The moderating effect of Expressway Construction on Environmental Governance: Evidence from China

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Abstract

With the increasing severity of pollution, environmental infrastructure (EI) has gained more attention as a means of environmental governance to achieve regional sustainability. However, the construction of EI is complex and systematic due to path dependence of cities on technology and traditional industries. This paper investigates the relationship between technology transfer, EI investment, and expressway construction using panel data collected 30 provinces in China from 2010 to 2019. A two-way fixed effects model is utilized to validate the hypothesis. The results show that regions with higher levels of technology transfer significantly promote EI investment; Expressway construction has a significant negative moderating effect on the relationship between EI investment and technology transfer. These findings indicate that regions that rely heavily on expressways may face challenges when transforming toward green development. Substitution variable method and time lag method were utilized to test the robustness of the results. This research not only reveals the micro mechanism of how technological transfer impacts EI investment, but also suggests the construction of EI should be region-specific by considering transport infrastructure.
Keywords: Environmental infrastructure investment, expressway construction, technology transfer.

1. INTRODUCTION

The deteriorating ecological environment has become a critical global issue, directly impacting human life and health (Pattberg and Widerberg, 2015). As pollution escalates, environmental infrastructure (EI), including sewage treatment, resource recovery, domestic waste management, solid waste disposal, et al., has become essential for achieving regional sustainability (Li et al., 2023). Enhancing EI construction helps reduce environmental pollution and reach carbon peaking. Recently, many governments have initiated large-scale EI investment to strengthen environmental governance (Pattberg and Widerberg, 2015). The Chinese government has been taking vigorous efforts in developing eco-cities by environmental governance investment (Lin, 2021). However, EI has challenges such as uneven regional development, low disposal quality and resource utilization levels, and weak technology transfer, which hinder effective environmental governance (Peng et al., 2021, Zhang et al., 2023).

Environmental governance is also pressured by the rapid development of transportation infrastructure, such as expressway construction. While expressway construction fosters economic growth, it also increases environmental pollution, but economic growth can diminish government commitment to environmental standards and investment in governance (Zhu et al., 2023). Duffydeno and Eberts (1991) suggests that economic development encourages expressway construction, which can lower investment in environmental governance. However, most research focuses on impact of regional differences in transportation infrastructure on environmental pollution, without considering coupling effect of expressway construction on environmental governance.

Thus, studying the relationship between expressway construction, technology transfer, and environmental governance is crucial for regional economic and social transformation. This study uses panel data from 30 Chinese provinces (2010-2019) and a two-way fixed-effects model to investigate these relationships. It examines the relationship between the scale of technology transfer and investment in environmental governance, explores the impact of expressway construction on environmental governance, and suggests strategies to promote investment in environmental governance to aid local governments in improving the ecological environment.

2. HYPOTHESES

Technology transfer, as a key component of green technology innovation, promotes the diffusion of environmental protection technologies, upgrading local environmental systems and reducing pollution emissions (Zhang et al., 2023). Promoting intelligent upgrading and green development, as crucial goals of environmental governance, requires accelerating technological innovation and transforming green technological achievements (Zhang and Yang, 2024). Thus, the scale of technology transfer positively impacts the level of environmental governance, leading to the first hypothesis:

H1: Technology transfer is significantly positively related to environmental governance.

The continuous improvement of expressway construction can facilitate the diffusion of advanced environmental protection technologies via spillover effects. Economic growth from expressway construction generates more funds for equipment renewal and environmental protection investments (Pieck, 2013). However, improved expressway construction also increases pollutant emissions and resource over-exploitation (Yang et al., 2021). This can result in lower environmental standards and reduced investment in environmental governance by local governments, leading to environmental degradation. Therefore, the second hypothesis is proposed:

H2: Expressway construction has a significant negative moderating effect on the relationship between technology transfer and environmental governance.

3. HYPOTHESES

3.1. Data

The sample for this study comprises panel data from 30 provinces in China, covering the years 2010 to 2019. The data are sourced from the China Macroeconomic Database, the China High Technology Industry Database, and the China Environmental Database.

3.2. Variables

Environmental Governance Level (EI): Environmental infrastructure is a critical component of environmental governance. Therefore, per capita investment in environmental infrastructure construction is used to measure the environmental governance level.
Technology Transfer Scale (TT): The scale of technology transfer is reflected by the turnover in the technology market.
Expressway Construction (EC): Expressways play a significant role in passenger and freight transportation and substantially contribute to environmental pollution. Thus, per capita expressway mileage is chosen as a measure of regional expressway construction.

Based on prior research, this study also controls for several factors including the level of openness to foreign trade, economic size, resident consumption level, industry structure, education, and environmental pollution. Table 1 details the specific definitions of the research variables.

Table 1. Variable description

Type	Name	Symbols	Description
Explained variable	Environmental infrastructure level	EI	Total investment in environmental infrastructure per square kilometres
Explanatory variable	Technology Transfer	TT	Technology Market Turnover (million yuan)
Control variable	Expressway construction level	EC	Expressway miles per person
	Level of openness to foreign trade	T	Amount of goods exported (USD million)
	Economic Size	ES	GDP per capita (yuan)
	Resident consumption level	RC	Resident consumption index
	Industry Structure	IS	The proportion of the secondary industry (%)
	Education	Edu	Average number of students in higher education
	Environmental pollution	EP	Emission level of SO_2 (tons)

3.3. Model

This study employs a two-way fixed effects method, incorporating province and time fixed effects to eliminate estimation bias (Fan et al., 2022). We construct multiple regression models 1 through 3 to test hypotheses H1 and H2. The models are structured as follows:

$$EI_{it} = \beta_0 + \beta_1 TT + \beta_2 T + \beta_3 ES + \beta_4 RC + \beta_5 IS + \beta_6 Edu + \beta_7 \sum Year_t + \mu_i + \varepsilon_{it} \quad (1)$$

$$EI_{it} = \beta_0 + \beta_1 TT + \beta_2 EC + \beta_3 T + \beta_4 ES + \beta_5 RC + \beta_6 IS + \beta_7 Edu + \beta_8 \sum Year_t + \mu_i + \varepsilon_{it} \quad (2)$$

$$\begin{aligned} EI_{it} = {} & \beta_0 + \beta_1 TT + \beta_2 EC + \beta_3 TT \times EC + \beta_3 T + \beta_4 ES + \beta_5 RC + \beta_6 IS + \beta_7 Edu \\ & + \beta_8 \sum Year_t + \mu_i + \varepsilon_{it} \end{aligned} \quad (3)$$

Where, β represents the coefficients, Year is the time trend variable. μ denotes province fixed effects, ε is the random disturbance term, i represents the i province, and t denotes time. The variables used in the models are explained in Table 1.

4. RESULTS

4.1. Descriptive Statistics and Regression Result

Table 2 presents the names, means, standard deviations, minimums, maximums, and VIF values. The average investment in environmental infrastructure construction per square kilometres is approximately 0.003, indicating uneven investment across Chinese provinces. The average scale of technology transfer is 33,743.96 million yuan, with a minimum of 5,666.144 million yuan and a maximum of 57,000 million yuan, highlighting disparities in the development of technology transfer markets. The average per capita expressway mileage is 1.040 km/person, ranging from 0.332 to 5.849, showing significant variations across provinces, with only a few provinces having higher mileage. We use the Variance Inflation Factor (VIF) to assess multicollinearity. A VIF value below 10 suggests no significant multicollinearity. As shown in Table 2, there is no significant multicollinearity among the independent variables, permitting further regression analysis.

Model 1 examines the relationship between technology transfer (TT) and environmental infrastructure investment, with a positive coefficient. This indicates that an increase in technology transfer significantly boosts environmental infrastructure investment, supporting H1. Model 2 includes the expressway construction variable (EC) and shows that TT positively impacts environmental infrastructure investment. However, the expressway construction coefficient is negative, suggesting that improved expressway construction reduces environmental infrastructure investment. Model 3, which includes an interaction term between expressway construction and technology transfer, shows a significantly negative coefficient. This indicates that expressway construction negatively moderates the relationship between technology transfer and environmental infrastructure investment. As expressway construction increases, the positive effect of technology transfer on environmental infrastructure investment decreases, confirming H2.

Table 2. Descriptive statistics of variables

Variables	Obs	Mean	Std.	Min	Max	VIF
EI	300	0.003	0.005	0	0.04	-
TT	300	3374396	7023083	5666.144	57000000	2.870
EC	300	1.040	0.745	0.332	5.849	1.490
T	300	7227929	12700000	29353.27	64700000	1.710
ES	300	52635	2626.53	13119	164222	3.240
RC	300	102.613	1.218	100.566	106.338	1.180
IS	300	44.403	8.661	16.2	59	1.990
Edu	300	2566.39	825.686	1082.149	6196.365	3.180
EP	300	504117.7	400268.9	1923	1827397	1.770

Table 3. Regression results of the moderating effect of expressway construction on environmental infrastructure investment

Variables	Model 1	Model 2	Model 3
TT	0.495*** (0.164)	0.491*** (0.165)	0.115 (0.124)
EC		-0.032 (0.038)	-0.408*** (0.126)
TT×EC			-0.905*** (0.266)
T	-0.821*** (0.196)	-0.831*** (0.2)	-0.754*** (0.191)
ES	0.039 (0.218)	0.287 (0.211)	0.066 (0.177)
RC	-0.146 (0.092)	-0.157 (0.097)	-0.150* (0.086)
IS	0.070 (0.128)	0.066 (0.131)	0.108 (0.097)
Edu	-0.192 (0.239)	-0.185 (0.239)	-0.088 (0.171)
EP	-0.010 (0.068)	0.017 (0.070)	0.017 (0.065)
Constant	0.109 (0.294)	0.092 (0.288)	-0.253 (0.247)
Year FE	Y	Y	Y
Province FE	Y	Y	Y
R^2	0.460	0.461	0.592
F	14.790	19.340	116.170

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.10.

Table 4. Robustness test

Variables	Substitution of variables	Time lag method
TT	0.321** (0.129)	0.368** (0.175)
TT×EC	-0.592** (0.246)	-0.552** (0.259)
EC	-0.227* (0.112)	-0.360*** (0.127)
T	-1.220* (0.637)	-0.184 (0.220)
ES	0.124 (0.243)	-0.058 (0.297)
RC	-0.002 (0.093)	-0.082 (0.080)
IS	0.303** (0.136)	0.369* (0.142)
Edu	0.197 (0.25)	0.017 (0.399)
EP	0.119 (0.118)	0.000 (0.000)

Constant	-0.557** (0.271)	-0.150 (0.408)
Year FE	Y	Y
Province FE	Y	Y
R2	0.444	0.340
F	80.150	12.980

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.10.

4.2. Robustness Tests

To ensure the robustness of the results, the following tests were conducted: 1) Re-regression with per capita environmental infrastructure investment instead of investment per square kilometre. 2) Lagging the explanatory variables by one period and re-regression to address endogeneity issues. The results from these robustness checks indicate that the signs of the main variable coefficients remain consistent with expectations. The results of robustness tests are presented in Table 4.

5. DISCUSSION

Technology transfer can boost investment in environmental infrastructure, thereby enhancing environmental governance. This finding is consistent with Zhang and Yang (2024) who indicate that technological innovation can improve government environmental governance capacity. Environmental infrastructure encompasses a wide range of technological systems and innovations. Technological innovation can improve the greenness and intelligence of environmental infrastructure, enhancing its environmental benefits (Zhang et al., 2023). Additionally, the spillover effect of technology transfer can facilitate the diffusion of environmental protection technologies, significantly enhancing the effectiveness of environmental governance investment. This demonstrates that promoting technology transfer helps elevate environmental governance.

However, investment in expressway construction can inhibit the positive relationship between technology transfer and environmental governance. This may be due to increased pollutant emissions from expressway construction and fiscal competition for environmental governance funds. As Duffydeno and Eberts (1991) noted, economic development encourages local governments to expand expressway investment. Additionally, the economic growth from expressway construction can reduce the effectiveness to invest in environmental governance due to the rapid economic expansion (Peng et al., 2018). Our findings support this view, indicating that regions reliant on expressway construction struggle to shift towards environmental infrastructure investment. Therefore, regions with extensive expressway networks need incentive policies to encourage government investment in environmental governance.

6. CONCLUSION

This paper constructs a two-way fixed-effects model and uses statistical data from 30 Chinese provinces from 2010 to 2019 to empirically study the interaction between expressway construction, technology transfer, and environmental infrastructure construction. The following valuable conclusions are obtained:
1) Technology transfer has a significant positive effect on the construction of environmental infrastructure.
2) Expressway construction plays a significant negative effect on the relationship between technology transfer and environmental infrastructure construction.
3) The moderating effect of expressway construction on environmental infrastructure construction is consistent with the path dependence on resource industries in regional development. The higher the level of expressway construction, the less the provinces invest in environmental infrastructure construction. In other words, the more dependent the region is on expressway construction, the more

difficult it is to shift to environmental infrastructure construction.
4) The robustness tests further support the findings.
These findings not only reveal the underlying mechanisms of how technology transfer affects EI construction, but also suggest that EI construction should be regionally targeted, especially in regions with uneven development levels of expressway infrastructure.

7. REFERENCES

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