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How Resource-Exhausted Cities Get Out of the Innovation Bottom? Evidence from China

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Abstract: The transformation and upgrading of resource-exhausted cities are crucial for regional sustainable development, but how to help them overcome innovation challenges remains to be explored. Based on data from 2003 to 2016, this study used a difference-in-differences (DID) method to examine the impact of China's support policy for resource-exhausted cities on urban innovation and tests for long-term mechanisms. The results indicate that the support policy significantly enhanced regional innovation levels. The mechanism tests showed that these policies promoted urban innovation through long-term mechanisms of increasing marketization and upgrading industrial structures. Further analysis revealed that the innovation-promoting effects of the policies were more significant in resource-exhausted cities located in the eastern region, those not dependent on coal, those with a low reliance on extractive industries, and those with a favorable talent environment. The findings suggest that the government should provide policy support to achieve the transformation, upgrading, and sustainable development of resource-exhausted cities through urban innovation.

Keywords: resource-exhausted cities; sustainable urban development; urban innovation; marketization; China

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1. Introduction

For a long time, developing countries have hindered sustainable development by trading high resource consumption for low economic growth [1]. In the early stages of national industrialization, resource-based cities relied on their abundant natural resources to transfer surplus value to other regions through low resource prices, contributing significantly to national development [2]. However, due to the constraints of limited resources and the laws of urban development, resource-based cities inevitably go through a process of construction, prosperity, decline, and transformation [3]. As resources are gradually depleted, the economic benefits of the resource industry diminish, and the development of these resource-based cities reaches its end stage, becoming known as resource-exhausted cities [4]. Thus, the transformation of resource-exhausted cities is a significant issue in the economic and social development of countries worldwide, including developed nations like Germany's Ruhr area and France's Lorraine region.

Contrary to the "convergence process" in Solow's growth theory, empirical evidence shows that abundant resources have not benefited regions; instead, they have constrained local economic development. This dilemma faced by resource-exhausted cities is termed the "resource curse" [5–7]. The "resource curse" refers to regions rich in resources becoming overly dependent on a single economic structure, resulting in low industrialization and difficult industrial transformation [8], as exemplified by Venezuela. International experience shows that financial aid can only address the surface issues of resource-exhausted cities. To

transform from resource-dependent to innovation-driven economies and achieve sustainable development, it is crucial to resolve the deeper contradictions of lacking long-term economic development mechanisms [9].

Innovation is a key driver of economic transformation and development. According to endogenous growth theory, sustained economic growth cannot rely on external forces, and endogenous technological progress is the determinant of long-term economic growth [10]. Urban innovation has become a critical driver of sustainable urban economic development. Concentrating talents, enterprises, capital, and other innovation elements, urban innovation is a significant carrier of national innovation activities and refers to the processes and products centered on urban technological progress [11,12]. For countries worldwide, exploring how to enhance urban innovation capacity is of great importance in promoting national innovation systems and sustainable economic development. Ample theoretical and empirical evidence suggests that urban innovation plays a vital role in cultivating new economic growth points, optimizing and upgrading industrial structures, improving resource utilization efficiency, enhancing urban resilience, and promoting inclusive social development [13–16]. However, resource-exhausted cities often lag in innovation. Long-term dependence on single resource-based industries leads to low innovation levels, while poor economic development further reduces innovation factors [17]. Effectively improving the innovation level of resource-exhausted cities is an important issue that is worth exploring.

As the world's largest developing country, China faces pronounced innovation challenges in its resource-exhausted cities. Low resource pricing and costless ecological exploitation are significant factors leading to the decline of China's resource-based cities [18]. Despite a series of government documents indicating the central government's determination to promote the transformation of resource-exhausted cities, there are concerns that these support policies may merely shift local development difficulties to the central government via lacking long-term mechanisms and hindering the transformation and upgrading of resource-exhausted cities [19]. Thus, whether the support policy promotes urban innovation, establishes long-term mechanisms in market and industrial structures, and exhibits heterogeneous effects due to other factors remains unanswered and requires empirical verification.

Our study was related to three broad literatures. First, our findings connect to the literature on the transformation and development of resource-based cities. International economics literature extensively discusses the importance of the positioning of resource-based cities within global value chains and explores how to leverage international trade value chains and the smile curve theory to develop cities based on their unique resources [20–22]. These studies underscore the crucial positioning of resource-rich cities and provide recommendations for their development. Despite their lagging economic scale, resource-rich regions can achieve economic growth and industrial upgrading through global value chains [23,24]. This perspective was further validated in numerous studies. For instance, Humphrey and Schmitz (2002) indicated that by integrating into international trade value chains, resource-based cities could gain technology transfer and knowledge spillover effects, thereby promoting local industrial upgrading and economic growth [25]. This study explored the transformation of cities as their dependent resources become exhausted, particularly focusing on how to foster innovation-driven transformation in resource-exhausted cities. This is closely related to the repositioning and transformation of resource-based cities in the context of the global economy.

Second, our results are relevant to the growing body of empirical work on Chinese policy studies. China serves as a significant case study in policy research, as the government frequently and systematically experiments with different policies in various regions before deciding on nationwide implementation. These numerous pilot policies provide experimental grounds for various developmental directions in China and offer an extensive quasi-natural environment for academic research [26,27]. Regarding policies for resource-exhausted cities in China, some literature discusses its localized characteristics

and impacts [28]. More closely related to our work are recent empirical studies on the effects of urban transformation policies in China. For instance, some studies examined the impact of industrial transformation and economic development efficiency [4,29], and the role of infrastructure, digital transformation, and smart city construction in promoting urban transformation and development [30–32]. Additionally, a few studies explored the development and industrial transformation of China's resource-based cities, highlighting that industrial diversification and market mechanisms are critical pathways for these cities to achieve sustainable development [33,34]. This study focused on the vulnerabilities and urgent need for transformation in resource-exhausted cities by investigating the significance of pilot transfer payment policies for their transformation and development. We further explored the mechanisms and effects of these supportive policies, enriching the existing literature on policy evaluation. Our study provides empirical evidence for understanding the effectiveness of policies in different contexts, offering valuable insights for formulating more effective policies.

Third, our findings speak to the empirical literature on the sustainability of policies. The impact of policies on the sustainable development of cities is a significant research area [35]. While supportive policies can promote innovation in resource-exhausted cities in the short term, their long-term sustainability presents challenges [36]. Our study revealed that the effects of the support policy on the innovation of resource-exhausted cities are not sustainably effective and vary across different city characteristics. The differences in policy effects may stem from variations in city-specific attributes and environmental factors [37,38]. We further analyzed the factors that influenced policy effectiveness, and thus, provided empirical insights for policy optimization. Our findings suggest that policymakers should consider the specific characteristics of resource-exhausted cities and implement more targeted policy measures to enhance long-term effectiveness and sustainability.

This study used data from 2003 to 2016 at the prefecture level to examine the impact of the support policy on the innovation of resource-exhausted cities, the differences in impact across regions and types of cities, and the long-term mechanisms of these policies. The potential contributions of this study are threefold. First, using scientific econometric methods, this study empirically analyzed the effectiveness of support policy in promoting urban innovation, supplementing theoretical research through causal inference. The quasi-natural experimental method effectively mitigated endogeneity issues in estimation, and thus, provided more reliable evidence for the transformation and upgrading of resource-exhausted cities. Second, this study was the first to analyze the long-term mechanisms of support policy in affecting urban innovation by empirically estimating the impact of marketization and industrial structure mechanisms, and thus, verified whether these policies provided long-term incentives for urban innovation. Third, using urban-level data, this study accurately identified the effects of support policy on resource-exhausted cities. Utilizing rich data across different dimensions of cities, this study deeply analyzed the heterogeneity of policy effects, thus supporting the further improvement of the support policy for resource-exhausted cities.

2. Institutional Background and Theoretical Framework

2.1. Institutional Background

The development challenges faced by China's resource-exhausted cities have garnered significant attention from the Chinese government. These cities commonly experience economic stagnation, single-industry reliance, severe environmental degradation, and underdeveloped market systems, making them weak points in China's sustainable development effort [4,39]. To promote sustainable development and transformation, the State Council issued the "Opinions on Promoting Sustainable Development in Resource-Based Cities" in 2007[1]. This document identified resource-exhausted cities as key support targets and proposed long-term mechanisms, such as resource development compensation, assistance for declining industries, resource product pricing formation, and the cultivation of alternative industries. In 2008, 2009, and 2011, the Ministry of Finance, the National

Development and Reform Commission, the Ministry of Land and Resources, and the Northeast Revitalization Office of the State Council identified a total of 69 resource-exhausted cities in three batches and provided them with corresponding policy support (referred to as the support policy). In China, prefecture-level cities are administrative units under the province. Districts, counties, and county-level cities are subordinate administrative units under prefecture-level cities. Due to data availability and comparability between cities, this study concentrated on 25 pilot prefecture-level cities, with each referred to as a "city" throughout the text. The specific list of these cities is shown in Table 1. The complete list of policies can be found in Table S1 of the Supplementary Materials.

Table 1. The list of pilot cities.

First Batch (2008)	Second Batch (2009)	Third Batch (2011)
Fuxin	Fushun	Wuhai
Panjin	Qitaihe	Hegang
Liaoyuan	Huaibei	Shuangyashan
Baishan	Tongling	Xinyu
Pingxiang	Zaozhuang	Puyang
Shizuishan	Tongchuan	Shaoguan
Baiyin	Fushun	Luzhou
Jiaozuo	Jingdezhen	Zibo
Yichun		

Figure 1 reports the GDP growth trends of resource-exhausted cities compared with other cities. It is evident that the GDP growth rate of the resource-exhausted cities was significantly slower than that of other cities. Among them, the cities included in the first batch of the support policy in 2008 faced the most challenging economic development conditions. The policy proposed support for these resource-exhausted cities to promote their sustainable development. This support policy included several measures: first, establish and improve long-term mechanisms for resource development, decrease industry assistance, and resource product price formation; second, foster alternative industries through agricultural industrialization, tertiary industry development, and the development of new industries tailored to local conditions; third, address employment and social issues; fourth, environmental remediation and ecological protection; and fifth, enhance resource exploration and mining rights management. The support measures for the transformation of resource-exhausted cities were primarily implemented through transfer payments. The Ministry of Finance established transfer payments specifically for resource-exhausted cities, starting in 2007. Once selected for policy support, these cities received special transfer payments from the central government for four consecutive years. Policy documents indicate that if these cities successfully transitioned within four years, the central government would continue to provide gradually decreasing financial subsidies for an additional three years. However, in practice, even if the resource-exhausted cities succeeded in transitioning or reached the end of the funding period, the central government continued to support them through special transfer payments. By 2018, the cumulative support amount had reached nearly CNY 160 billion[2]. Additionally, the policy not only provided special financial support but also clarified the use of funds and establishes a transfer payment system. To further enhance the effectiveness of financial assistance, provincial governments also introduced supporting policies, special funds, and sustainable development loans. These special financial funds were used to develop alternative industries, primarily by supporting industrial development projects, building industrial parks, and constructing infrastructure.

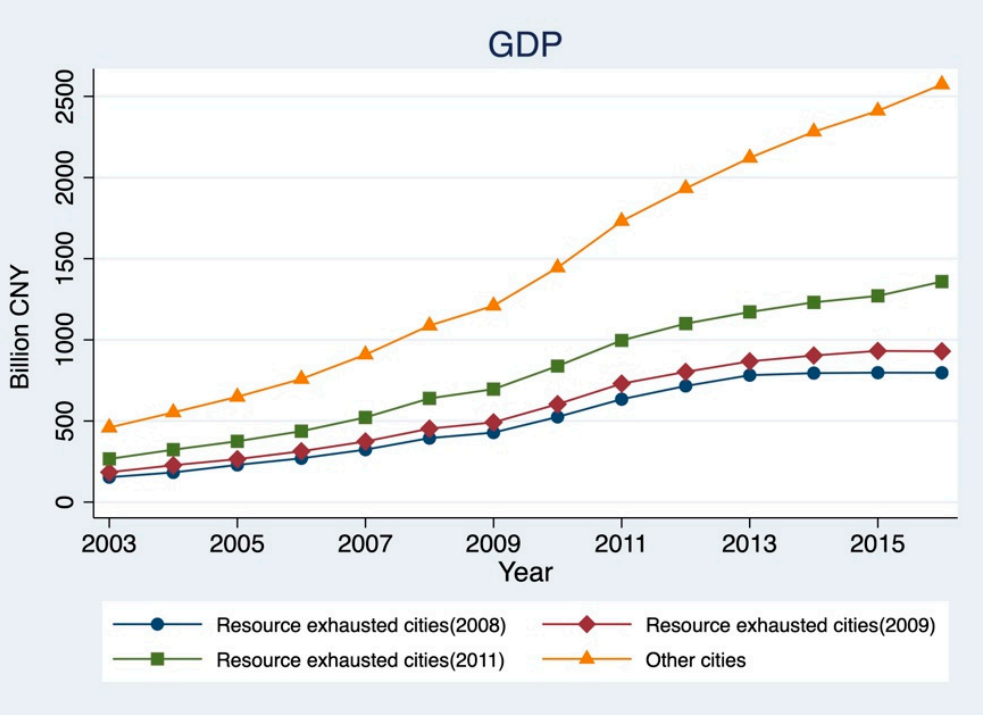

Figure 1. GDP growth trends in Chinese cities.

2.2. Hypothesis Development

Despite the central government's provision of special transfer payments and supporting policy guidance to address the sustainable development issues of resource-exhausted cities, whether these support policies effectively promote innovation in these cities still requires further scientific examination. In particular, it is necessary to investigate whether they have fostered market-oriented reforms and the establishment of long-term mechanisms, such as industrial structure upgrades.

On one hand, the low level of marketization in resource-exhausted cities constrains their development [4]. Influenced by China's early planned economy, resource-based industries have implemented highly centralized planned resource allocation methods, resulting in long-term monopolistic conditions in resource-exhausted cities and low market vitality [40]. The low pricing of resources not only fails to reflect the true supply and demand relationships in the market but also weakens the market system in resource-exhausted cities [39,41]. This can lead to rent-seeking issues, distort the market allocation of factors, and negatively impact the availability of innovation elements in these cities. In response, the support policy explicitly proposed "fully leveraging the fundamental role of the market in resource allocation and stimulating the intrinsic vitality of various market entities". An increase in marketization can significantly promote urban innovation. Higher marketization implies improved overall resource allocation efficiency in cities, with innovative elements shifting from low-efficiency to high-efficiency sectors, thereby promoting urban innovation [42]. Additionally, higher marketization means reduced government intervention in the market, creating a fairer and more orderly market environment [43]. This enhances competition as private enterprises grow, compelling local enterprises to innovate to stay competitive, thereby boosting urban innovation [44]. Based on this analysis, we propose the following research hypothesis:

H1. *By increasing the level of marketization, the support policy for resource-exhausted cities promotes urban innovation.*

On the other hand, the problem of a single industrial structure is prominent in resource-exhausted cities [34]. Early development in these cities centered around resource-based industries, with other industries primarily serving the resource sector. Thus, resource depletion also leads to the decline of other industries in the city [45]. The key to the transformation and development of resource-exhausted cities lies in industrial transformation, which drives sustainable economic development through industrial upgrading [4,46]. The support policy clearly states the need to "establish industrial assistance mechanisms" and "accelerate the development of the tertiary sector". Therefore, the support policy may drive the industrial structure upgrade in resource-exhausted cities, which, in turn, promotes urban innovation, as confirmed by numerous studies [47–49]. Industrial structure upgrades can facilitate technology diffusion and knowledge spillovers within and between cities, increasing the demand for innovation and directly promoting autonomous urban innovation [50,51]. Moreover, industrial structure upgrades can expand niche markets, stimulate demand growth, intensify market competition, and encourage enterprises to innovate to enhance competitiveness, thereby driving the overall urban innovation [52,53]. Based on the above, we propose the following research hypothesis:

H2. *By upgrading the industrial structure, the support policy for resource-exhausted cities promotes urban innovation.*

3. Methodology and Data

3.1. Data Source

The Urban Innovation Data originate from the China Research Data Service Platform (CNRDS). The CNRDS is a high-quality, specialized platform for Chinese innovation research data. The Chinese Innovation Research Database (CIRD) is part of this platform and was developed based on patent applications and authorizations from various listed and non-listed companies, as well as different regions. The data quality is reliable and was utilized in other high-quality research studies [54,55]. This study used the number of city patent authorizations as an indicator of urban innovation [38,56,57].

Other city characteristic variables primarily come from the "China City Statistical Yearbook" and statistical bulletins of various cities. Following the methodology of Brandt et al., 2006 and 2012 [58,59], these variables were deflated using the year 2000 as the base year. These data were utilized for control variables, mechanism analysis, and other heterogeneity analyses.

To comprehensively reflect the changes in resource-exhausted cities before and after the policy implementation and accurately measure the effects of the policy, this study selected data from five years before the pilot began and five years after the pilot ended, spanning 2003–2016. Given the significant differences in economic development levels and administrative status between the four direct-controlled municipalities (Beijing, Tianjin, Shanghai, and Chongqing) and the Hong Kong, Macau, and Taiwan regions compared with prefecture-level cities, this study excluded samples from these four municipalities and three regions. First, since these cities are directly governed by the central government and are equivalent to provincial-level units in terms of administrative and political status, with significant differences in GDP and political status, this makes direct comparisons inappropriate. In related literature, these cities are often excluded or treated separately. Second, the data for some cities, such as Macau and Hong Kong, as well as Taiwan, are not available, making it impossible to conduct a comprehensive and accurate analysis. Additionally, samples with missing key variables are excluded. Consequently, the final dataset of this study included 3878 samples from 277 prefecture-level cities over 14 years, with the treatment group comprising 25 prefecture-level cities. The definitions of variables and descriptive statistics are presented in Table 2.

Table 2. Variable definitions and descriptive statistics.

Panel A. Variable Definitions	
Variable	**Definition**
CityInnov	Log value of number of patents granted
Control Variables	
MineRatio	Proportion of mining industry in the total output
FiscalExp	Log value of government expenditure
PCW	Log value of per capita wage
UnempRate	Unemployment rate
PCTRS	Log value of per capita retail sales of consumer goods
Mechanism Variables	
Industry	Ratio of the value added of the tertiary industry to the total GDP
Market	Fan Gang's marketization index

Panel B. Descriptive Statistics					
Variable	**Obs**	**Mean**	**SD**	**Min**	**Max**
CityInnov	3878	6.025	1.770	1.099	11.419
MineRatio	3878	0.107	0.169	0	0.793
FiscalExp	3878	13.633	0.940	10.410	17.219
PCW	3878	9.932	0.491	2.225	11.675
UnempRate	3878	3.349	0.770	1.310	5.060
PCTRS	3878	8.673	0.865	−1.337	11.580
Industry	3878	0.364	0.084	0.086	0.764
Market	3878	8.893	2.678	1.959	16.949

3.2. Empirical Methodology

The Chinese government announced the list of resource-exhausted cities in 2008, 2009, and 2011, which provided an opportunity to employ a "quasi-natural experiment" approach. Within this institutional context, three batches of cities in the treatment group received interventions by following a typical staggered difference-in-differences (DID) framework. First, the DID model effectively controlled for time and individual fixed effects, which reduced the bias from omitted variables. Second, the DID model was particularly suitable for evaluating the differences between the affected and unaffected groups before and after the policy implementation, which aligned with our research on the impact of the support policy on urban innovation in resource-exhausted cities. Therefore, referencing Beck et al., 2010 [60], we constructed a staggered DID model (Equation (1)) to determine the causal impact of the support policy for resource-exhausted cities on urban innovation:

$$CityInnov_{i,t} = \alpha + \beta Traet_i \times Post_{it} + \varphi X'_{it} + \lambda_i + \lambda_t + \lambda_i t + \varepsilon_{it} \quad (1)$$

where i and t represent the city and year, respectively. $CityInnov_{i,t}$ represents the natural logarithm of the total number of patent grants in city i at year t. $Traet_i$ is a dummy variable representing whether a city belonged to the treatment group, with resource-exhausted cities assigned a value of 1, and others assigned a value of 0. $Post_{it}$ is used to identify whether a city has been affected by the policy. If a city was listed as a resource-exhausted city in a given year, it took a value of 1; otherwise, it was 0. X'_{it} is a vector of control variables composed of various city characteristics, the specifics of which are elaborated upon below. λ_i represents city fixed effects, and λ_t denotes time fixed effects. We included $\lambda_i t$ fixed effects to control for development trends of different cities across different years [61]. ε_{it} represents city-clustered robust standard errors to mitigate potential inter-group correlation issues [62,63].

The feature vector X_{it} is the interaction of the predetermined variables with the time dummy variables λ_t, i.e., $Z_{i2007} \times \lambda_t$ [64]. This was to control for factors that influenced the selection of pilot cities and eliminate the possibility that these factors could change over time and affect urban innovation.

The predetermined variable Z_{i2007}, which refers to a series of control variables influencing the selection of policy pilots, was primarily chosen based on the standards and procedures for defining resource-exhausted cities. The National Development and Reform Commission, the Ministry of Natural Resources, and the Ministry of Finance jointly established the principles, standards, and work plan for defining resource-exhausted cities. This followed a declaration-based principle, with applications submitted by provincial governments. The final list was determined based on a comprehensive scoring system that included four major categories of indicators: resource reserves, mining development, people's livelihood, and fiscal economy. Even if a city met the scoring standards, it may not be included in the list for funding if the provincial government did not apply or due to intense competition, as seen in the case of Jixi City[3]. This means that controlling for the four predetermined conditions, the selection of resource-exhausted cities was more random. Additionally, resource-exhausted cities were characterized by a declining industrial efficiency, a single industrial structure, weak local financial strength, and low worker incomes [4,39,65]. Based on the data availability, this study selected several predetermined variables: the proportion of extractive industries (MineRatio), the number of state-owned enterprises (SOEs), fiscal expenditure (FiscalExp), fiscal deficit ratio (DeficitRatio), average wage (PCW), unemployment rate (UnempRate), and per capita retail sales of consumer goods (PCTRS). This study used data from 2007, which was the year before the first list of resource-exhausted cities was announced, to verify through regression analysis whether these variables influenced a city's inclusion in the list of resource-exhausted cities. Table 3 shows the results of an employed stepwise regression method for verification, which revealed that the above variables significantly impacted whether a city was listed as a resource-exhausted city. Therefore, the vector of predetermined variables Z_{i2007} that influenced the selection of resource-exhausted cities should include the proportion of extractive industries (MineRatio), fiscal expenditure (FiscalExp), average wage (PCW), unemployment rate (UnempRate), and per capita retail sales of consumer goods (PCTRS).

Table 3. Pre-treatment analysis.

	(1) $Treat_i$	**(2)** $Treat_i$	**(3)** $Treat_i$
MineRatio	0.360 ***	0.337 ***	0.374 ***
	(0.099)	(0.099)	(0.097)
SOEs	−0.069 ***	−0.014	−0.016
	(0.024)	(0.034)	(0.034)
FiscalExp		−0.107 ***	−0.120 ***
		(0.037)	(0.042)
DeficitRatio		−0.570 *	0.032
		(0.332)	(0.453)
PCW			−0.204 **
			(0.095)
UnempRate			10.926 ***
			(3.831)
PCTRS			0.110 **
			(0.049)
Observations	277	277	277
R-squared	0.087	0.118	0.186

Note: ***, **, and * represent the significant levels of 1%, 5%, and 10%, respectively. Standard errors are in parentheses.

4. Empirical Results

4.1. Baseline Results

The baseline regression results are presented in Table 4. Column (1) shows the regression results without any control variables or fixed effects, with a regression coefficient of 1.143 and an R^2 of 0.051. Column (2) shows the estimation results with λ_i, λ_t, and $\lambda_i t$ city and year fixed effects, as well as city fixed effects interacted with year. In this case, the coefficient decreased to 0.216, but due to the inclusion of fixed effects, the R^2 increased to

0.979. Column (3) further incorporates the vector of city characteristics. From the regression results in each column, it can be observed that the support policy for resource-exhausted cities significantly increased the number of patent grants in pilot cities, indicating a positive impact of these policies on innovation in resource-exhausted cities. Column (3) shows that the regression coefficient for the core independent variable was 0.249, and it was significant at the 1% level. This indicates that the support policy, through transfer payments and corresponding institutional guidance, increased the logarithm of the number of patent grants in resource-exhausted cities by 0.249. This coefficient had important economic implications, signifying that the support policy increased the number of patent grants in resource-exhausted cities by an average of 28.44% compared with the pre-policy average number of patent grants ($\left(e^{\ln(167.32+1)+0.249}-1-167.32\right)/167.32$). The support policy for resource-exhausted cities significantly enhanced the level of urban innovation.

Table 4. The average effect of policy assistance on urban innovation.

	(1) CityInnov	(2) CityInnov	(3) CityInnov
$Treat_i \times Post_{it}$	1.143 ***	0.216 **	0.249 ***
	(0.120)	(0.093)	(0.091)
λ_i	No	Yes	Yes
λ_t	No	Yes	Yes
$\lambda_i t$	No	Yes	Yes
X'_{it}	No	No	Yes
Observations	3878	3878	3878
R-squared	0.051	0.979	0.981

Note: *** and ** represent the significant levels of 1% and 5% respectively. Standard errors are in parentheses.

4.2. Parallel Trend Test

The most important assumption of the difference-in-differences (DID) model is the comparability between the treatment group and the control group, also known as the parallel trend assumption. We used an event study approach to test whether the number of authorized patents in pilot cities and non-pilot cities had the same trend before policy implementation. Following Beck et al., 2010 [60], we constructed Equation (2):

$$CityInnov_{i,t} = \alpha + \sum_{k=-5}^{k=+5} \beta_k Treat_i \times Year_k + X'_{it}\gamma + \lambda_i + \lambda_t + \lambda_i t + \varepsilon_{it} \quad (2)$$

In this model, $Year_k$ is a series of dummy variables that equal 1 when city i is a resource-exhausted city and is in the $Year_k$ year of policy implementation, and 0 otherwise. All other terms have the same meanings as in Equation (1). The regression coefficients β_k indicates whether there is a significant difference in the number of patent grants between the treatment and control groups in the kth year of the policy implementation. The period before policy implementation was set as the baseline (reference period), and we trimmed the extreme values of the observations to examine the dynamic changes over the five years before and after the policy implementation.

Figure 2 visualizes the regression results and reports the 95% confidence intervals. It can be observed that when $k < 0$, the estimated coefficient β_k was not significantly different from zero, indicating that before the implementation of the support policy for resource-exhausted cities, there was no significant difference in the trend of patent grant numbers between the treatment and control groups. This confirmed the parallel trend assumption. The dynamic effects show that the support policy for resource-exhausted cities had a significant positive impact on urban innovation. On the one hand, the policy had a certain lag effect, where it became significantly positive in the second year after implementation. On the other hand, as time progressed, this innovation-promoting effect began to weaken, and by the fifth year after the policy implementation, the estimated coefficient β_k was not significant, indicating poor policy sustainability.

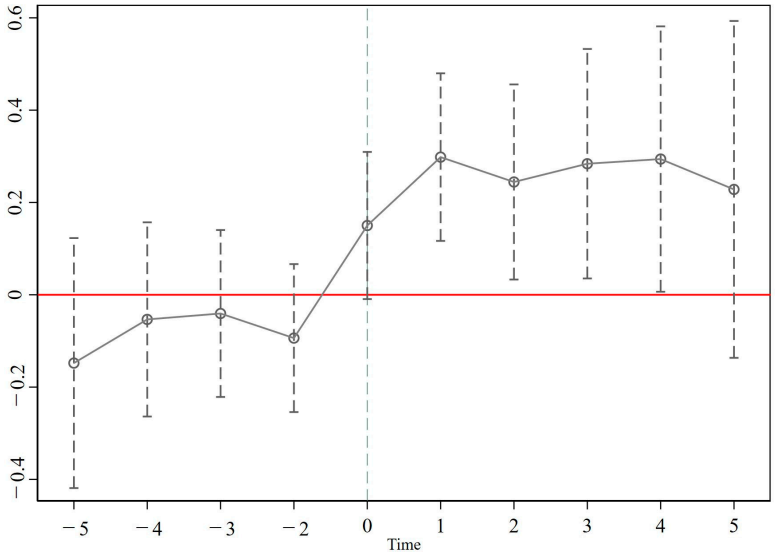

Figure 2. Dynamic effect on urban innovation.

4.3. Robustness Checks

Building on the baseline regression, this study more cautiously verified the robustness of the promotion effect of the support policy for resource-exhausted cities on urban innovation. We conducted robustness checks by using balance tests, replacing the dependent variable, altering the representation of policy implementation time, shortening the window period, substituting the control group, and performing placebo tests.

4.3.1. Balance Test

Differences between the treatment and control groups before policy implementation are a significant cause of estimation bias in baseline results [66]. Therefore, considering the control variables, we examined other factors that might influence urban innovation before policy implementation to verify the sample balance. The econometric model we used is shown in Equation (3):

$$UCV_{i2007} = \alpha + \beta Treat_i + \gamma Z_{i2007} + \varepsilon_i \quad (3)$$

where UCV_{i2007} represents the observable other urban characteristic variables of cities in 2007. We selected six variables: GDP (GDP), fiscal deficit (Deficit), number of state-owned enterprises (SOEs), expenditure on science and education (ESTE), number of higher education institutions (College), and number of scientific personnel (Tec_Prac). If the estimated coefficient β is significant, it indicates heterogeneity between the two groups of samples. Table 5 reports the estimation results of Equation (3). After including the control variables, the estimated coefficients of the aforementioned variables on β are all insignificant, indicating that the samples pass the balance test and that the treatment and control groups are homogeneous and comparable.

Table 5. The balance test.

	(1) GDP	(2) Deficit	(3) SOEs	(4) ESTE	(5) College	(6) Tec_Prac
$Treat_i$	−0.026	0.030	−0.058	−0.060	0.030	−0.122
	(0.060)	(0.103)	(0.113)	(0.045)	(0.134)	(0.153)
Z_{i2007}	Yes	Yes	Yes	Yes	Yes	Yes
Observations	277	277	277	277	277	277
R-squared	0.912	0.593	0.541	0.920	0.564	0.440

Note: Standard errors are in parentheses.

4.3.2. Replace the Variable Measurement

To further validate the robustness of our results, we replaced the measurement methods of the dependent and explanatory variables. For the dependent variable, we utilized the Urban Innovation Index released by Fudan University in the "China City and Industrial Innovation Report 2017" to measure the urban innovation levels by replacing the original dependent variable [67]. This index, like the number of authorized patents used in this study, served as an indicator of urban innovation capacity. However, the measurement method differed. The Urban Innovation Index estimates the average value of patents based on legal status updates and annual fee structures, and comprehensively considers a city's innovation output and entrepreneurial activities, and thus, represents the city's innovation level [68,69]. The regression results are reported in columns (1) and (2) of Table 6, where the regression coefficient of the core independent variable remained significantly positive. This indicates that the support policy for resource-exhausted cities significantly increased the urban innovation index of pilot cities, and thus, it had a positive impact on urban innovation.

Table 6. The effect of policy assistance on urban innovation: robustness 1.

	(1)	(2)	(3)	(4)	(5)
	InnovIndex			**CityInnov**	
$Treat_i \times Post_{it}$	2.209 ***	1.730 ***		0.227 ***	0.234 ***
	(0.649)	(0.546)		(0.087)	(0.090)
$Treat_i \times Post_{it}'$			0.232 **		
			(0.093)		
λ_i	Yes	Yes	Yes	Yes	Yes
λ_t	Yes	Yes	Yes	Yes	Yes
$\lambda_i t$	Yes	Yes	Yes	Yes	Yes
X_{it}	No	Yes	Yes	Yes	Yes
Observations	3822	3822	3878	3324	3047
R-squared	0.937	0.938	0.981	0.983	0.983

Note: *** and ** represent the significant levels of 1% and 5% respectively. Robust standard errors clustered at the city level are in parentheses.

Regarding the independent variables, considering the differences in the announcement timings of the three batches of resource-depleted cities [70], the variable $Traet_i \times Post_{it}$ was set based on the announcement months of each batch separately. Specifically, the specific announcement dates for the three batches of resource-depleted cities were 17 March 2008, 5 March 2009, and 15 November 2011. Therefore, for each year when the resource-depleted cities were announced, the respective values were set to 3/4, 5/6, and 1/12, while the values for other years remained unchanged. The estimation results are reported in column (3) of Table 6, where the estimated coefficient of the core independent variable remained positive and significant at the 5% level, which enhanced the robustness of the baseline regression results.

4.3.3. Shortening the Window Period

The choice of the window period may affect the estimation results. This study utilized a sample spanning from 2003 to 2016, which totaled 14 years. One potential concern was that the regression results might be driven by the relatively long window period. To verify the robustness of the baseline regression results under a reduced sample size and shortened window periods, we conducted regressions using samples from 2004 to 2015 and 2005 to 2015, where the sample window was gradually narrowed. The results are shown in columns (4) and (5) of Table 6. It can be observed that there were no significant differences between the core explanatory variables and baseline regression results. The regression coefficients remained significantly positive, which further enhanced the robustness of the baseline regression results.

4.3.4. Changing the Control Group

Considering the crucial importance of comparability between the experimental and control groups in the DID method, we set multiple control groups to verify the robustness of the baseline results.

(1) Resource-based cities: Given potential differences between resource-based cities and general cities, we only selected resource-based cities as control groups. The list of resource-based cities was sourced from China's "National Sustainable Development Plan for Resource-Based Cities (2013–2020)" published in 2013, which listed 126 prefecture-level resource-based cities and covered all samples of resource-exhausted cities. We used this published list of resource-based cities as the control groups for the regression. The regression results are shown in column (1) of Table 7 and indicate that the impact of resource-exhausted city support policy on urban innovation remained significantly positive.

Table 7. The effect of policy assistance on urban innovation: robustness 2.

Control Groups	(1) Resource-Based Cities CityInnov	(2) The Same Province CityInnov	(3) PSM-DID CityInnov
$Treat_i \times Post_{it}$	0.199 **	0.244 ***	0.241 ***
	(0.088)	(0.093)	(0.092)
λ_i	Yes	Yes	Yes
λ_t	Yes	Yes	Yes
$\lambda_i t$	Yes	Yes	Yes
X_{it}	Yes	Yes	Yes
Observations	1582	2492	3535
R-squared	0.969	0.979	0.982

Note: *** and ** represent the significant levels of 1% and 5% respectively. Robust standard errors clustered at the city level are in parentheses.

(2) Cities in the same province: Considering that cities in the same province as resource-exhausted cities have more similar political, economic, and transportation conditions, we chose cities in the same province as resource-exhausted cities as control groups to enhance the comparability. After retaining samples that contained resource-exhausted cities within the province, the regression results are shown in column (2) of Table 7, where the regression coefficient of the core independent variable was still significantly positive.

(3) PSM-DID: Using the propensity score matching (PSM) method, we adopted a 1:1 nearest neighbor caliper matching method to rematch the pilot samples with more similar control groups and then re-run the regression using the matched samples. Figure 3 displays the kernel density distribution of the propensity scores before and after matching between the treatment and control groups. It can be observed that after matching, the difference in kernel density distribution between the two groups significantly decreased, indicating that the PSM significantly enhanced the comparability between the experimental and control groups. Column (3) of Table 7 presents the estimation results of PSM-DID, where the regression coefficient of the core independent variable remained significant at the 1% significance level. A series of tests that replaced the control groups all strengthened the robustness of the baseline regression results.

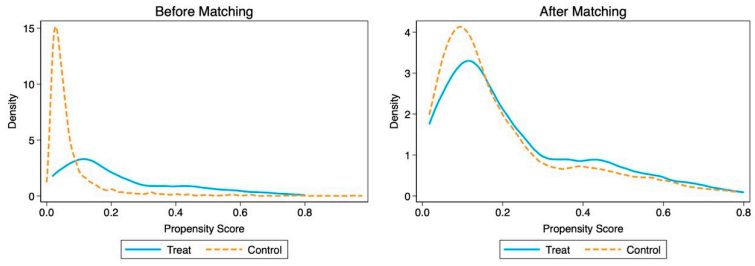

Figure 3. Kernel density of the treatment and control groups.

4.3.5. Placebo Tests

Despite incorporating multiple control variables and fixed effects in the baseline model, concerns persisted that the effects of the resource-exhausted city support policy may stem from other unobservable factors. This study randomly generated policy implementation times and treatment group samples as placebos [71,72]. Specifically, we randomly assigned policy effective times to each city based on the policy implementation process and non-repetitively selected nine, eight, and eight cities in three batches from all cities to be added to the virtual list of resource-exhausted cities as experimental groups for regression. We repeated this randomization process 500 times. The kernel density distributions of all estimated coefficients and *p*-values are shown in Figure 4, which indicates that the estimated coefficients of the placebo variables were closely associated with a normal distribution that was primarily centered around zero and lacked statistical significance. In contrast, the estimated values obtained from the baseline regression were distinguished by the red dashed line and displayed significant deviations from zero. Therefore, the results of the placebo tests reinforced the conclusion drawn from the baseline results that the effect of urban innovation promotion stemmed from the resource-exhausted city support policy rather than other unobservable random factors.

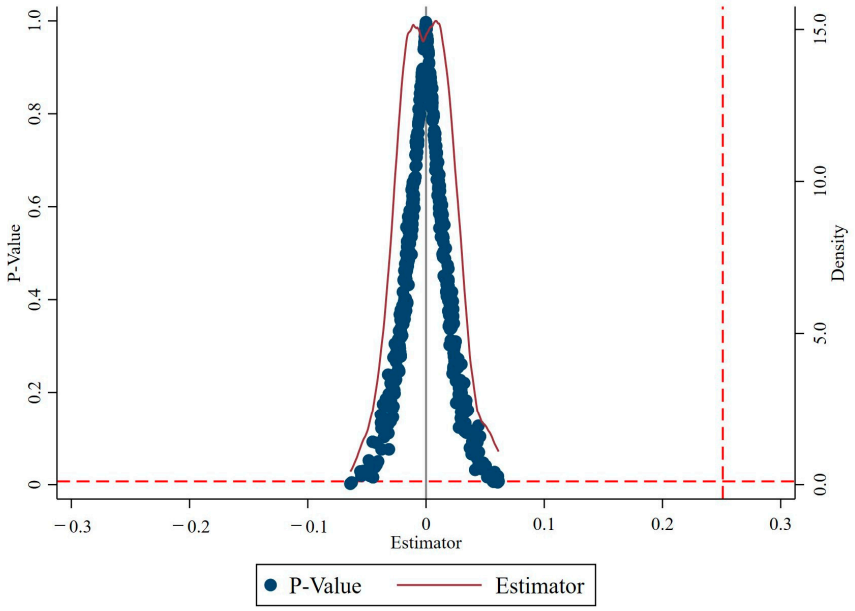

Figure 4. Placebo test. Note: The red horizontal dashed line represents $p = 0.007$, and the red vertical dashed line represents $\beta = 0.249$, which are the results of the baseline regression.

4.4. Mechanism Analyses

Based on the background and theoretical analysis, we proposed two mechanistic hypotheses to explain how supportive policies impacted the innovation in resource-exhausted cities: the degree of marketization and the industrial structure of the city. In this section, we describe the two-step method used to validate these hypotheses [73,74]. The specific model was as follows:

$$MV_{i,t} = \alpha + mTraet_i \times Post_{it} + \varphi X'_{it} + \lambda_i + \lambda_t + \lambda_i t + \varepsilon_{it} \quad (4)$$

The two-step method for the mechanism testing primarily included two equations, namely, Equations (1) and (4). Equation (1) was already validated in the previous section. In Equation (4), $MV_{i,t}$ represents the mechanism variables *Market* and *Industry*, and the meanings of the other terms remain consistent with those in Equation (1). We aimed to verify the effect of the regression coefficient m of the policy on the mechanism variables. The detailed analysis of the two mechanisms is provided below.

4.4.1. Marketization

The marketization level is one of the important factors influencing regional innovation levels. In resource-exhausted cities, many enterprises are resource-dependent state-owned enterprises, and the phenomenon of integration between the government and enterprises is severe. High market entry barriers for private enterprises result in generally low levels of marketization in these cities. The policy documents explicitly state the need to fully utilize the market to allocate resources and improve the efficiency of resource-exhausted cities. Therefore, this study explored the mechanism by which the resource-exhausted city support policy promoted urban innovation by examining whether they enhanced the city's marketization level. Drawing on the calculation method of Fan Gang's marketization index [75], we calculated the urban marketization index to measure the level of marketization.

Table 8 reports the estimated results of the impact of resource-exhausted city support policy on urban marketization. Column (1) presents results without controlling for any variables or fixed effects (FEs), with a coefficient of 3.233, which was significant at the 1% level. As shown in column (2), after adding fixed effects, the coefficient decreased to 0.152, significant at the 5% level. It can be observed in the third column that the net impact of the policy on urban marketization was 0.186, which was significant at the 5% level. This indicates that the support policy significantly improved the marketization level of resource-exhausted cities, which enhanced the efficiency of market factor allocation and thereby promoted urban innovation [76]. The research hypothesis H1 of this study was validated.

Table 8. Results of mechanism analysis: marketization.

	(1) **Marketization**	**(2)** **Marketization**	**(3)** **Marketization**
$Treat_i \times Post_{it}$	3.233 ***	0.152 **	0.186 **
	(0.161)	(0.070)	(0.074)
λ_i	No	Yes	Yes
λ_t	No	Yes	Yes
$\lambda_i t$	No	Yes	Yes
X'_{it}	No	No	Yes
Observations	3878	3878	3878
R-squared	0.0669	0.990	0.990

Note: *** and ** represent the significant levels of 1% and 5%. Robust standard errors clustered at the city level are in parentheses.

4.4.2. Industrial Structure

The single structure of industries is another factor constraining innovation in resource-exhausted cities. With resource-dependent industries at their core, resource-exhausted cities face severe impacts on their development as resources become depleted. The resource-exhausted city support policy proposed measures such as establishing industrial assistance mechanisms and vigorously developing alternative industries to promote the upgrade of urban industrial structure and achieve sustainable development. This study used the ratio of the value added of the tertiary industry to the total GDP to measure industrial structure upgrades.

Table 9 reports the estimated results of the impact of resource-exhausted city support policy on the urban industrial structure. As shown in column (1), when not controlling for pre-determined variables and any FEs, the estimated coefficient of the policy was very small and not significant. As shown in column (2), after adding FEs, the estimated coefficient was 0.022 at the 1% level. In the most stringent model control, as shown in column (3), which controlled for pre-determined variables and FEs, the estimated coefficient of the policy was 0.013 and still significant at the 10% level. This indicates that the resource-exhausted city support policy significantly increased the ratio of the tertiary industry to the secondary industry in urban areas, which promoted industrial structure upgrades. Industrial upgrades, by fostering the spillover of technology and knowledge within cities

and increasing market competitiveness, were shown in the literature to effectively promote urban innovation [77]. Thus, hypothesis H2 of this study was confirmed.

Table 9. Results of mechanism analysis results: industrial structure.

	(1) Industrial Structure	(2) Industrial Structure	(3) Industrial Structure
$Treat_i \times Post_{it}$	0.003	0.022 ***	0.013 *
	(0.009)	(0.007)	(0.007)
λ_i	Yes	Yes	Yes
λ_t	Yes	Yes	Yes
$\lambda_i t$	Yes	Yes	Yes
X'_{it}	No	No	Yes
Observations	3878	3878	3862
R-squared	0.0276	0.942	0.949

Note: *** and * represent the significant levels of 1% and 10% respectively. Robust standard errors clustered at the city level are in parentheses.

4.5. Heterogeneity Analyses

The above results indicate that the support policy effectively enhanced the innovation performance of resource-exhausted cities. Considering the differences between cities, this policy may have different effects on resource-exhausted cities with different characteristics. Therefore, this study analyzed the heterogeneity of policy effects in different regions and types of resource-exhausted cities.

4.5.1. Region

China is vast in territory, with significant differences in economic, transportation, and natural environments across regions. The National Bureau of Statistics of China divides provinces into eastern, central, western, and northeastern regions, with the eastern region being geographically and economically superior to other regions [78]. Therefore, we divided the sample into eastern and non-eastern regions for the regression analysis. The regression results are reported in columns (1) and (2) of Table 10. It can be observed that whether in the eastern region or the non-eastern region, the support policy had a significant promoting effect on the innovation level of resource-exhausted cities. However, the effect of promoting urban innovation in the eastern region was more significant. This may have been because, compared with other regions, the eastern region was more economically developed, with better infrastructure and a greater concentration of innovative elements [29,79]. These objective advantages provided a better innovation environment for resource-exhausted cities in the eastern region, which made the promotion effect of the support policy on innovation more significant in the eastern region.

Table 10. Results of heterogeneity analyses: region, types of resource, and mining dependency.

	Region		Types of Resource		Mining Dependency	
Variables	(1) Eastern CityInnov	(2) Others CityInnov	(3) Coal Resources CityInnov	(4) Other Resources CityInnov	(5) Low CityInnov	(6) High CityInnov
$Treat_i \times Post_{it}$	0.379 ***	0.238 **	0.136	0.274 ***	0.558 **	0.168 *
	(0.084)	(0.105)	(0.166)	(0.101)	(0.270)	(0.092)
λ_i	Yes	Yes	Yes	Yes	Yes	Yes
λ_t	Yes	Yes	Yes	Yes	Yes	Yes
$\lambda_i t$	Yes	Yes	Yes	Yes	Yes	Yes
X_{it}	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1162	2716	406	1176	1946	1932
R-squared	0.984	0.974	0.972	0.971	0.984	0.975

Note: ***, **, and * represent the significant levels of 1%, 5%, and 10%, respectively. Robust standard errors clustered at the city level are in parentheses.

4.5.2. Types of Resources

Each resource-type city harbors different types of resources, and the objective differences in resource endowments prompt the differentiated development of urban industrial structures, which may affect the implementation of the support policy. The Development Research Center of the State Council of China categorizes resource-type cities into five types: coal, forest industry, metallurgy, petroleum, and others. At the prefectural level, coal-type cities account for a large proportion of resource-exhausted cities. Additionally, due to the greater difficulty in the industrial restructuring of coal-type cities, they are the key targets of policy support. Therefore, we divided the sample of resource-type cities into coal-type cities and other cities for separate analysis. The estimation results are reported in columns (3) and (4) of Table 10. We found that the impact of the support policy on coal-type cities was not statistically significant, while the promoting effect of innovation levels in other types of resource-exhausted cities was significant at the 1% level. This aligned with our expectations; as compared with the coal industry, the supporting industries in the petroleum and metallurgical industries were more technologically advanced and had more complete industrial chains, which were more conducive to urban innovation [80]. The results suggest the need for greater attention to the transformation and innovation of coal-type cities.

4.6. Further Analyses

This study further explored the factors that influenced the effectiveness of the support policy, with the aim to understand how differences in urban characteristics affect policy implementation effectiveness and provide insights for policy optimization.

4.6.1. Mining Dependency

The higher the proportion of the mining industry in the total industrial output value of a city, the lower the level of manufacturing development, which implies greater challenges for innovation assistance in such resource-exhausted cities [81]. Since it is difficult to obtain industry output data at the city level, we followed the approach of Sun and Abraham [82] and aggregated micro-enterprise output data from the China Industrial Enterprise Database to obtain data on the proportion of the mining industry at the city level. During the integration process, samples with liquid assets exceeding total assets, fixed assets exceeding total assets, missing enterprise codes, and incorrect establishment years were excluded [59,83]. This study conducted group regression based on the median proportion of the mining industry in 2007. The regression results in columns (5) and (6) of Table 10 indicate that in cities with a higher dependence on the mining industry, the impact of the support policy on urban innovation was smaller and less significant. This suggests that differences in urban industrial foundations affected the urban innovation promotion effect of the support policy for resource-exhausted cities. Overreliance on the mining industry in resource-exhausted cities exacerbated the problem of industrial structure singularity, further limiting the promotion effect of the support policy on urban innovation. Therefore, policymakers need to consider further guiding these cities to move away from resource dependence and transform their development dynamics.

4.6.2. Talent Environment

Innovation can be seen as an output process of input factors, where the input of human resources has a crucial impact on innovation output [84]. This study explored whether the regional talent environment affected the innovation promotion effect of the support policy for resource-exhausted cities, with a focus on two aspects: the number of higher education institutions and the number of science and technology professionals. On one hand, higher education institutions are one of the key drivers of regional innovation, with advantages in fundamental research, abundant scientific talents, and interdisciplinary integration [50]. We divided the samples into two groups based on the median number of universities in the cities and conducted regression analyses separately.

The regression results in columns (1) and (2) of Table 11 indicate that resource-exhausted cities with a higher number of universities showed a more significant improvement in urban innovation after being influenced by the support policy. On the other hand, talent was the primary resource for innovation and the foundational element for innovative development [85]. Therefore, a higher number of science and technology professionals were conducive to promoting urban innovation. Since only four resource-exhausted cities had a number of science and technology professionals above the median in the total sample, we grouped the samples based on the median number of science and technology professionals in resource-exhausted cities and conducted regression analyses. The results in columns (3) and (4) of Table 11 similarly demonstrate that the support policy had a stronger and more significant innovation promotion effect on resource-exhausted cities with more science and technology professionals. In other words, the issue of talent drain in resource-exhausted cities significantly limited the innovation promotion effect of the support policy. Addressing the supply of human resources in the transformation and development of resource-exhausted cities is a problem that policies need to further solve.

Table 11. Results of heterogeneity analyses: talent environment.

	Higher Education Institutions		**Science and Technology Professionals**	
Variables	**(1)** **Low Quantity**	**(2)** **High Quantity**	**(3)** **Low Quantity**	**(4)** **High Quantity**
$Treat_i \times Post_{it}$	0.169	0.393 **	0.212	0.172 **
	(0.116)	(0.164)	(0.150)	(0.077)
λ_i	Yes	Yes	Yes	Yes
λ_t	Yes	Yes	Yes	Yes
$\lambda_i t$	Yes	Yes	Yes	Yes
X_{it}	Yes	Yes	Yes	Yes
Observations	1708	2170	770	3108
R-squared	0.965	0.984	0.958	0.984

Note: ** represent the significant levels of 5%. Robust standard errors clustered at the city level are in parentheses.

5. Conclusions

The sustainable development transformation of resource-exhausted cities is a global challenge. Urban innovation is a key pathway to achieving sustainable urban development, making it crucial to explore ways to enhance the innovation capacity of resource-exhausted cities, both theoretically and practically. This study utilized the exogenous shock from China's support policy to construct a difference-in-differences model, which empirically analyzed the impact of these policies on urban innovation and their long-term mechanisms based on panel data from 277 prefecture-level cities in China from 2003 to 2016. The main conclusions of this study are summarized as follows: First, the support policy for resource-exhausted cities significantly promotes innovation. Specifically, the implementation of central transfer payments and supporting policies increased the number of authorized patents by 28.34%. Second, our findings indicate that the support policy established two long-term mechanisms—industrial structure upgrades and increased marketization—which substantially enhanced the urban innovation levels. Third, the effect of these policies on urban innovation varies depended on the region, city resource type, reliance on extractive industries, and regional talent supply. Specifically, the innovation-promoting effect of the policies was more pronounced in cities located in the eastern region, non-coal cities, cities with low reliance on extractive industries, and cities with higher levels of science and education.

In this critical era of global sustainable development, this study used empirical data to investigate the impact of government support policy on the innovation of resource-exhausted cities, which has significant policy implications. A fundamental recommendation is that the economic transformation of resource-exhausted cities requires corresponding financial and institutional support from the government, alongside differentiated support

policies. These cities face poor economic foundations, insufficient growth momentum, and severe talent loss, making it difficult to accelerate urban innovation based on their own resources, thereby achieving sustainable development transformation. According to the main findings of this study, the government should consistently provide financial support and guidance on transformation systems to promote urban innovation and sustainable development.

Second, based on the results of mechanism analysis, policies should enhance the transformation of resource-exhausted cities from two aspects: industrial structure and market orientation. This study found that upgrading the industrial structure is pivotal in promoting innovation in resource-exhausted cities through supportive policies. To advance this transformation, it is essential to extend dominant industries, develop alternative sectors, and foster a diversified industrial system that promotes growth in both established and emerging industries, thereby driving urban innovation transformation. Moreover, the traditional government-led economy in resource-exhausted cities significantly stifles innovation dynamics. Therefore, accelerating market-oriented reforms in these cities to foster urban innovation is crucial. On one hand, the government should streamline administration, decentralize authority, reduce economic interventions, and allow the market to play a decisive role in resource allocation to create an efficient market environment. On the other hand, enhancing market supervision through improved legal frameworks to safeguard innovation outcomes and actively guiding urban transformation is essential.

Third, based on further research findings, it is evident that the support policy had varying effects on different types of resource-exhausted cities in terms of innovation. On one hand, these policies significantly promoted innovation in resource-exhausted cities in the central and western regions, but their impact was less pronounced in eastern resource-exhausted cities. Specifically, cities that were reliant on oil showed significant policy effects, whereas those that were reliant on coal exhibited less clear effects. Therefore, the central government should comprehensively consider multiple factors in formulating targeted strategies for urban transformation. For instance, differential treatment in transfer payments should address specific challenges faced by resource-exhausted cities during their transformation, particularly by increasing support for those in the central and western regions. Additionally, the government should continuously assess the transformation performance of these cities through ongoing monitoring processes by evaluating aspects such as economic diversification, improvement in residents' living standards, and environmental remediation. Based on these assessments, establishing incentive mechanisms and gaining deeper insights into the strengths and weaknesses of each city type should serve as critical references for formulating differentiated policies. On the other hand, the magnitude of policy effects was also influenced by the talent environment and mining dependency. The lagging industrial base and lack of human capital in resource-exhausted cities constrained the innovation-promoting effects of the policies. This underscores the need for the government to address the potential mechanisms through which the talent environment and mining industry affect the innovation transformation of resource-exhausted cities. Future relevant policies should ensure the effectiveness of the support policy by improving industrial infrastructure and guaranteeing the supply of human resources.

Regarding the limitations of this study: First, the data used can be further refined. This study employed data at the prefecture level, but future research could use more granular county-level data to more comprehensively and meticulously evaluate the net effects of the support policy on urban innovation. Second, caution is needed when generalizing the conclusions of this study. China is the largest developing country in the world and has different economic and institutional environments compared with other developing countries. Therefore, when other countries seek to draw on China's empirical evidence to promote the transformation and development of their resource-exhausted cities, they must consider their own socio-economic contexts.

Supplementary Materials: The following supporting information can be downloaded from https://www.mdpi.com/article/10.3390/land13081153/s1: Table S1. Full list of pilot cities.

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Conflicts of Interest: The authors declare no conflicts of interest.

Notes

[1] For detailed content, refer to the following, website: https://www.gov.cn/zwgk/2007-12/24/content_841978.htm (accessed on 5 June 2024).

[2] For detailed content, refer to the following website: https://chinanews.com.cn/sh/2021/09-14/9564788.shtml (accessed on 10 July 2024).

[3] For detailed content, refer to the following website: https://zfxxgk.ndrc.gov.cn/web/iteminfo.jsp?id=17391; https://www.gov.cn/zwgk/2007-12/24/content_841978.htm; https://www.gov.cn/zwgk/2013-12/03/content_2540070.htm (accessed on 10 July 2024).

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