

# The Impact of State Subsidies on Green Innovation in Heavily Polluting Enterprises

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**Abstract:** In recent years, China has adhered to the concept of green development as well as focused on building a “community of human and natural life”. Since 2017, it has been proposed that China’s economic development has shifted from high-speed growth to high-quality development. In this context, the green and low-carbon transformation and development of heavily polluting corporations is imminent. In view of this, we start from state subsidies, explore their impact on the green innovation of high-polluting corporations, and select the data of China’s A-share listed high-polluting corporations from 2008 to 2020 as research samples, construct multiple regression models, and conduct empirical analysis. We find that state subsidies have a catalytic effect on green innovation of high-polluting corporations. In order to help China continuously improve state subsidies and green development management, and make better use of state subsidies in promoting green innovation of high-polluting corporations, we put forward relevant suggestions.

**Keywords:** State Subsidies; Heavy Polluting Enterprises; Enterprise Transformation; Green Innovation; Sustainable Development

## 1. Introduction

Nowadays, China has adhered to the concept of green development as well as focused on building a “community of life between man and nature.” China’s economic development has changed from a stage of high-speed growth to a stage of high-quality development. In this context, the green and low-carbon transformation progress of heavy polluting enterprises is imminent. In recent years, China’s heavy polluting enterprises have been

active in green innovation activities. In order to solve the problems of high green innovation costs and financing difficulties encountered by high-polluting corporations in their transformation, guide high-polluting corporations to implement green innovation and boost their vitality of green innovation, the state continues to increase subsidies to heavy pollution corporations, in order to improve the level of green innovation of heavy pollution corporations and promote the green development of corporations. But can state subsidies really promote green innovation for corporations? This needs to be tested.

In view of this, we start from the state subsidy to discuss its impact on the green innovation of high-polluting corporations, which has certain theoretical and practical significance. In terms of theoretical significance, exploring the state subsidies for green innovation for high-polluting corporations has enriched the relevant research for the economic consequences of state subsidies and the elements affecting corporations’ green technology innovation. In practical terms, in the context of China’s green and low-carbon transformation and upgrading, the study of the relationship among state subsidies and high-polluting corporations’ green development is conducive to clarifying the influencing factors of green innovation of high-polluting corporations and providing thinking and exploration for China’s improvement of national subsidies and green development policies.

## 2. Literature Review

We summarize the previous literature views from the economic consequences of state subsidies and the green innovation of high-polluting corporations.

### 2.1 Economic Consequences of State Subsidies

To boost the green innovation and progress of enterprises, China has taken serial methods to stimulate their development, such as the state's green subsidies to corporations. The state subsidizes corporations to implement green technology innovation. It not only helps corporations lower the cost of green innovation, solves the problem of inadequate funds in the process of green technology innovation, and lower the marginal cost and R&D risk of enterprises. At the same time, the signal transmission effect of state subsidies in the process of corporations green technology progress can solve the problem of information asymmetry among corporations and external investors, effectively reduce the risk and cost of corporations, also better help enterprises grow and develop [1]. This stimulates corporations to innovate and provides more possibilities for the development of green technology [2]. The state's subsidies to enterprises mainly include interest subsidies, appropriations, and tax rebates. After research, it has been found that the state's allocation to enterprises can better stimulate the innovation ability of enterprises [3]. However, the national R&D subsidies should also be moderate. Studies have shown that excessively high national subsidies will ultimately be detrimental to the green innovation of enterprises [4], because excessive subsidies will cause corporations to rely on subsidies and cause their corporations to have a crowd-out effect for green innovation.

## 2.2 Green Innovation of Heavy Pollution Corporations

Innovation is the fundamental driving force for development and the fundamental strategy for the survival and sustainable development of enterprises. Under the current situation of global warming and serious environmental pollution in some parts of China, it is urgent for heavy polluting corporations to develop innovation capabilities and green transformation. Corporations urgently need to break through the shackles through green innovation to achieve sustainable development. Green innovation not only ensures the economic development of corporations but also contributes to the protection of the environment. It is an important force for corporations to accelerate transformation, upgrading and green development [5]. By

summarizing multiple research results, it is found that the green transformation of heavy pollution corporations is inseparable from technological innovation [6]. In terms of green technology innovation, corporations mostly focus on energy conservation and alternative energy production [7]. However, most enterprises lack the motivation in green transformation, mainly due to the high cost and lack of financial support; the weak ability of independent innovation, the lack of technical talents and advanced equipment; and the lack of institutional guarantee, which makes the development momentum of corporations insufficient [8]. In terms of green innovation for the sustainable development of corporations, some studies have pointed out that the innovation of technology and equipment of corporations can better improve environmental performance; while green innovation of products can better improve the performance level of enterprises [9] and ultimately promote the sustainable development of corporations. For the level of green innovation and development of corporations, there are many factors that affect the level and the impact is not symmetrical [10].

## 3. Research Design

### 3.1 Research Hypothesis

Since the reform and opening-up, China's economy has developed rapidly, but the economic growth of many places has been achieved at the cost of environmental sacrifice. The contradiction between economic growth and ecological environment has become increasingly prominent. The state has repeatedly proposed and emphasized the policy orientation of "green mountains and clear waters are as valuable as gold and silver mountains", and has adopted the approach of imposing environmental protection taxes on polluting corporations to encourage heavily polluting corporations to transform and upgrade to green and low-carbon. However, due to the characteristics of high R&D investment, long cycle, and high uncertainty in corporate green innovation, corporations often face difficulties in financing when carrying out green innovation activities. Financial constraints have become an important factor restricting heavily polluting corporations from

improving their green innovation level. Based on the theory of resource-based view of the firm [11], we believe that state subsidies, as an important resource for corporations, can alleviate the financial constraints faced by heavily polluting corporations in the process of carrying out green innovation, thereby enabling them to increase green innovation investment and improve green innovation output.

In view of the above analysis, the following hypothesis is proposed:

H1: state subsidies can promote green innovation in heavily polluting corporations.

### 3.2 Data Source and Variable Explanation

#### 3.2.1 Data source and basic processing

According to the industry classification standard revised by the China Securities Regulatory Commission in 2012, China's heavily polluting industries are concentrated in the coal industry, manufacturing, and the electricity, heat, gas, and water production and supply industries. Therefore, we selected the data of heavily polluting corporations listed on the A-share market in China from 2008 to 2020 as samples. To avoid the influence of extreme data on the results, we excluded ST\* and ST companies, as well as samples with more missing values. At the same time, to prevent the empirical analysis results from

being affected by outliers, we performed bilateral trimming at the 1% and 99% levels, and finally obtained 1242 observations. All data used in this article are from the CSMAR database.

#### 3.2.2 Explanation of relevant variables

**Dependent variable:** Referring to existing research, we use the number of green patent applications by corporations as a proxy indicator for green innovation variables (EGI) of heavily polluting corporations, and perform logarithmic transformation on it.

**Independent variable:** As for state subsidies (SUB), different from previous studies that directly selected the "state subsidies" amount disclosed in the notes to the corporate financial statements, we selected green project subsidies (GPG) and green project awards (GPA) as proxy variables for state subsidies to align with our research goals.

**Control variables:** To ensure the correctness and credibility of the research results, we selected the following enterprise-level control variables in accordance with the practices of existing literature: enterprise size (Size), enterprise age (Age), asset-liability ratio (Lev), fixed asset ratio (Fix), working capital ratio (Wcr), and Tobin's Q (TBQ).

Specific explanations of each variable are shown in Table 1 below:

**Table 1. Main Variable Descriptions**

Variable Type	Symbol	Variable Description
Dependent Variable (EGI)	<i>EGI</i>	Green Innovation of Heavily Polluting Corporations, Ln(1 + Number of Green Patent Applications)
Independent Variable (SUB)	<i>GPG</i>	Green Project Subsidy, Natural Logarithm of state's Financial Special Fund Support for Green Projects
	<i>GPA</i>	Green Project Award, Natural Logarithm of state's Green Project Award
Control Variables (Controls)	<i>Size</i>	Corporations Size, Natural Logarithm of Total Assets at the End of the Period
	<i>Age</i>	Corporations Age, Natural Logarithm of the Duration of the Corporation
	<i>Lev</i>	Asset-Liability Ratio, Total Liabilities/Total Assets
	<i>Fix</i>	Fixed Asset Ratio, Fixed Assets/Total Assets
	<i>Wcr</i>	Working Capital Ratio, Current Assets/Current Liabilities
	<i>TBQ</i>	Tobin's Q, Market Value at the End of the Year/Total Assets at the End of the Year

### 3.3 Descriptive Statistics and Correlation Analysis

Table 2 reports the descriptive statistics of each variable. It can be observed that the mean of green innovation (EGI) in heavily polluting corporations is 1.442, with a standard deviation of 0.954, a minimum value of 0.693, and a maximum value of 4.419. This indicates

that there are significant differences in green innovation among different heavily polluting corporations. Exploring the reasons for these differences has certain significance for improving the level of green innovation in heavily polluting corporations in China. The mean and standard deviation of green project subsidies (GPG) are both large, with a range of up to 13199, indicating that the green project

subsidies, as an indicator of green innovation for heavily polluting corporations, have large volatility. This may be caused by the differences in the intensity of state subsidies in different regions, or it may be related to the size and qualifications of the corporations. The mean of the logarithm of state green project rewards is 0.981, with a standard deviation of 0.242, a minimum value of 0.693, and a maximum value of 1.386, with a median of 1.099, indicating that green project rewards (GPA) have certain volatility.

In terms of control variables, it is not difficult to find that the standard deviations of variables such as enterprise size (Size), corporations age (Age), asset-liability ratio (Lev), fixed asset ratio (Fix), working capital ratio (Wcr), and Tobin's Q value (TBQ) are all greater than 1, indicating that there are large differences in scale between corporations samples in different heavily polluting industries. It is necessary to control variables at the company level.

**Table 2. Descriptive Statistics**

Variables	N	Mean	SD	Min	Max	P25	P50	P75
EGI	1242	1.442	0.954	0.693	4.419	0.693	1.099	1.946
GPG	1242	638.743	1842.009	1	13200	27.571	101.895	345.458
GPA	1242	0.981	0.242	0.693	1.386	0.693	1.099	1.099
Size	1242	23.003	1.418	20.229	26.207	21.907	22.951	24.022
Age	1242	2.931	0.26	2.197	3.434	2.773	2.944	3.135
Lev	1242	51.86	19.843	7.359	89.782	37.781	52.946	67.922
Fix	1242	39.043	16.76	6.506	75.121	25.747	39.745	51.920
Wcr	1242	1.454	1.62	0.196	11.241	0.662	0.958	1.607
TBQ	1242	1.196	1.139	0.139	5.911	0.419	0.813	1.558

Table 3 presents the correlation coefficients of the main variables in the article. We find that there is a significant positive correlation at the 1% level between green project subsidies (GPG) and green project awards (GPA), as well as between green project subsidies (GPG) and green innovation in heavily polluting corporations (EGI), with relatively high correlation coefficients. However, the correlation coefficient between green project awards (GPA) and green innovation in heavily polluting corporations (EGI) is lower and significant at the 5% level. In addition, the correlation coefficients between the two independent variables and the dependent variable are all positive, which indicates that, keeping other factors constant, the level of green innovation in heavily polluting corporations will increase with the increase of green project subsidies and green project awards. That is, green innovation in heavily polluting corporations can be promote by state subsidies effectively ,preliminarily verifying the research hypotheses proposed in the above text.

**Table 3. Correlation of Main Variables**

Variable	EGI	GPG	GPA
EGI	1.000		
GPG	0.193***	1.000	
GPA	0.072**	0.111***	1.000

#### 4. Empirical Analysis

##### 4.1 Benchmark Regression Analysis

To further test the research hypothesis H1 proposed in the previous section, namely that state subsidies can help heavily polluting enterprises to perform green innovation, we found the following basic model:

$$EGI_{i,t+1} = \alpha + \beta SUB_{i,t} + \gamma Controls_{i,t} + \varepsilon_{i,t} \quad (1)$$

In model (1), EGI is the explained variable, representing heavily polluting corporations's green innovation; SUB is the explanatory variable, representing state subsidies, and is represented by green project subsidies (GPG) and green project awards (GPA) as proxy indicators; Controls are control variables.  $\alpha$  represents the intercept term,  $\beta$  and  $\gamma$  on behalf of the regression coefficients of the above variables, and  $\varepsilon$  on behalf of the random error term. Given that there is a certain time lag from receiving state subsidies to applying for green innovation patents, we lag the green innovation variable (EGI) of heavily polluting corporations by one period.

Table 4 reports the benchmark regression results of state subsidies and green innovation in heavily polluting corporations. The two columns in the above table show the impact of green project subsidies (GPG) and green

project awards (GPA) on green innovation (EGI) in heavily polluting corporations, controlling for company-level variables. We can see that the regression coefficients of green project subsidies (GPG) in the first column and green project awards (GPA) in the second column are both positive and significant at the 1% level, manifesting that when state subsidies increase, green innovation's level in heavily polluting corporations will also increase. This proves that state subsidies have a positive promoting effect on heavily polluting corporations's green innovation, which means that hypothesis H1 is established. This may be because state subsidies help alleviate the financial pressure on heavily polluting corporations to perform green innovation, enabling them to fund more material, financial, and human resources into green innovation research and development activities, thereby increasing green invention patent applications' number and ultimately facilitating the green transformation and upgrading of heavily polluting corporations.

**Table 4. Benchmark Regression Analysis on State Subsidies and Heavily Polluting Corporations'S Green Innovation**

variable	(1)	(2)
	L1.EGI	L1.EGI
GPG	0.008*** (3.75)	
GPA		0.312*** (3.15)
Size	0.373*** (14.80)	0.382*** (15.92)
Age	0.527*** (5.98)	0.511*** (5.82)
Lev	0.008*** (4.99)	0.008*** (4.57)
Fix	-0.004** (-2.16)	-0.004** (-2.16)
Wcr	-0.022 (-1.46)	-0.021 (-1.37)
TBQ	0.063** (2.56)	0.062** (2.55)
Constant	-8.164*** (-13.30)	-8.666*** (-14.61)
N	1242	1242
R2	0.348	0.353

Note: The t-value is enclosed in parentheses; \* represent  $p < 0.1$ , \*\* represent  $p < 0.05$ , \*\*\* represent  $p < 0.01$ .

Besides, it is not hard to find that the regression coefficient of green project awards (GPA) is 0.312, much higher than the regression coefficient of 0.008 for green project subsidies (GPG). This indicates that compared to directly issuing green project subsidies, when local states adopt green project awards to provide state subsidies to heavily polluting corporations, the positive promoting effect on green innovation is more significant. This research conclusion has a high reference value for the state in choosing the way of state subsidies.

Finally, among the control variables, except for the Tobin's Q (TBQ) value, which has a partially insignificant regression coefficient, the remaining coefficients are significant at the 5% or 1% level. By analyzing the regression coefficients of each control variable, we find that when state subsidies are granted to heavily polluting enterprises with longer survival time, larger scale, and better business performance, their positive impact on improving green innovation' level will be more pronounced, which is basically the same as our daily understanding.

#### 4.2 Robustness Test

On the basis of baseline regression analysis, for the robustness of the empirical results, we regression the green innovation level variable of heavy polluting corporations after two periods. Table 5 shows the results of regression.

**Table 5. Robustness Test Results**

variable	(1)	(2)
	L2.EGI	L2.EGI
GPG	0.012*** (2.84)	
GPA		0.290** (2.00)
Age	0.750*** (4.80)	0.716*** (4.55)
Lev	0.003 (0.97)	0.001 (0.47)
Fix	-0.000 (-0.17)	0.000 (0.03)
Wcr	-0.052 (-1.03)	-0.049 (-0.98)
TBQ	0.127*** (2.86)	0.136*** (3.05)
Constant	-0.530 (-0.95)	-0.771 (-1.35)

N	697	697
R <sup>2</sup>	0.169	0.164

Note: the value of t is in brackets; \* denotes  $p < 0.1$ , \*\* denotes  $p < 0.05$ , \*\*\* denotes  $p < 0.01$ .

We can see that the regression coefficient of Green Project Grant is 0.012 and significant at the 1 % level after lagging the EGI of heavy polluting corporations by two periods; the regression coefficient of GPA is 0.29 and significant at the 5 % level. This indicates that there is a positive correlation between government subsidies and the level of green innovation in heavy polluting corporations. Moreover the regression coefficient of green project award is still higher than the regression coefficient of green project grant, which proves again that the use of green project awards to issue government subsidies is more obvious than the direct issuance of green project grants to facilitate the advancement of innovation in heavily polluting industries. This aligns with the findings of the baseline regression, validating the robustness of the baseline regression results.

## 5. Conclusions and Recommendations of the Study

### 5.1 Research Conclusions

We conducted an empirical study on A-share listed companies in China, specifically focusing on heavily polluting enterprises from 2008 to 2020. Our study focuses on examining how government subsidies impact the environmental innovation of these businesses and formulating research hypotheses. After conducting benchmark regression analysis, we discovered a noteworthy positive association between the amount of state subsidies and the volume of green patent applications from heavily polluting companies. Moreover, it is important to note that the coefficient for green project awards exceeds that of green project subsidies in terms of magnitude. In our test for resilience, we analyzed the delayed impact of green innovation on companies with high levels of pollution over a span of two periods. The results from the regression show a significant positive relationship between the national provision of green project subsidies and rewards and the green innovation demonstrated by these companies, with statistical significance at least at the 5% level.

Additionally, our findings indicate that the impact of green project rewards on promoting green innovation in heavily polluting enterprises is greater than that of green project subsidies. Consequently, it can be inferred that state subsidies effectively stimulate the adoption of environmentally friendly practices among heavily polluting enterprises, which can be further enhanced through incentivizing them with green project rewards.

### 5.2 Relevant Suggestions

Based on the above research conclusions, in order to help China continuously improve state subsidies and green development policies, and better play the role of state subsidies in promoting green innovation of heavy polluting enterprises, we propose the following suggestions:

First, it is recommended that the state should continue to improve, promote and implement state subsidies policies. The level of subsidies and project awards for environmentally harmful companies can be incrementally raised to ease their financial burden and resource limitations during green innovation initiatives. This will encourage these companies to increase their motivation for participating in environmentally friendly innovation and improve their performance in this field.

Second, we will further optimize the way state subsidies are distributed. It is recommended that the primary approach should be based on rewarding green projects, supplemented by providing subsidies for such initiatives. Furthermore, it is essential to strengthen post-project rewards for environmentally innovative practices in heavily polluting industries to prevent companies from misusing environmental protection subsidies. At the same time, it can also be used in combination with tax reduction and exemption, financial interest discount and other means to reduce the cost of green innovation of heavy polluting enterprises. State subsidies can be realized from multiple angles to further create green typical enterprises of heavy polluting enterprises and create a good atmosphere for green innovation.

Third, it is crucial to execute the national initiatives on green subsidies, enhance the subsidy program, specify the direction of subsidies, and foster the eco-friendly

conversion and advancement of heavily polluting industries. Strengthen oversight of the proper distribution of subsidy funds, outline the specific purposes for each subsidy, and ensure effective utilization of green innovation funds for heavily polluting enterprises. Reduce fraudulent activities related to misappropriation of green innovation subsidies in heavy polluting industries, and actively encourage both the quantity and quality of green innovation to promote environmentally friendly and low-carbon transformations within these enterprises.

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