ultimately confirm that fiscal decentralization at the provincial level in China indeed has a significant impact on ecological welfare performance.

Concurrently, Li, L., et al. (2022), using panel data from 30 provincial administrative divisions over a 13-year period from 2004 to 2017, systematically explore the direct, time-lagged, and spatial-lagged effects of fiscal decentralization on ecological welfare performance by establishing static panel models, dynamic panel models, and spatial Durbin models. They analyze the patterns and mechanisms of the impact of fiscal decentralization on ecological welfare performance. In this study, they reach conclusions similar to those of Guo, B., et al. (2022), namely that fiscal decentralization at the provincial level in China has a significant impact on ecological welfare performance.

It is noted that both Guo, B., et al. (2022) and Li, L., et al. (2022) use the traditional Human Development Index as a measure of social welfare level when calculating the comprehensive index of ecological welfare performance, which has certain limitations. Additionally, the indicator chosen for measuring fiscal decentralization, "the proportion of local general budget revenue to local general budget expenditure," 忽视s the decentralization relationship between the central and local governments and also has certain limitations (Li, L., et al., 2022). Furthermore, environmental pollution emissions, which are undesired outputs, are not considered in the calculation of ecological welfare performance, which is another shortcoming.

Kuang, M. (2021) studies the α -convergence, absolute β -convergence, and relative β -convergence of ecological welfare performance in regional space based on panel data from 30 provinces from 2010 to 2019, and finds that there is regional heterogeneity in the spatial convergence of ecological welfare performance. Regarding the issue of the spatial convergence of ecological welfare performance, Xiao, L.M., and Xiao, Q.L. (2021) also find that it exists. In summary, existing literature has adequately demonstrated that ecological welfare performance itself exhibits absolute spatial convergence. However, there is a lack of high-quality literature on the impact of fiscal decentralization on the spatial relative convergence of ecological welfare performance. This study believes that research on this topic will contribute to a deeper understanding of the mechanism by which fiscal decentralization affects the development of regional ecological welfare performance, and has high practical and theoretical value for regional coordination and balanced development. It is worth conducting exploratory empirical research on this topic.

In summary, based on panel data covering a longer time period (2000-2021) and improving upon the measurement indicators for fiscal decentralization and ecological welfare performance used by Li, L., et al. (2022), this study verifies the research finding that fiscal decentralization at the provincial level in China has a significant impact on ecological welfare performance. Furthermore, it explores the issue of the impact of fiscal decentralization at the provincial level in China on the spatial convergence of ecological welfare performance.

3. Research Methodology

3.1. Model Specification

1) Baseline Panel Regression Model

This study first establishes a static panel model to examine the impact of fiscal decentralization on ecological welfare performance. By refining the indicator systems for both fiscal decentralization and ecological welfare performance, this model aims to validate the findings of Li, L., et al. (2022) and provide a more comprehensive empirical assessment.

$$\ln stfl_{i,t} = \alpha + \alpha_1 lnczf_{i,t} + \sum_{j=2}^5 \alpha_j control_{j,i,t} + u_i + \varepsilon_{i,t} \quad (1)$$

In the model, $lnczf_{i,t}$ the degree of fiscal decentralization in province i at time t , $\ln stfl_{i,t}$ indicates the level of ecological welfare performance, $control_{j,i,t}$ represents the value of the j -th control variable in province i at time t , u_i denotes the fixed effects, $\varepsilon_{i,t}$ represents the error term.

2) Spatial β -Convergence Model

The spatial convergence and divergence of ecological welfare performance depict the evolution over time of disparities (or heterogeneity) in ecological welfare performance among different provinces. If these disparities diminish over time, it is termed as spatial convergence; conversely, if they widen, it is referred to as spatial divergence. Drawing on the research methodologies of Wang, L.H., and Wang, Z. (2020), Wang, Q.R. (2020), and Kuang, M. (2021), this study examines the spatial beta convergence of provincial ecological welfare performance. Based on panel data, the following econometric model is established:

$$\ln \left(\frac{stfl_{i,t}}{stfl_{i,t-1}} \right) = \alpha + \beta \ln stfl_{i,t-1} + \varepsilon_{i,t} \quad (2)$$

In this model, $\ln stfl_{i,t}$ and $\ln stfl_{i,t-1}$ represent the ecological welfare performance levels of province i in $year_t$ and $year_{t-1}$, respectively. α is the constant term, β is the regression coefficient, and $\varepsilon_{i,t}$ is the random error term. If β is less than 0 and significant, it indicates the presence of spatial absolute β -convergence. This means that provinces with lower ecological welfare performance will experience faster improvements in their performance compared to provinces with higher ecological welfare performance. As a result, regional disparities in ecological welfare performance will gradually diminish, ultimately leading to balanced development. In contrast, if β is greater than 0 or if β is less than 0 but not significant, it suggests spatial divergence in ecological welfare performance. This implies that provinces with lower ecological welfare performance will improve at a slower rate compared to those with higher performance, leading to an increase in regional disparities.

Furthermore, this study first establishes the following model (3) to examine the spatial relative β -convergence of ecological welfare performance. If $\beta < 0$ and is significant, it suggests the presence of spatial relative β -convergence in ecological welfare performance. Additionally, if $\gamma_1 > 0$ and is significant, it indicates that fiscal decentralization positively promotes spatial convergence in ecological welfare performance. Conversely, if $\gamma_1 > 0$ and is significant, it suggests that fiscal decentralization has a negative inhibitory effect on spatial convergence in ecological welfare performance.

$$\ln \left(\frac{stfl_{i,t}}{stfl_{i,t-1}} \right) = \alpha + \beta \ln stfl_{i,t-1} + \gamma_1 lnczf_{i,t} + \sum_{j=2}^5 \gamma_j control_{j,i,t} + \varepsilon_{i,t} \quad (3)$$

3.2. Variable Selection

1) Dependent Variable

The dependent variable in this study is ecological welfare performance. Based on the measurement indicators for ecological welfare performance developed by scholars such as Deng (2020), Chen & Liu (2024), Xiao & Xiao (2021), Zhu & Pang (2022), and Sun & Wang (2022), this study constructs a specific indicator system for ecological welfare performance tailored to the research context (see Table 1). To estimate ecological welfare performance, the study employs the Slacks-Based Measure (SBM) model of super-efficiency Data Envelopment Analysis (DEA), incorporating undesirable outputs.

Table1: indicator system of ecological welfare performance

Primary Indicator	Secondary Indicator	Tertiary Indicator
Resource Consumption	Energy Consumption	Per Capita Coal Usage (tons)
	Water Resource Consumption	Per Capita Water Usage (cubic meters)
	Land Resource Consumption	Per Capita Construction Land Area (square meters)
Welfare Level	Economic Development Welfare	Urban-Rural Income Gap
		Per Capita Disposable Income (Yuan)
		Per Capita GDP
	Healthcare Welfare	Number of Health Personnel per 1,000 People
		Number of Medical and Health Institution Beds per 1,000 People
		Average Life Expectancy (years)
	Environmental Welfare	Green Coverage Rate in Built-up Areas (%)
		Per Capita Park Green Space Area (square meters/person)
		Rate of Non-hazardous Treatment of Domestic Waste (%)
	Educational Welfare	Average Years of Education
Environmental Pollution	Wastewater Discharge	Per Capita Sewage Discharge (tons)
	Solid Waste Emission	Per Capita Solid Waste Discharge (tons)
	Air Pollution	Per Capita Air Pollutant Emission (tons)
	Household Waste	Per Capita Household Waste (tons)

2) Explanatory Variables

The explanatory variable is fiscal decentralization. In this study, we adopt a specific measurement approach, drawing on the methodology proposed by scholars such as Tian, H., and He, B.J. (2021), to quantify fiscal decentralization. This measurement method considers both the central and provincial dimensions, taking into account both fiscal expenditures and revenues.. The measurement is as follows:

Fiscal Revenue Decentralization = Provincial per capita fiscal revenue / (Provincial per capita fiscal revenue + Central per capita fiscal revenue) ;

Fiscal Expenditure Decentralization = Provincial per capita fiscal expenditure / (Provincial per capita fiscal expenditure + Central per capita fiscal expenditure);

Fiscal Decentralization = Fiscal Revenue Decentralization / Fiscal Expenditure Decentralization.

3) Control Variables

This study selects variables that have a significant impact on ecological welfare performance as control variables. Drawing on the research of scholars such as Fang, S.J., and Xiao, Q. (2019), Guo, B.N., and Tang, L. (2023), Gu, D., and Chen, Y. (2020), and Zhao, L., et al. (2024), we choose openness to the outside world, innovation level, industrial structure, and environmental regulation as the control variables in this study. [Author citation for the current study, if applicable: Guo, B., et al.

Table 2: Control Variables

Control Variable	Operational Definition
Degree of Openness	Foreign Direct Investment / GDP
Level of Innovation	Number of Invention Patent Applications Accepted Annually
Industrial Structure	Value Added of the Tertiary Industry / Value Added of the Secondary Industry
Environmental Regulation	Investment in Industrial Pollution Control / Industrial Value Added

3.3.Data Collection

In order to ensure the integrity and accessibility of the data for the specified indicators, this study collects data for the 30 provincial-level administrative regions of China (excluding Tibet, Taiwan, Macau, and Hong Kong) from 2000 to 2021. The data sources for the indicators within the ecological welfare performance framework are as follows:

For the resource input indicators, energy consumption data are sourced from the China Energy Statistical Yearbook, while land and water resource consumption data are obtained from the China Statistical Yearbook.

The three indicators related to economic development welfare are derived from the China Statistical Yearbook.

Health welfare indicators are drawn from the China Health Statistical Yearbook and the China Population and Employment Statistical Yearbook.

The three environmental welfare indicators are based on data from the China Statistical Yearbook.

Data for the four undesirable output indicators are sourced from the China Environmental Statistical Yearbook. Fiscal decentralization indicators are collected from the China Fiscal Statistical Yearbook.

4. Empirical Results and Discussion

4.1.Pre-Modeling Assumption Tests

To enhance the temporal stability of the variables, a logarithmic transformation is first performed. Subsequently, the following three preconditions for modeling are tested: (1) the existence of significant correlations between variables, (2) the stationarity of each variable's time series, and (3) the cointegration between the variables.

1)Correlation Test

As shown in Table 3, the correlation coefficient between the dependent variable, ecological welfare performance (lnstfl), and the explanatory variable, fiscal decentralization (lnczfq), is 0.493, which is significant at the 1% level. The correlation coefficients between the dependent variable and the control variables—environmental regulation (lnhjgz), industrial structure (lncyjg), innovation level (lncxsp), and degree of openness (lndwxf)—are -0.321, 0.349, 0.595, and 0.110, respectively, all of which are significant at the 1% level. These results indicate strong correlations among the variables, providing a solid foundation for the construction of the econometric model.

Table 3 Correlation Test Between Variables

Variables	(1)	(2)	(3)	(4)	(5)	(6)
(1) lnstfl	1.000					
(2) lnczfq	0.493	1.000				
(3) ln hjgz	-0.321	-0.264	1.000			
(4) lncyjg	0.349	0.230	-0.385	1.000		
(5) lndw kf	0.110	0.611	-0.151	-0.005	1.000	
(6) lncxsp	0.431	0.521	-0.520	0.316	0.164	1.000

2) Stationarity Test

To test the stationarity of the first-order differences of each variable, both the Fisher and LLC tests were applied. The results presented in Table 4 indicate that all variables exhibit significant first-order stationarity, confirming that the data sequences are stationary.

Table 4: Stationarity Test of Variables

variable	Test statistical indicators		Statistic	p-value
D.lnstfl	Fisher	Inverse chi-squared(60)	P	354.4733
		Inverse normal	Z	-11.0818
		Inverse logit t(154)	L*	-16.9422
		Modified inv. chi-squared	Pm	26.8816
	Levin-Lin-Chu		Adjusted t*	-11.257
D.lnczf q	Fisher	Inverse chi-squared(60)	P	304.638
		Inverse normal	Z	-11.2492
		Inverse logit t(154)	L*	-14.9791
		Modified inv. chi-squared	Pm	22.3323
	Levin-Lin-Chu		Adjusted t*	-9.1427
D.lnhjg z	Fisher	Inverse chi-squared(60)	P	263.745
		Inverse normal	Z	-10.8419
		Inverse logit t(154)	L*	-12.8764
		Modified inv. chi-squared	Pm	18.5993
	Levin-Lin-Chu		Adjusted t*	-2.8574
D.lncyj g	Fisher	Inverse chi-squared(60)	P	131.5651
		Inverse normal	Z	-5.297
		Inverse logit t(154)	L*	-5.469
		Modified inv. chi-squared	Pm	6.533
	Levin-Lin-Chu		Adjusted t*	-4.9121
D.lncxs p	Fisher	Inverse chi-squared(60)	P	194.709
		Inverse normal	Z	-8.0048
		Inverse logit t(154)	L*	-9.0504
		Modified inv. chi-squared	Pm	12.2972
	Levin-Lin-Chu		Adjusted t*	-6.3822
D.lndw kf	Fisher	Inverse chi-squared(60)	P	245.8863
		Inverse normal	Z	-9.285
		Inverse logit t(154)	L*	-11.3392
		Modified inv. chi-squared	Pm	16.969
	Levin-Lin-Chu		Adjusted t*	-7.5173

3) Cointegration test

First, the lag order for the cointegration of the variables such as ecological welfare performance,

fiscal decentralization, environmental regulation, industrial structure, innovation level, and foreign openness is determined based on information criteria. The output results indicate that, under the information criteria MBIC, MAIC, HQIC, and SBIC, the optimal lag order for cointegration among the variables is one.

Table 5: Order of cointegration among the variables

lag	CD	J	J pvalue	MBIC	MAIC	MQIC
1	184.0828	0.0135145	-704.9424	-103.9172	-340.1672*	184.0828*
2	111.115	0.3992773	-555.6539	-104.885*	-282.0725	111.115
3	55.64499	0.9230199	-388.8676	-88.35501	-206.48	55.64499
4	33.46407	0.5898056	-188.7922	-38.53593	-97.59842	33.46407

To further investigate the cointegration among the variables, both Pedroni and Kao tests were conducted. The results reveal the presence of cointegration among the variables, indicating that there is a long-term equilibrium relationship among them.

Table 6: Pedroni and Kao cointegration test

Statistics of the cointegration test		Statistic	p-value
westerlund		-1.9538	0.0254
Pedroni	Modified Phillips–Perron t	3.4735	0.0003
	Phillips–Perron t	-4.8449	0.0000
	Augmented Dickey–Fuller t	-4.6613	0.0000
Kao	Modified Dickey–Fuller t	-5.1023	0.0000
	Dickey–Fuller t	-5.8123	0.0000
	Augmented Dickey–Fuller t	-3.2027	0.0007
	Unadjusted modified Dickey–Fuller t	-10.4540	0.0000
	Unadjusted Dickey–Fuller t	-7.7612	0.0000

In summary, the variable series of ecological welfare performance, fiscal decentralization, environmental regulation, industrial structure, innovation level, and foreign openness are first-order stationary. Additionally, the variables exhibit significant correlations and demonstrate significant first-order cointegration, thus providing a foundation for constructing and analyzing the econometric regression model.

4.2. Analysis of the Benchmark Regression Model

Considering the scatter plot between ecological welfare performance and fiscal decentralization (see below), a positive linear trend is observed between the two variables.

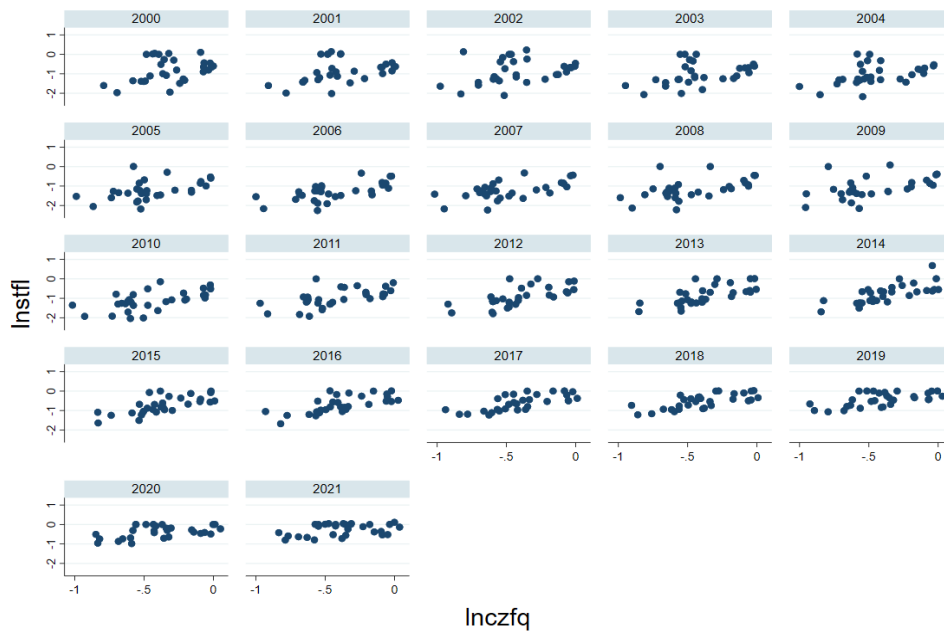


Fig. 1: Scatter Plot of Ecological Welfare Performance and Fiscal Decentralization in Chinese Provincial Regions

In order to examine the impact of fiscal decentralization on ecological welfare performance, several regression models were constructed with fiscal decentralization as the explanatory variable and ecological welfare performance as the dependent variable. Specifically, Model (1) is a hybrid regression model without control variables, Model (2) is a hybrid regression model with control variables; Model (3) is a panel random effects regression model without control variables, and Model (4) is a panel random effects regression model with control variables; Model (5) is a panel fixed effects regression model without control variables, and Model (6) is a panel fixed effects regression model with control variables. The results of model fitting are presented in the table below. The model fitting results indicate that, from Model (1) to Model (6), fiscal decentralization has a significant positive impact on ecological welfare performance at the 1% significance level, demonstrating the robustness of the conclusion regarding the positive effect of fiscal decentralization on ecological welfare performance.

Table 7: Model Fitting Results of the Impact of Fiscal Decentralization on Ecological Welfare Performance

	Mixed Model		Random Effects Model		Fixed Effects Model	
	(1)	(2)	(3)	(4)	(5)	(6)
lnczfq	1.0871*** (14.5177)	1.1761*** (11.1703)	1.5636*** (10.2820)	1.6826*** (11.1158)	2.2606*** (10.1406)	2.1166*** (11.3704)
lnhjgz		-0.0720*** (-2.9381)		-0.0816*** (-3.8222)		-0.0860*** (-4.0390)
lndwkwf		-0.1220*** (-5.9478)		-0.1390*** (-6.3889)		-0.1192*** (-5.2247)
lncyjg		0.2197*** (4.4294)		0.4429*** (7.5260)		0.4968*** (8.1160)
lncxsp		0.2017** (2.0168)		0.1801* (1.9109)		0.1764* (1.8537)
_cons	-0.4116*** (-11.4797)	-1.7188*** (-8.0516)	-0.2171*** (-2.7365)	-1.5870*** (-7.2857)	0.0673 (0.7287)	-1.3432*** (-6.0974)
adj. R^2	0.241	0.358			0.100	0.396

t statistics in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Furthermore, a Hausman test was conducted for both the random effects model and the fixed

effects model. The test results indicated $\chi^2(6) = 25.04$, $\text{Prob} > \chi^2 = 0.0003$. Since the p-value is less than 0.05, the Hausman test rejects the null hypothesis of no systematic bias in the coefficient differences. This suggests that the fixed effects model should be prioritized for analysis. Based on this, the study selects model (6) to examine the impact of fiscal decentralization on ecological welfare performance. The results from this model demonstrate a significant positive impact of fiscal decentralization on ecological welfare performance.

Table 8 Hausman Test for Fixed Effects Model of the Impact of Fiscal Decentralization on Ecological Welfare Performance

	(b)	(B)	(b-B)	$\sqrt{\text{diag}(V_b - V_B)}$
	Fixed Effects	Random Effects	Difference	Std. err.
lnczfq	2.1166	1.6826	0.4340	0.1133
lnhjgz	-0.0860	-0.0816	-0.0045	0.0036
lncyjg	0.4968	0.4429	0.0538	0.0201
lncxsp	0.1764	0.1801	-0.0037	0.0214
lndwkwf	-0.1192	-0.1390	0.0198	0.0080
_cons	-1.3432	-1.5870	0.2438	0.0512

It is noted that, under the consideration of the impact of fiscal decentralization, the control variables also have significant effects on ecological welfare performance. Specifically, the industrial structure and innovation level exhibit positive effects, with coefficients of 0.4968 (p-value < 0.01) and 0.1764 (p-value < 0.1), respectively. This suggests that a higher proportion of the tertiary industry and a higher level of technological innovation are conducive to the improvement of ecological welfare performance. On the other hand, environmental regulation has a negative effect on ecological welfare performance (-0.0860, p-value < 0.01). This may be due to factors such as increased economic costs, insufficient policy enforcement, and limited adaptability of enterprises, which result in the negative impact of environmental regulations on ecological welfare performance. Furthermore, foreign openness also exerts a negative effect (-0.1192, p-value < 0.01). This phenomenon may stem from the fact that foreign direct investment tends to prioritize commercial economic benefits while neglecting concerns about environmental and social welfare, leading to environmental degradation, regulatory challenges, and socio-economic inequalities.

4.3. Spatial β -Convergence Model Analysis

This section examines the impact of fiscal decentralization on the spatial convergence of ecological welfare performance. In this study, the first-order lagged term of ecological welfare performance (l.lnstrfl), fiscal decentralization (lnczfq), and the control variables are used as explanatory variables in the spatial β -convergence model, with ecological welfare performance as the dependent variable. The model fitting results are presented in the table below.

The first step is to examine the spatial absolute β -convergence of ecological welfare performance. The results, as shown in column (1) of the table, indicate that the coefficient of the first-order lagged term of ecological welfare performance is negative (-0.1929) and significant ($p < 0.01$), which suggests that ecological welfare performance exhibits significant spatial absolute β -convergence.

Next, the impact of fiscal decentralization on the spatial β -convergence of ecological welfare performance is further explored. Based on model (1), fiscal decentralization (lnczfq) is added as an explanatory variable. The results, as shown in column (2), reveal that the coefficient of fiscal decentralization is significantly positive (0.7021, $p < 0.01$). At the same time, the coefficient of the first-order lagged term of ecological welfare performance remains negative and significant (-0.2385, $p < 0.01$). Furthermore, the absolute value of this coefficient increases from 0.1929 to 0.2385. This indicates that, in the absence of other factors, fiscal decentralization has a significant effect on the

spatial relative β -convergence of ecological welfare performance, accelerating its spatial relative β -convergence.

Column (3) of the table shows the impact of the control variables on the spatial relative β -convergence of ecological welfare performance, while column (4) presents the model results after adding fiscal decentralization to the model in column (3). Comparing the results of columns (3) and (4), it is evident that the absolute value of the coefficient of the first-order lagged term of ecological welfare performance increases from 0.3197 to -0.3682, and the coefficient of fiscal decentralization remains significantly positive. This further suggests that fiscal decentralization accelerates the spatial relative β -convergence of ecological welfare performance, even when considering the impact of the control variables on the spatial relative β -convergence.

It is important to note that, from the model outputs in columns (3) and (4), each control variable significantly influences the spatial convergence of ecological welfare performance. Specifically, environmental regulation and foreign openness inhibit the spatial convergence of ecological welfare performance, while innovation level and industrial structure have a positive accelerating effect. These results demonstrate a high degree of robustness and consistency.

Table 9: Model Fitting Results for the Spatial β -Convergence of Ecological Welfare Performance under Fiscal Decentralization

	(1)	(2)	(3)	(4)
l.lnstfl	-0.1929*** (-7.2318)	-0.2385*** (-8.2828)	-0.3197*** (-11.0435)	-0.3682*** (-11.6160)
lnctzf		0.7021*** (3.9332)		0.6403*** (3.5835)
lnhjgz			-0.0439*** (-2.6351)	-0.0487*** (-2.9430)
lnctyjg			0.0800 (1.5719)	0.1186** (2.3017)
lnctwkf			-0.0236 (-1.2835)	-0.0355* (-1.9216)
lnctxsp			0.4701*** (6.0747)	0.3707*** (4.5485)
_cons	-0.1441*** (-5.5415)	0.1053 (1.5393)	-1.6031*** (-9.0788)	-1.2486*** (-6.2150)

t statistics in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

4.4. Heterogeneity Analysis

1) Heterogeneity of the Impact of Fiscal Decentralization on Ecological Welfare Performance

This section examines the heterogeneity of the impact of fiscal decentralization on ecological welfare performance across different regions. Based on the classification criteria provided by the National Bureau of Statistics of China, which divides regions by geographic location and economic development level, the 30 provincial-level administrative divisions covered in this study are categorized into three regions: Eastern, Central, and Western China. Separate models are then established to analyze the effect of fiscal decentralization on ecological welfare performance in each region.

The results indicate that, regardless of the region—Eastern, Central, or Western—there is a significant positive impact on ecological welfare performance, consistent with the national trend, which demonstrates the robustness of the findings. Notably, from a regional perspective, the impact of fiscal decentralization on ecological welfare performance is the largest in the Eastern region, with a coefficient of 3.4299 ($p < 0.01$), followed by the Central region (3.2678, $p < 0.01$). The impact of fiscal decentralization on ecological welfare performance in the Western region is relatively smaller, with a coefficient of 1.6904 ($p < 0.01$). These findings indicate that the effect of fiscal decentralization on ecological welfare performance exhibits regional heterogeneity.

Table 10: Results of Heterogeneity Analysis on the Impact of Fiscal Decentralization on Ecological Welfare Performance

	(1) Eastern Region	(2) Central Region	(3) Western Region	(4) National
lnczfq	3.4299*** (5.9989)	3.2678*** (7.7873)	1.6904*** (5.5664)	2.2606*** (10.1406)
_cons	-0.1730** (-2.0589)	0.7060*** (3.5595)	-0.0432 (-0.2451)	0.0673 (0.7287)

t statistics in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

2) Heterogeneity Analysis of the Impact of Fiscal Decentralization on the Spatial Convergence of Ecological Welfare Performance

This section investigates the heterogeneity of the impact of fiscal decentralization on the spatial relative β -convergence of ecological welfare performance across different regions. Spatial convergence models for the impact of fiscal decentralization on ecological welfare performance were established for each region. The results show that, in the Eastern, Central, and Western regions, there is significant spatial convergence of ecological welfare performance, with fiscal decentralization having a significantly positive effect on the spatial convergence of ecological welfare performance in all regions. This result is consistent with the national situation, which strengthens the robustness of the conclusion.

It is noteworthy that the absolute value of the first-order lag coefficient for ecological welfare performance in the Central region is the largest (0.3276), indicating that the speed of interprovincial ecological welfare performance convergence is the fastest in the Central region, where provinces tend to converge toward balanced development more quickly. The fiscal decentralization coefficient in the Eastern region has a significance level between 0.01 and 0.05, whereas the significance level of fiscal decentralization in the Western and Central regions is below 0.01, meaning that the effect of fiscal decentralization on the spatial convergence of ecological welfare performance is weakest in the Eastern region compared to the Central and Western regions. This suggests that the impact of fiscal decentralization on the spatial convergence of ecological welfare performance exhibits regional heterogeneity.

Table 11: Heterogeneity Analysis of the Impact of Fiscal Decentralization on the Spatial Convergence of Ecological Welfare Performance

	(1) Eastern Region	(2) Central Region	(3) Western Region	(4) National
lnnstfl	-0.1898*** (-3.9208)	-0.3276*** (-4.4308)	-0.2420*** (-5.7344)	-0.2385*** (-8.2828)
lnczfq	0.8193* (1.7886)	1.1478** (2.6102)	0.6063** (2.5801)	0.7021*** (3.9332)
_cons	0.0150 (0.2548)	0.2819 (1.5763)	0.1287 (0.9859)	0.1053 (1.5393)

t statistics in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5. Conclusions and Recommendations

5.1. Conclusions

This study investigates the relationship between fiscal decentralization and ecological welfare performance, as well as its spatial convergence. Based on panel data from 30 provincial-level regions in China between 2000 and 2021, and employing the Super Efficiency SBM model for measuring ecological welfare performance, this study constructs benchmark regression models and spatial convergence models to explore the impact of fiscal decentralization on ecological welfare

performance and its spatial convergence, with a further examination of regional heterogeneity in this effect.

The study finds that ecological welfare performance exhibits both spatial absolute β convergence and relative β convergence. Fiscal decentralization has a significant positive impact on ecological welfare performance, and it also significantly promotes spatial relative β convergence of ecological welfare performance. Under the control of fiscal decentralization, various control variables significantly influence ecological welfare performance and its spatial relative β convergence: industrial structure and innovation level have a positive impact on ecological welfare performance and significantly promote its spatial relative β convergence; environmental regulation and openness to foreign trade negatively affect ecological welfare performance and significantly inhibit its spatial relative β convergence. The influence of fiscal decentralization on both ecological welfare performance and its spatial relative β convergence also exhibits regional heterogeneity. In the eastern region, fiscal decentralization has the greatest impact on ecological welfare performance, while in the western region, its impact is relatively minimal. In the central region, the speed of spatial relative β convergence of ecological welfare performance between provinces is the fastest, indicating a quicker convergence toward balanced development. Moreover, fiscal decentralization in the eastern region has the weakest positive effect on the spatial relative β convergence of ecological welfare performance compared to the central and western regions.

5.2. Policy Recommendations

Based on the insights revealed by this study regarding the mechanisms through which fiscal decentralization affects ecological welfare performance and its spatial convergence, and the identification of regional heterogeneity in fiscal decentralization effects, the following policy recommendations are proposed:

Consolidate the Ecological Effects of Fiscal Decentralization and Strengthen Provincial Environmental Incentives: The study finds that fiscal decentralization has a significant positive impact on ecological welfare performance. Therefore, the fiscal decentralization system should be further optimized to enhance local governments' incentive mechanisms for environmental governance. Specifically, provincial governments should be granted more fiscal autonomy in environmental protection and sustainable development, and a fiscal transfer system based on ecological performance should be established, allowing local governments to receive more financial support for improving environmental quality, thus enhancing their motivation for sustainable development.

Promote Regional Coordinated Development and Reduce Inter-Provincial Disparities in Ecological Welfare Performance: The study shows that ecological welfare performance exhibits spatial β convergence, with the central region having the fastest spatial convergence speed. However, the impact of fiscal decentralization on ecological welfare performance differs across regions. Therefore, fiscal decentralization policies should be adjusted according to regional conditions to enhance fiscal autonomy in the western regions and strengthen their environmental governance capacity. Additionally, the central government should increase fiscal support for ecologically fragile areas, particularly in environmental infrastructure construction, green technology promotion, and industrial structure upgrading, to promote balanced regional development and reduce spatial disparities in ecological welfare performance.

Optimize Industrial Structure and Promote the Green Industry Transformation: The study finds that industrial structure upgrading contributes to improving ecological welfare performance and promoting its spatial convergence. Therefore, the development of green and low-carbon industries should be accelerated, and traditional high-pollution industries should be transformed into green industries. The government should incentivize enterprises to adopt clean production technologies through tax reductions and fiscal subsidies, and foster the development of emerging industries such as environmental protection and circular economy, thereby optimizing industrial structure and improving regional sustainable development capacity.

Strengthen Innovation-Driven Growth and Leverage Technological Advancements for Ecological Welfare Performance: The study indicates that innovation level significantly positively impacts both ecological welfare performance and its spatial convergence. Thus, the government should increase support for green technology research and development, encourage enterprises and research institutions to strengthen innovation in environmental protection technologies and renewable energy technologies. At the same time, regional technological exchange and cooperation should be promoted to accelerate the diffusion of advanced environmental technologies across regions, enhancing overall ecological welfare performance and achieving spatial balance.

Moderately Strengthen Environmental Regulations to Avoid Negative Impacts on Ecological Welfare Performance: The study shows that environmental regulations negatively impact ecological welfare performance, potentially due to the over-reliance on administrative measures for environmental governance in some regions, which may hinder economic vitality. Therefore, environmental regulation policies should be optimized to balance ecological protection goals with the scientific and flexible implementation of these policies.

Enhance the Quality of Foreign Trade and Prevent "Pollution Haven" Effects: The study finds that foreign trade negatively affects ecological welfare performance, suggesting that some regions may be facing the "pollution haven" or "pollution transfer" effect. Thus, environmental supervision of foreign-invested enterprises should be strengthened, and higher environmental standards should be imposed to prevent the concentration of pollution in regions with lower ecological standards. Furthermore, the government can attract high-value-added, low-carbon, and environmentally friendly foreign enterprises by providing policy incentives, thereby promoting the introduction of green technologies and upgrading industries to improve the quality of foreign trade and contribute to ecological sustainability.

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