Pollution Transfer in the Decentralization of Non-capital Functions: Based on the Perspective of Beijing-Tianjin-Hebei region

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Abstract. Due to factors such as differences in environmental regulation standards and internal structural contradictions in the Beijing-Tianjin-Hebei region, some highly polluting industries may form a pollution transfer effect during regional transfer, resulting in environmental pollution in the receiving areas and slowing down economic development. This paper uses the difference-in-differences method for empirical testing. By dividing the sample period according to the policy implementation year (2017), it compares the degree of pollutants before and after the policy implementation to analyze the institutional effect, effectively reflecting the impact of institutional intervention on the environment of the receiving areas. Control variables such as GDP of municipal districts, the number of industrial enterprises above a designated size, and population density are introduced. The regression results confirm that the policy of decentralizing non-capital functions has had a pollution transfer effect on the receiving areas. This paper proposes solutions to overcome pollution transfer from four aspects, providing an empirical basis for promoting the green development of industries and regional coordinated development.

Keywords: Pollution transfer, Green development, Difference-in-differences method, Beijing-Tianjin-Hebei, Decentralization of non-capital functions.

1. Introduction

The decentralization of non-capital functions is an important part of the coordinated development strategy of the Beijing-Tianjin-Hebei region. The task of decentralizing industrial enterprises is a component of the decentralization of non-capital functions. Since the implementation of the coordinated development strategy of the Beijing-Tianjin-Hebei region in 2014, Beijing has relocated more than 3,000 general manufacturing enterprises. Non-capital functions such as wholesale markets and logistics centers have been accelerating their transfer to Hebei and Tianjin. In 2017, the Beijing Municipal Government issued the "Implementation Opinions on Organizing and Carrying out the 'Decentralization, Rectification, and Promotion' Special Action (2017 - 2020)", and the Beijing Development and Reform Commission issued official policy documents such as the "Catalogue of Prohibited and Restricted New Industries in Beijing (2017 Edition)". Due to differences in environmental regulation standards and internal structural contradictions in the Beijing-Tianjin-Hebei region, some highly polluting industries may form a pollution transfer effect during regional transfer, resulting in environmental pollution in the receiving areas and slowing down economic development. This issue urgently needs to be studied [1,2].

This paper attempts to take the accompanying problem of pollution transfer in the regional industrial green transformation as a starting point. Through the differential performance of prefecture-level cities in Hebei Province affected by the policy, it uses the difference-in-differences method to design and prove the existence of pollution transfer, and explores the coordinated governance mechanism and path innovation methods for regional green transformation.

The marginal contribution of this paper is to reveal the pollution transfer problem during the integrated development of the Beijing-Tianjin-Hebei region, filling a gap in current research to a certain extent. Corresponding policy recommendations are put forward, which is of great practical significance.

2. Theoretical Basis and Research Hypotheses

The problem of pollution transfer in the decentralization of non-capital functions is essentially a coupling process of regional industrial restructuring and the spatial redistribution of environmental externalities [3]. According to the research of Li Yonggang et al., based on the "pollution haven" hypothesis in environmental economics, Beijing's strict control of the increment of polluting industries through policy means may lead to Hebei relaxing the environmental supervision threshold in the short term, forming a "regulation depression", and there is a certain policy gradient difference, providing an institutional space for the cross-regional transfer of polluting industries [4,5].

Based on the path dependence theory of evolutionary economics, Hebei's industrial structure, which is dominated by traditional industries such as steel and chemicals, makes it more likely to absorb homogeneous and highly polluting production capacity when undertaking the industries decentralized from Beijing, forming a "technology-industry lock-in" effect.

Based on the above analysis, referring to the "pressure-response-spillover" chain mechanism, the pollution transfer is analyzed as follows [6]:

First, in terms of the pressure layer, Beijing forms a decentralization thrust through administrative means and market tools, while Hebei forms a receiving pull due to the strategic positioning of coordinated development, along with geographical proximity and economic development needs.

Second, from the perspective of the response layer, industrial enterprises choose migration strategies based on the logic of cost minimization. The compliance cost advantage of regions with low environmental standards promotes the transfer of pollution-intensive industries.

Third, in the spillover layer, relocated enterprises trigger the coordinated diffusion of upstream and downstream pollution through industrial chain linkages such as local supply chains, forming a compound pollution effect of "primary transfer-secondary derivation".

Based on this, an impact mechanism of "policy release - enterprise transfer - pollution formation" is constructed.

Based on the above theory, the following hypotheses are proposed:

Hypothesis 1: The decentralization of non-capital functions significantly intensifies the industrial pollution intensity in the receiving areas. This effect is prominent in regions (Tangshan, Langfang, Baoding, Cangzhou) with low environmental regulation intensity and a heavy industry-dominated industrial structure.

Hypothesis 2: There is an "industrial chain lock-in effect" in pollution transfer. That is, the higher the industrial correlation degree in the receiving areas, the wider the spatial diffusion range of pollution spillover, and it shows a non-linear threshold characteristic.

3. Research Design

3.1. Data Sample Description

In the division of the experimental group and the control group, this paper selects Baoding, Tangshan, and Langfang, which are typical cities that have received a large number of enterprise transfers from Beijing, as the experimental group, and Zhangjiakou and Chengde, which have received fewer enterprise transfers from Beijing, as the control group. The panel data of these cities from 2005 to 2021 are selected. The establishment of Xiong'an New Area on April 1, 2017, marked a substantial progress in the decentralization of Beijing's non-capital functions. Therefore, 2017 is set as the year when enterprise transfer has a substantial impact, with 2005 - 2016 as the unaffected years and 2017 - 2021 as the years affected by the policy. All data are from the China Environmental Statistics Yearbook, the Hebei Provincial Ecological Environment Bulletin, and the CSDN official data platform. The data statistics refer to the measurement methods of Cong Jianhui et al. [7].

Due to partial data missing during data collection: some variables in the early years (2005) are missing due to incomplete records; in the later years (2020 and 2021), data statistics are incomplete due to the impact of the public health incident, and data for the relatively recent years (2022 and 2023)

are not fully statistically available. These affect the accuracy of the regression design. The missing data years are deleted, and the data from 2006 to 2019 are retained. 2006 - 2016 are regarded as the unaffected years, and 2017 - 2019 are regarded as the years affected by the policy.

3.2. Model Design

The difference-in-differences method (DID) is a widely used method for evaluating policy effects in recent years. This paper refers to the research of Shi Dan and Li Shaolin, uses DID to evaluate the pollution transfer effect of the policy of decentralizing non-capital functions on the receiving cities, and designs the following model [8]:

$$Y_{it} = \alpha + \beta_1 Treat_i + \beta_2 Post_t + \beta_3 (Treat_i \times Post_t) + \gamma X_{it} + City_i \times Year_t + \epsilon_{it} \quad (1)$$

Where *i* and *t* represent cities and years respectively; Y_{it} is the explained variable, that is, the pollution index indicating the degree of pollution. The indicators selected in this paper include carbon dioxide emissions (10,000 tons) during industrial production, industrial wastewater (10,000 tons), and smoke and dust (10,000 tons); $Treat_i$ is the treatment group dummy variable. Prefecture-level cities in Hebei Province, those that have received a large number of industrial enterprise transfers (Baoding, Tangshan, Langfang, Cangzhou, Shijiazhuang) are 1, and those that have received fewer industrial enterprise transfers (Chengde, Zhangjiakou) are 0; $Post_t$ is the policy time dummy variable. Years after the implementation of the decentralization policy are 1, and years before the implementation are 0; X_{it} is the control variable. In this paper, the GDP of each municipal district, the number of industrial enterprises above a designated size in each city, and the population density of each city are selected as control variables; $City_i \times Year_t$ is the city - individual time effect, aiming to control the impact of unobservable factors that change over time in each city on the estimation results, and ϵit represents the random error term.

4. Empirical Results and Stability Tests

4.1. Regression Results of the DID Model

This paper conducts empirical tests using the difference-in-differences method. By dividing the sample period according to the policy implementation year (2017), it compares the degree of pollutants before and after the policy implementation to analyze the institutional effect, effectively reflecting the impact of institutional intervention on the environment of the receiving areas. The results are shown in Table 1. After introducing control variables such as the GDP of municipal districts, the number of industrial enterprises above a designated size, and the population density, after the promulgation of the policy of decentralizing non-capital functions, the regression results show that among the three pollution indicators of cities that have received more enterprise transfers, one shows an upward trend at the 1% significance level and one at the 10% significance level compared with cities that have received fewer enterprise transfers, confirming that the policy of decentralizing non-capital functions has had a pollution transfer effect on the receiving areas.

Table1. Empirical regression result

	(1)	(2)	(3)
VARIABLES	ln_pwater	ln_pCO2	ln_smoge
DID	1.125***	0.084*	-0.868***
	(0.200)	(0.049)	(0.273)
GDP	3.17e-09	1.43e-08***	1.62e-07***
	(1.80e-08)	(4.37e-09)	(1.81e-08)
nIP	0.002**	-0.0003*	-0.002***
	(0.0007)	(0.0002)	(0.0008)
PD	0.0002***	2.39e-05***	-3.11e-05
	(2.41e-05)	(6.25e-06)	(2.89e-05)
2007.year	0.015	0.084**	-0.238
	(0.210)	(0.034)	(0.413)
2008.year	0.025	0.163***	-0.616*
	(0.217)	(0.042)	(0.333)
2009.year	0.0804	0.151***	-0.815**
	(0.211)	(0.042)	(0.355)
2010.year	0.129	0.137***	-0.925***
	(0.211)	(0.043)	(0.309)
2011.year	0.211	0.216***	-0.141
	(0.246)	(0.050)	(0.287)
2012.year	0.254	0.284***	-0.410
	(0.276)	(0.048)	(0.293)
2013.year	0.389	0.203***	-0.201
	(0.241)	(0.056)	(0.323)
2014.year	0.492**	0.399***	-0.001
	(0.243)	(0.046)	(0.310)
2015.year	0.716***	0.318***	-0.311
	(0.218)	(0.059)	(0.301)
2016.year	0.994***	0.331***	-1.036***
	(0.187)	(0.065)	(0.336)
2017.year	1.304***	0.319***	-0.923***
	(0.202)	(0.063)	(0.343)
2018.year	1.602***	0.383***	-0.986***
	(0.221)	(0.070)	(0.344)
2019.year	1.706***	0.0298	-0.199
	(0.230)	(0.080)	(0.485)
2.cid	0.407***	-0.0425	-0.432***
	(0.129)	(0.028)	(0.135)
Constant	8.343***	6.611***	10.69***
	(0.181)	(0.0401)	(0.268)

Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

4.2. Parallel Trend Test

For the empirical results, a parallel trend test was carried out to determine that the change trends of each pollution index were relatively stable before the implementation of the decentralization policy. The benchmark year was set as 2017, the year when the decentralization policy was proposed. The event study method was used to analyze the explained variables separately for the three years before and after the benchmark year. As shown in Fig. 1, the coefficients of $(Treat_i \times Post_t)$ after the policy time point are not significant, indicating that there was no significant difference between cities

that received more transfers and those that received fewer transfers before 2017, meeting the parallel trend assumption.

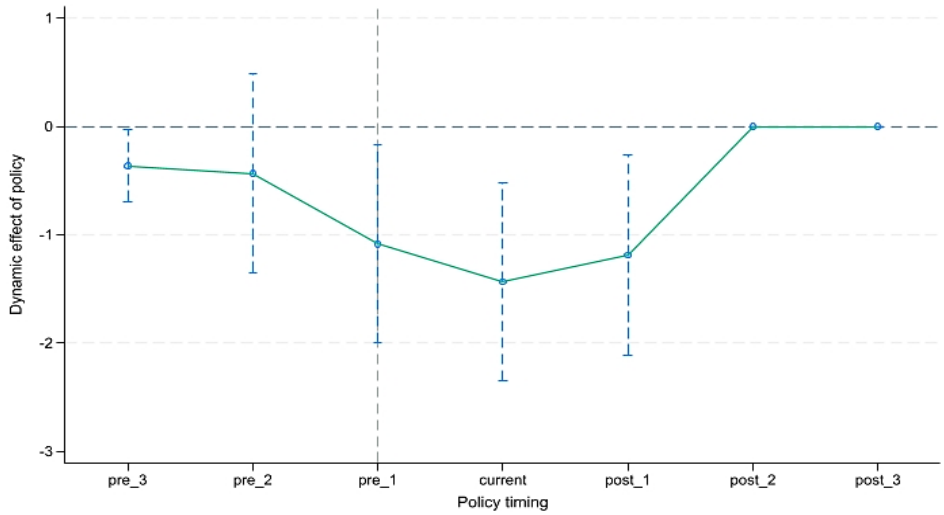

Fig. 1 Parallel Trend Test Chart of Pollution Indicators (Photo credit: Original)

4.3. PSM-DID Estimation

Although this paper only selects 7 cities in Hebei Province for analysis, to ensure the rigor of the research results, the propensity score matching (PSM) was used to screen the control group with characteristics similar to the treatment group, reducing the selection bias, and then the DID estimation was carried out on the matched samples. According to Table 2, the three control variables are not significant after matching, and the standard deviations are all less than 10%. According to Fig. 2, the three control variables change from discrete to concentrated after matching, with reduced deviations, proving a good fitting effect. According to Table 3, the two pollution indicators that showed significance above are significant at the 10% level, all passing the PSM-DID estimation, proving the stability of the conclusions of this paper.

Table 2. Balance Test 1 of Cross-Sectional PSM

Variable	Unmatched Matched	%bias	%reduct |bias|	t-test t	p >|t|
GDP	U	126.3		4.57	0.000
	M	0.1	99.9	0.01	0.992
nIP	U	127.9		4.62	0.000
	M	2.2	98.3	0.52	0.606
PD	U	118.2		4.35	0.000
	M	-7.1	94.0	-0.90	0.33

Note: if variance ratio outside [0.61; 1.64] for U and [0.36; 2.76] for M.

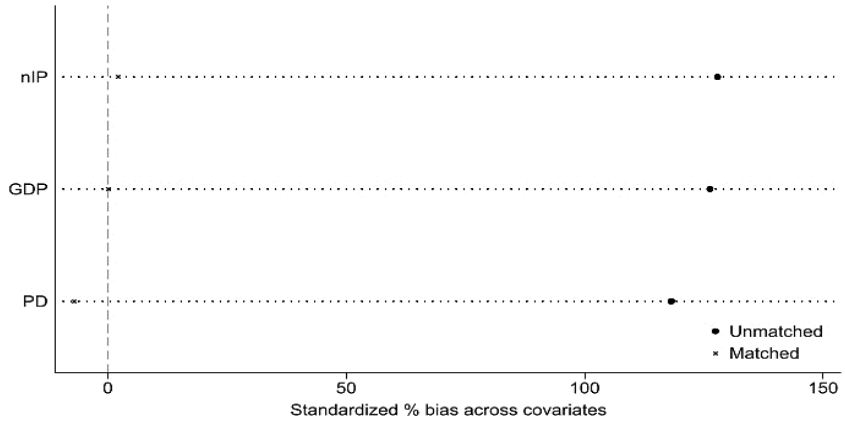

Fig. 2 Standardized Deviation Diagram of Each Variable (Photo credit: Original)

Table 3. PSM-DID Estimation

VARIABLES	(1)	(2)
	psm(ln_smoge)	psm(ln_pCO2)
DID	1.5628*	1.4125*
	(2.1085)	(2.2927)
GDP	0.0001	0.0001
	(0.5968)	(0.4754)
nIP	0.0044	0.0123
	(0.2452)	(1.5987)
PD	0.0002	0.0001
	(0.2657)	(0.3417)
2007.year	0.015	-0.0658
	(0.210)	(0.410)
2008.year	0.025	-0.0556
	(0.217)	(0.410)
2009.year	0.0804	-0.0737
	(0.211)	(0.410)
2010.year	0.129	-0.0973
	(0.211)	(0.410)
2011.year	0.211	-0.209
	(0.246)	(0.410)
2012.year	0.254	-0.214
	(0.276)	(0.410)
2013.year	0.389	-0.344
	(0.241)	(0.410)
2014.year	0.492**	-0.343
	(0.243)	(0.410)
2015.year	0.716***	-0.504
	(0.218)	(0.410)
2016.year	0.994***	-0.756*
	(0.187)	(0.410)
2017.year	1.304***	-1.988***
	(0.202)	(0.488)
2018.year	1.602***	-2.189***
	(0.221)	(0.488)
2019.year	1.706***	-2.190***
	(0.230)	(0.488)
2.cid	0.0333	0.1926
	(0.0924)	(0.6490)
Constant	9.3588**	11.0175***
	(2.4619)	(5.9921)
Observations	91	91
R-squared	0.686	0.721

Note: t-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

5. Suggestions

First, unify environmental regulations and emission standards. Develop coordinated emission standards for the Beijing-Tianjin-Hebei region, unify the concentration thresholds of pollutants such as PM2.5 and industrial sewage, and eliminate the "institutional arbitrage" problem caused by

differences in regional regulations [9]. Focus on pilot areas such as the Caofeidian Circular Economy Demonstration Zone and the Baiyangdian Ecological Reserve, and gradually extend to the whole region to avoid the "policy depression" effect. Second, promote green industrial transfer and manufacturing standardization [10, 11]. Promote industrial greening, implement negative lists and green access mechanisms, and require core enterprises to drive upstream and downstream enterprises to implement clean production simultaneously. Develop regional manufacturing process specifications, enforce the adoption of internationally advanced technologies, and provide policy incentives (such as preferential procurement and low-interest loans) for green enterprises, while implementing disciplinary measures such as regional restrictions and subsidy cancellations for backward enterprises. Third, establish cross-regional ecological compensation and interconnection of carbon markets [12]. Establish a cross-regional ecological compensation fund to promote the interconnection of carbon markets in Beijing, Tianjin, and Hebei. Allow Hebei enterprises to sell carbon quotas to Beijing and Tianjin through projects such as "forest carbon sinks" and "industrial emissions reduction", activate the regional carbon trading market, and promote the sharing mechanism of green finance and taxation. Fourth, empower with technology and conduct intelligent supervision. Promote blockchain and AI technologies, build pollution traceability and early warning platforms, achieve real-time sharing of pollution data, and prevent enterprises from evading supervision. At the same time, establish a Beijing-Tianjin-Hebei Green Technology Transformation Center to support Hebei enterprises in undertaking advanced technologies (such as hydrogen metallurgy and carbon capture), and mitigate the environmental risks brought about by industrial transfer.

6. Conclusion

Based on the empirical research results, this paper concludes that during the coordinated development of the Beijing-Tianjin-Hebei region, there still exists the problem of the pollution transfer effect of the non-capital function decentralization policy on the receiving areas. Due to factors such as mechanism optimization and buffering properties, the duration of this impact effect is relatively short, but it has still been proven to exist. Through this research, solutions are proposed, and future research directions are determined.

The limitations of this paper lie in the limited research area, resulting in a relatively small data sample. Only 7 cities in Hebei Province were selected for the study. There are few control group cities, and due to geographical proximity, they are inevitably affected to some extent by the function decentralization policy. In addition, the pollution transfer problem in the Beijing-Tianjin-Hebei region caused by the decentralization of capital functions is a new problem that emerged recently and exists for a short time. The policy impact period is short, and it is possible to suppress the pollution impact in a relatively short time after the existence of the pollution transfer problem is confirmed. Moreover, due to the proximity of the research time, there is a lack of recent statistical data for research and analysis as data for post-policy years, which has a certain impact on the accuracy of empirical analysis.

Based on the existing research and limitations of this paper, the following research directions are proposed: First, this paper focuses on Beijing and Hebei in the Beijing-Tianjin-Hebei region, but does not involve research on Tianjin. Obviously, as a municipality directly under the central government and one of the key industrial cities in northern China, Tianjin has certain differences in GDP volume, industrial development level, and scientific and technological level compared with Hebei Province. Therefore, this paper can ask the question: Are there differences in the impact of the decentralization strategy on Hebei Province and Tianjin? Relevant regional heterogeneity research can be carried out for the purpose of policy analysis in the later stage. Second, as mentioned in the above analysis of limitations, the pollution transfer brought about by the industrial decentralization policy exists for a short time and is impactful. Whether, with the passage of time, the pollution transfer forces the overall adaptation of policies and the improvement of regulatory quality, so that the pollution transfer

problem is gradually alleviated and resolved, is a question worthy of further research. Third, it can be considered that enterprises in Beijing have a higher scientific and technological conversion rate in industrial production compared with those in Hebei Province due to their overall advanced scientific and technological level. Due to the differences in environmental regulations and policy systems between Beijing and Hebei, after the implementation of the decentralization policy, the transfer of Beijing enterprises to Hebei Province may squeeze out local enterprises with backward production capacity, relatively backward technology, and high pollution emissions due to their relative technological advantages, and bring technological progress to new upstream and downstream enterprises. Therefore, there is a possibility that the environmental pollution indicators in the receiving areas will decrease. Based on this hypothesis, relevant research can be carried out to verify whether the transfer of high-level enterprises between adjacent regions due to differences in environmental regulations and policies can bring about improvements in environmental pollution and promote technological progress for the receiving areas and their industrial upstream and downstream.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

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