# Research on the influence of air pollution on Enterprise Green Innovation Based on the adjustment effect of enterprise credit level

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**Abstract.** Enterprise green innovation is committed to the coordinated development of regional economic growth and ecological environment protection. It is of great practical significance to explore the internal linkage between air pollution and enterprise green innovation in the era of double carbon policy. Based on the data of all A-share listed companies in China from 2014 to 2019, this paper studies the impact of air pollution on enterprise green innovation and the regulatory effect of enterprise credit level on air pollution and enterprise green innovation. The research finds that: first, air pollution will significantly promote enterprises to carry out green innovation, that is, increase the total number of green patent applications; Second, compared with the quality of green innovation, the promotion of air pollution on the number of green innovation is more obvious, that is, the number of green utility model patents is significantly increased; Third, the improvement of enterprise credit level will strengthen the negative effect between air pollution and enterprise green innovation. According to the research conclusion, this paper also puts forward rationalization suggestions for green innovation of enterprises and financial market problems.

**Keywords:** Enterprise green innovation; Air pollution; Enterprise credit.

## 1. Introduction

Since the reform and opening up, China's economy has been completely transformed. However, in the process of industrialization, the early economic development mode is more extensive, leading to the aggravation of ecological environment pollution and the shortage of natural resources. For a long time in the past, the fog lock world has become the normal in the middle and eastern regions of China. The deterioration of air conditions not only brings inconvenience to people's transportation, work and life, but also poses an unprecedented threat to people's physical and mental health. According to the report on China's ecological environment in 2020, among the 337 cities that implement the new standards to monitor environmental pollution, the proportion of cities whose concentrations of six pollution indicators such as PM2.5 exceed the standard is as high as 43.3%. Air pollution control is still a serious task facing China.

As the fusion point of "innovation driven" and "green development", enterprise green innovation can directly affect the emission of pollutants and promote the green and sustainable development of enterprises (Ma Yongqiang, 2021) .At the same time, enterprise green innovation can play a role in the coordinated development of economic growth and environmental protection , but as a new thing emerging with environmental pollution, it cannot be achieved overnight . It also has the characteristics of "double externality", "high investment and high risk" and "lagging return", Moreover, the uncertainty of the technological prospect of green innovation development will also cause the lack of energy and caution of enterprises (Cao Hongjun, 2017; Fang Xianming, 2020) [4-5]. In addition, considering that the current enterprises practice the concept of green finance, there is a demand for financing for green innovation, and the importance of enterprises to green innovation may vary according to different credit levels of each enterprise. Based on the above facts, the extended questions include: how will air pollution affect the green innovation of enterprises? What is the impact mechanism of enterprise credit level on local enterprises' green innovation?

The existing literature is rich in analyzing the negative effect of air pollution and the influence mechanism of enterprise green innovation. Existing studies on air pollution mostly focus on the

relationship between the impact of pollution on public health (Wang Yuze, 2020) and social and economic development (Li Chao et al., 2017) , while the factors that promote enterprise green innovation focus on the decision-making body (Xiao Xiaohong, 2021) and the acquisition of environmental regulations (Deng Yang, 2022) , and rarely explore the impact of air pollution on enterprise green innovation from the micro level. Under this background, based on the A-share data of all listed companies from 2014 to 2019, this paper attempts to empirically test the impact of air pollution on enterprise green innovation in the places where enterprises are listed, and explore the regulatory role of enterprise credit on the relationship between the two, with the aim of further clarifying the relationship among the three, and providing new ideas for air pollution control under the double carbon target and helping enterprises green performance.

## 2. Research hypothesis

In the context of the double carbon target, the comprehensive prevention and control of air pollution, as an important part of it, is bound to bring governance pressure to the governments of various regions and urge them to formulate more specific environmental regulation measures and corresponding green subsidy policies under the double carbon target according to the current situation of ecological civilization construction. In order to comply with the requirements of environmental regulation, enterprises must adjust their economic structure and reduce carbon emissions. The most direct way is to reduce production costs through green technologies innovation to maximize production efficiency. At the same time, the external pressure exerted by environmental regulation on enterprises can produce "innovation compensation effect", which complements the internal control and management mechanism of enterprises. The government's green subsidy policy also provides financial support for the growth of enterprises' green performance, reducing the risk and uncertainty of enterprises' technological innovation (Li Ping, 2013) . On the other hand, from the perspective of human resources, sufficient human capital is the carrier of enterprise survival and development, and R & D human capital is the core power of enterprise technology upgrading. The aggravation of urban air pollution will reduce the attractiveness of urban human capital, produce a "expulsion effect" on human capital, and then have a negative impact on the business performance and production efficiency of enterprises (Chay K y, 2005; Luo Yonggen, 2019) [26-27]. The pressure of enterprise development forces enterprise executives to fulfill their social responsibilities, adjust the internal control management system, and promote the improvement of green innovation ability, so as to achieve the long-term development of the enterprise. Therefore, this paper proposes the following assumption:

H1: air pollution will significantly promote enterprises to carry out green innovation, that is, the higher the degree of air pollution in the place where the enterprise is located, the higher the degree of innovation of the enterprise.

The internal power of enterprise green transformation depends on green innovation. The R&D of green innovation technology of enterprises is generally measured from the perspective of green patent, which is divided into invention, utility model and appearance design. Among them, the invention patent is the most innovative and has more advantages in terms of protection scope, protection time and legal effectiveness. However, the approval procedure is strict, the cost is high, and the transformation period of R&D achievements is long . It is favored by large-scale enterprises with high R&D intensity, and is not so friendly to small and micro enterprises in the development stage. Compared with invention patents, the application conditions for practical patents are relatively loose, the examination and approval are rapid, and the costs are low. However, to some extent, they can not be converted into actual productivity, reflecting the "low quality" of green innovation technology. For a long time, they have been used as substitutes for invention patents and are a "secondary protection system" (Jin Xiao, 2020) . Therefore, whether an enterprise applies for a green patent and the choice of the type of green patent application is related to the strategic layout of green innovation of the enterprise, and further affects the business performance and social responsibility of the

enterprise. It has guiding significance for the formulation of the future development strategy of the enterprise. The motivation of enterprise innovation behavior is divided into pursuing high-quality substantive innovation and pursuing speed and quantity strategic innovation (Li Wenjing, 2016) . Under the macro background of the double carbon goal, faced with the stringent environmental regulations of the government, the continuous policy pressure and the performance requirements of local government officials, enterprises will favor strategic innovation that can be authorized quickly, with low application difficulty and low risk, that is, increase the number of green and practical patents, only pursue the "speed" and "quantity" of innovation to whitewash the surface innovation ability ,, and also realize short-term legal monopoly, gaining competitive advantages and economic benefits. Therefore, this paper proposes the following assumption:

H2: compared with the quality of green innovation, air pollution plays a more significant role in promoting the quantity of green innovation of enterprises.

The inherent characteristics of green innovation, such as large capital investment, high risk and long return cycle, make it necessary to have a higher level of enterprise credit than ordinary innovation activities. Enterprise credit is often obtained from banks or third-party lending platforms after a certain review. If the enterprise's green innovation activities face serious credit bottlenecks and cannot obtain sufficient financial support, it is difficult to effectively allocate innovation resources such as green technology and R&D personnel to green innovation projects, which will lead to low efficiency of green innovation and reduction of innovation output, The air pollution in the place where the enterprise is listed is aggravated (Ye Cuihong, 2021) . The action plan for carbon peak before 2030 clearly indicates that green credit will be a new green financial tool to provide long-term and low-cost funds for enterprises to meet their needs for green innovation activities. Zhu Hebin et al. (2021) believe that the credit level of listed enterprises will be significantly improved due to the implementation of the green credit policy, the long-term business conditions of enterprises will be improved, and the capital constraints will be eased to a certain extent, so as to take a more positive attitude towards the development of green innovation activities, focus on deep emission reduction and improve air quality. Therefore, this paper proposes the following assumption:

H3: enterprise credit level can positively regulate the relationship between air pollution and enterprise green innovation.

## 3. Research design

### 3.1 Sample selection and Data source

Since 113 key cities for environmental protection and national model cities for environmental protection took the lead in implementing and releasing AQI in 2013, less data on urban air pollution index can be obtained in 2013. Therefore, the starting point of this paper is 2014; On the other hand, since the green patent data of enterprises in CSMAR database is updated to 2019, 2019 is the time end of this article.

The data of the air quality index of the provinces and cities where the enterprises are located in the article are from CNRDS database; Enterprise green patent data, enterprise credit level and other control variables are all from CSMAR database.

In the process of using Excel software to sort out and merge the original data, this paper deals with the data as follows: (1) Eliminate the samples with more missing values of variables; (2) xcluding financial industry and ST company; (3) To avoid the influence of outliers, all continuous variables were winsorized at 1% and 99% levels.

### 3.2 Variable definition

Enterprise green innovation degree (*Grelno*), enterprise green innovation quality (*Grelnoqua*), enterprise green innovation quantity (Grelnodis). Referring to the research of Qi Shaozhou et al. (2018) , this paper uses the number of green patent applications of listed enterprises each year to

measure the green innovation level of enterprises, and further subdivides green patents into the number of green utility model patents and the number of invention patents.

**Table 1.** Variable definition and description

| Variable | | Variable meaning and measurement method |
|---|---|---|
| Dependent variables | *GreInoqua* | The green innovation quality of an enterprise is equal to the natural logarithm of the number of green invention patent applications of the enterprise plus 1 |
| | *GreInodis* | The number of green innovation of the enterprise is equal to the number of green utility model patent applications of the enterprise plus 1, taking the natural logarithm |
| | *GreIno* | The degree of green innovation of the enterprise is equal to the natural logarithm of the number of green patent applications of the enterprise plus 1 |
| Independent variable | *Airpol* | The degree of air pollution is equal to the average value of the air pollution index of the enterprise group in that year |
| Regulating variable | *Debt* | Enterprise credit, equal to the natural logarithm of enterprise long-term loan |
| Control variables | *Fcb* | Equity balance, equal to the ratio of the shareholding ratio of the 2nd-5th largest shareholder to the shareholding ratio of the first largest shareholder |
| | *Size* | Enterprise scale, equal to the natural logarithm of the total assets of the enterprise |
| | *Lev* | Asset liability ratio, equal to net profit / total owner's equity |
| | *Roa* | Return on total assets, equal to net profit / total assets |
| | *State* | Property right attribute: the actual controller of the company is state-owned; the value is 1; otherwise, the value is 0 |
| | *Board* | The size of the board of directors is equal to the natural logarithm of the number of directors of the company |
| | *Indboard* | Proportion of independent directors, equal to the number of independent directors / total number of directors of the company |
| | *Top10* | The shareholding ratio of the top 10 shareholders is equal to the number of shares held by the top 10 shareholders / the total number of shares |
| | *Duality* | If the chairman is concurrently the general manager, the value is 1; otherwise, the value is 0 |
| | *IND* | Industry virtual variable |
| | *YEAR* | Annual virtual variable |

**Table 2.** Descriptive Statistics

| Variable | Observed | average | Standard | Minimum | Maximum |
|---|---|---|---|---|---|
| *AQI* | 17118 | 101.71 | 74.11 | 30 | 351 |
| *GreInoqua* | 17118 | 5.05 | 11.38 | 0 | 83 |
| *GreInodis* | 17118 | 3.95 | 7.88 | 0 | 50 |
| *GreIno* | 17118 | 9.22 | 18.42 | 0 | 132 |
| *Debt* | 17118 | 19.39 | 2.27 | 13.26 | 24.83 |
| *Top10* | 17118 | 59.56 | 15.25 | 24.33 | 93.94 |
| *State* | 17118 | 0.33 | 0.47 | 0 | 1 |
| *Lev* | 17118 | 0.42 | 0.21 | 0.06 | 0.92 |
| *Roa* | 17118 | 0.05 | 0.07 | -0.32 | 0.23 |
| *Duality* | 17118 | 0.29 | 0.46 | 0 | 1 |
| *Board* | 17118 | 8.45 | 1.67 | 5 | 15 |
| *Indboard* | 17118 | 37.70 | 5.37 | 33.33 | 57.14 |
| *Size* | 17118 | 22.19 | 1.33 | 19.73 | 26.24 |
| *Fcb* | 17118 | 0.77 | 0.62 | 0.03 | 2.91 |

The descriptive statistics of the main variables are shown in Table 2.

Air pollution level (Airpol). In this paper, the air quality index (AQI) is selected to measure the air pollution level of the provinces and cities where the enterprises are located. Air quality and air pollution are positively correlated, the larger the index value, the more obvious the negative effect will be.

Enterprise credit level (Debt). This paper chooses the credit level of enterprises as the adjustment variable to measure whether the credit level of enterprises has an impact on air pollution and green innovation of enterprises. The credit level of an enterprise can be measured by the logarithm of its long-term borrowings.

Other control variables. Nine variables reflecting the economic characteristics of enterprises are included. In addition, this paper also introduces industry dummy variable (IND) and annual dummy variable (Year). See Table 1 below for descriptions of relevant variables.

### 3.3 Model setting

Referring to the research on the relationship between air pollution and enterprise innovation by Wang Yuze et al. (2019) , on the basis of theoretical analysis, this paper uses the double fixed effect model of fixed industry and fixed time to conduct regression analysis to test the impact of air pollution on the number of green patent applications of enterprises, as shown below:

$$GreIno=\beta_0+\beta_1 Airpol+\beta_2 Controls+\sum Year+\sum Ind+\varepsilon \quad (1)$$

Among them, $GreIno$ represents enterprise green innovation; $Airpol$ refers to the annual air quality index of each province and city where the company is located; $Controls$ includes 9 control variables that reflect the economic characteristics of enterprises; ε is the error term; At the same time, the virtual variables of industry (IND) and year (YEAR) are also added.

From the perspective of motivation of enterprise green innovation, it can be divided into strategic innovation and substantive innovation, Therefore, this paper sets up models (2) and (3) to test the different effects of air pollution on strategic innovation and substantive innovation of enterprises.

$$GreInodis=\beta_0+\beta_1 Airpol+\beta_2 Controls+\sum Year+\sum Ind+\varepsilon \quad (2)$$

$$GreInoqua=\beta_0+\beta_1 Airpol+\beta_2 Controls+\sum Year+\sum Ind+\varepsilon \quad (3)$$

In addition, this paper discusses whether the credit level of enterprises can play a regulatory effect on the relationship between air pollution and enterprise green innovation. Considering that under the background of the double carbon target, the government will provide relevant policy support and financial subsidies to innovative enterprises, which will promote the improvement of enterprise credit level, this paper builds (4), (5) and (6) models to test whether the improvement of enterprise credit level will play a positive regulatory role on air pollution and the overall level, quantity and quality of enterprise green innovation.

$$GreIno=\beta_0+\beta_1 Airpol+\beta_2 Debt+\beta_3 Debt*Airpol+\beta_4 Controls+\sum Year+\sum Ind+\varepsilon \quad (4)$$

$$GreInodis=\beta_0+\beta_1 Airpol+\beta_2 Debt+\beta_3 Debt*Airpol+\beta_4 Controls+\sum Year+\sum Ind+\varepsilon \quad (5)$$

$$GreInoqua=\beta_0+\beta_1 Airpol+\beta_2 Debt+\beta_3 Debt*Airpol+\beta_4 Controls+\sum Year+\sum Ind+\varepsilon \quad (6)$$

The cross term in the model represents the regulatory effect of enterprise credit level on the relationship between air pollution and enterprise green innovation.

## 4. Empirical test

### 4.1 Benchmark regression analysis

Table 3 shows the regression results of models (1), (2) and (3).The results show that columns (1) and (2) respectively take the quality and quantity of green innovation as the explanatory variables. The estimated coefficient of air quality index obtained under the quantity of green innovation has passed the significance test at the level of 1% and is significantly positive, indicating that serious air pollution will force enterprises to increase the quantity of green innovation, that is, significantly increase the number of green practical patents; As for the quality of green innovation, the aggravation of air pollution will even weaken the number of green invention patent applications of enterprises to a certain extent, which is consistent with the hypothesis H2.The specific reason is that the characteristics of the invention patent itself, such as strict examination and approval procedures, high

costs and long transformation period of research and development achievements, have deterred many small and micro enterprises that are still in the development stage. Although the practical patent has a low level of productivity transformation and poor quality of green innovation technology, it is still favored by more listed enterprises because of its loose application conditions, rapid examination and approval and low costs. Through strategic innovation, enterprises whitewash the surface innovation ability, hoping to meet the environmental regulations, meet the environmental policies, and achieve the requirements of officials' performance. At the same time, they can achieve short-term legal monopoly and obtain scale benefits.

Column (3) takes the total amount of green patent applications of enterprises as the explanatory variable, and the estimated coefficient of the air quality index obtained has passed the significance test at the level of 1%, and is significantly positive, which indicates that air pollution has a positive effect on the green innovation of enterprises, that is, the local air pollution intensifies, and the number of green patent applications of enterprises will increase. The research conclusion supports hypothesis H1.The specific reason is that under the background of double carbon target, the local serious air pollution makes the government formulate more specific environmental regulation measures. The external pressure exerted by environmental regulation on enterprises produces "innovation compensation effect", which forces enterprises to optimize the economic structure and reduce carbon emissions. At the same time, the green subsidy policy provided by the government can also alleviate the plight of enterprises with insufficient green innovation funds, and encourage enterprises to actively carry out green technology innovation Improve the efficiency of technological innovation and increase the number of green patent applications; at the same time, as far as the enterprise itself is concerned, the "expulsion effect" caused by the aggravation of air pollution on human capital will cause the enterprise to lose the core power of technology reserves and technological innovation, and have a negative impact on the enterprise's business performance and production efficiency. For the long-term development of the enterprise, the enterprise executives will take the initiative to improve the green innovation ability by increasing the number of green patent applications of the enterprise and increase the attraction to the high-quality human capital of the city.

**Table 3.** Benchmark regression results

| Variables | (1) *GreInoqua* | (2) *GreInodis* | (3) *GreIno* |
|---|---|---|---|
| *Airpol* | -0.000063 | 0.000563*** | 0.000383*** |
| | (-0.55) | (5.33) | (3.27) |
| *top10* | -0.001164** | -0.000102 | -0.001158** |
| | (-2.21) | (-0.21) | (-2.14) |
| *State* | 0.088805*** | -0.012216 | 0.048051** |
| | (4.79) | (-0.71) | (2.52) |
| *Roa* | -0.201313* | -0.389324*** | -0.352482*** |
| | (-1.83) | (-3.82) | (-3.12) |
| *Duality* | -0.011130 | -0.029785* | -0.027391 |
| | (-0.63) | (-1.83) | (-1.52) |
| *Board* | 0.007901 | 0.008368 | 0.006019 |
| | (1.36) | (1.55) | (1.01) |
| *Inboard* | 0.005204*** | 0.002347 | 0.004188** |
| | (3.06) | (1.49) | (2.40) |
| *Size* | 0.146895*** | 0.124645*** | 0.161140*** |
| | (22.11) | (20.24) | (23.60) |
| YEAR | YES | YES | YES |
| IND | YES | YES | YES |
| Constant | -2.421452*** | -2.678373*** | -2.523793*** |
| | (-14.79) | (-17.65) | (-14.99) |
| Observations | 17,118 | 17,118 | 17,118 |
| R-squared | 0.052 | 0.102 | 0.064 |

### 4.2 Adjustment effect analysis

On the basis of Table 2, this paper further introduces the cross term of air pollution level and enterprise credit level into the model, discusses the adjustment effect of enterprise credit level on the relationship between air pollution and enterprise green innovation, and obtains the regression results in Table 4.Under any regression result, the cross term coefficient of air pollution level and enterprise credit level is negative, and it is significantly negative under the quality of enterprise green innovation, which indicates that the higher the credit level of enterprises, the weaker the incentive of enterprises to improve air pollution through green innovation, that is, the more serious the short-sighted behavior of reducing green innovation investment and green invention patent application. This is contrary to hypothesis H3. The empirical results reject the original hypothesis and conclude that the improvement of enterprise credit level does not have a positive regulating effect on the relationship between air pollution and enterprise green innovation, but will strengthen the negative relationship between them. The reason is that in the economic environment with imperfect system and legal system, the problem of credit rent-seeking has become the main obstacle in the stage of capital allocation. The agent subjectively does not include the enterprise's green innovation activities into the scope of capital allocation, and the enterprise's green innovation activities are restricted .On the other hand, under the pressure of the internal urgent need for funds to change the operating difficulties and government policies, rent-seeking has become a way for enterprises to obtain more financing funds. However, at the same time, the additional costs to be paid have increased the operating costs of enterprises, making enterprises ignore the green innovation with "high investment", "high risk" and "lagging return" and allocate funds to short, medium and fast projects, thus causing a mismatch of financial resources, It suppresses the investment in green innovation of enterprises (Zhen liming, 2019) .

**Table 4.** Regulation effect

| Variables | (1) *GreInoqua* | (2) *GreInodis* | (3) *GreIno* |
|---|---|---|---|
| *Airpol* | 0.003837*** | 0.002087 | 0.003063** |
| | (2.72) | (1.58) | (2.11) |
| *Debt* | 0.014153 | 0.010575 | 0.009658 |
| | (1.50) | (1.20) | (1.00) |
| *Airpol* Debt* | -0.000163** | -0.000049 | -0.000090 |
| | (-2.26) | (-0.72) | (-1.22) |
| *top10* | -0.000242 | -0.000323 | -0.000601 |
| | (-0.32) | (-0.45) | (-0.77) |
| *State* | 0.048176* | -0.051608** | 0.007882 |
| | (1.87) | (-2.15) | (0.30) |
| *Roa* | 0.085965 | -0.072166 | 0.027586 |
| | (0.51) | (-0.46) | (0.16) |
| *Duality* | -0.004324 | -0.019986 | -0.007530 |
| | (-0.16) | (-0.79) | (-0.27) |
| *Board* | 0.010378 | 0.009105 | 0.005175 |
| | (1.28) | (1.20) | (0.62) |
| *Inboard* | 0.005822** | 0.002638 | 0.003873 |
| | (2.42) | (1.17) | (1.56) |
| *Size* | 0.163294*** | 0.141606*** | 0.180554*** |
| | (14.49) | (13.44) | (15.57) |
| YEAR | YES | YES | YES |
| IND | YES | YES | YES |
| Constant | -3.086308*** | -3.074730*** | -3.038455*** |
| | (-11.23) | (-11.97) | (-10.75) |
| Observations | 8,674 | 8,674 | 8,674 |
| R-squared | 0.061 | 0.115 | 0.076 |

# 5. Robustness test

## 5.1 Change the measurement method of independent variables

In this paper, the mass concentration indexes of SO2, NO2 and PM2.5 of the provinces and cities where the enterprises are located (Airpol2) are selected as the measurement method of air pollution status, and the data unit is $\mu g / m^3$, then re tested using the above model. The results show that the regression coefficient of Airpol2 has passed the significance test at the level of 1% under the terms of enterprise green innovation degree and enterprise green innovation quantity, and is still significantly negative under the terms of enterprise green innovation quality, indicating that air pollution will promote enterprises to carry out green innovation, and the aggravation of air pollution in provinces and cities will significantly increase the number of green utility model patent applications but not the number of green invention patent applications; at the same time, the regression coefficients of Airpol2 *debt are all negative, indicating that with the improvement of enterprise credit level, the negative effect between air pollution and enterprise green innovation will be strengthened. This result does not change the main conclusions of this paper.

## 5.2 Change the measurement method of dependent variable

In addition, this paper selects the ratio of the total number of green patents applied by enterprises to the total number of patents (Grelno2) to measure the green innovation strategy of enterprises; the ratio of the number of green utility model patents and invention patents applied by the enterprise to the total number of patents in that year is used to measure the number (Grelnodis2) and quality (Grelnoqua2) of green innovation of the enterprise, and re test how air pollution affects the green innovation of the enterprise and the regulatory effect of enterprise credit level on the two. The empirical results are basically consistent with the previous results.

## 5.3 Add control variables

In order to ensure the robustness of the results, this paper further adds the urban level control variables that may affect the green innovation of enterprises on the basis of the original benchmark regression, the per capita GDP (GDP), which is the most commonly used measure of urban economic development in the existing literature, and the proportion of the second industry(second), which is the measure of urban industrial structure. In addition, according to the research of Xiao Renqiao et al. (2020) , urban infrastructure conditions will affect regional talent gathering, technological exchange and economic and trade cooperation, and then affect enterprise green innovation. Therefore, the control variable of infrastructure perfection (lnfper) is increased. The regression results are consistent with the previous ones.

## 5.4 Exclude samples in 2014

Since 2014 is the first year of systematic monitoring of air pollution, there may be some disadvantages such as incomplete data and strong experimental nature. Moreover, the monitoring and releasing of AQI in China are carried out by regions and batches. Since 2015, national coverage of monitoring points has been implemented. Therefore, this paper excludes the data of 2014 for robustness analysis. The results show that air pollution will significantly increase the number of green patent applications, which is basically consistent with the previous results.

## 5.5 Endogenous problems

The possible causes of endogenous problems in this paper are as follows: First, reverse causality. Air pollution will promote enterprises to carry out green innovation, and the innovation of green technology and the adjustment of production mode will also improve the air pollution situation of the provinces and cities to a certain extent. Second, the relevant explanatory variables may be omitted during the model setting, and the omitted variables have a contemporaneous correlation with the explanatory variables of the model. There are many factors affecting the green innovation of

enterprises and there may still be other factors other than enterprises and cities.Third, there are measurement errors in variables. In this paper, the average value of daily air pollution index in CNRDS database is used to measure the annual air pollution status of the provinces and cities where the enterprises are located, which cannot guarantee the complete accuracy; In addition, the data at the enterprise level are all from the CSMAR database, and there may be manual errors and omissions.

In order to alleviate the endogenous problem, this paper selects instrumental variables to replace the endogenous explanatory variables related to random interference. Referring to the research of Luo Nengsheng et al. (2019) , the paper selects the AQI mean value of surrounding provinces and cities within 175km from the sample enterprise as the instrumental variable of air pollution. The reason is that the pollutants in the air will diffuse due to meteorological conditions and geographical environment conditions, and then affect the air pollution level of the sample provinces and cities, meeting the conditions highly related to the explanatory variable; In addition, there is no direct correlation between the air pollution level of surrounding provinces and cities and the green innovation of enterprises in the sample provinces and cities, which satisfies the exogenous hypothesis. The empirical results are consistent with the benchmark regression results, indicating that after overcoming the endogenous problems, the relevant results maintain good robustness.

## 6. Conclusions and Policy implications

This paper takes the data of all A-share listed companies in China from 2014 to 2019 as a sample to empirically test whether air pollution will affect the green innovation of enterprises, and increase the credit level of enterprises to analyze the regulatory effect of the two. The research finds that: 1) Air pollution will significantly promote enterprises to carry out green innovation, that is, increase the total number of green patent applications; 2)Compared with the quality of green innovation, air pollution has a more obvious role in promoting the number of green innovation, that is, the number of green utility model patents has increased significantly; 3) The improvement of enterprise credit level will strengthen the negative effect between air pollution and enterprise green innovation.

Based on the above conclusions, this paper gives the following policy recommendations:

The government strengthened the control of air pollution. Local governments should give full play to their functional advantages as the main force of air pollution control, making reasonable division of work responsibilities, establishing and improving the supervision and management system in which relevant functional departments perform their respective duties. At the same time, in order to correct the local government's abnormal view of political achievements, a scientific and green assessment system should be taken as an important indicator to comprehensively measure the government's substantive work, so that the government can focus on the ecological benefits brought by ecological projects and projects rather than the inherent benefits, and blindly pursue the government's political achievements.

Enterprises shall earnestly fulfill their social responsibilities and adjust the bad management structure within enterprises, so as to attract high-quality talents to lead enterprises to continuously innovate technologies, improve innovation level, and increase innovation output. In addition, strategic innovation is not a long-term plan. Enterprises should stand on the perspective of sustainable development, pay attention to the difficulty of innovation behavior and the potential value of innovation achievements, and make substantive innovation the main theme of future innovation development of enterprises.

The objectively existing credit rent-seeking behavior in the financial market may not be able to coordinate the balance between the acquisition of financial resources and the financial demand of enterprises, resulting in the mismatch of financial resources. Even though the credit level of enterprises has been improved, the resource input in green innovation has not increased but decreased, and even crowded out and replaced the green innovation of enterprises. Therefore, only by further improving the financial system, stabilizing the financial market, and strengthening financial

supervision can we eliminate the adverse effects of credit rent-seeking arbitrage on green innovation financing of micro enterprises.

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