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AN EMPIRICAL STUDY OF ENTREPRENEURSHIP ON ENVIRONMENTAL POLLUTION: EVIDENCE FROM 30 PROVINCES IN CHINA

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Abstract

The failure of the local government’s regulations on environmental issues has become a pain point for the sustainable development of China's economy. In fact, enterprises are the main cause of environmental pollutant emissions, and entrepreneurship is basis of the decision-making regarding corporate pollution. Therefore the relationship between entrepreneurship and environmental pollution is worthy of in-depth consideration. This paper constructs a general equilibrium model for corporate pollution discharge decisions, and uses the dynamic GMM model to empirically test the relationship between entrepreneurship and environmental pollution in China based on a panel statistics of 30 provinces in China from 2006 to 2017. The study found that: First, entrepreneurship can effectively alleviate China's environmental pollution *problems, and the role of innovative spirit is significant. Second, the effectiveness of entrepreneurship in improving environmental pollution is easily affected by the negative externalities of environmental pollution in adjacent regions. At the same time, local entrepreneurship has certain spatial spillover characteristics, which can encourage entrepreneurs in adjacent regions to imitate that behavior, and thus indirectly improve their environmental pollution problems. Third, in the critical stage of transition from an industrialized economy to a service-oriented economy, the effect of entrepreneurial innovation in improving China's environmental pollution has shown a significant upward trend, while the negative effect of entrepreneurial entrepreneurship on environmental pollution has turned into a positive promoting effect.*

Keywords: regulatory failure, Chinese provinces, entrepreneurship, environmental pollution

INTRODUCTION

Adhering to the path of green development, making up for the "weaknesses" of the ecological environment, and creating a sustainable interaction between environmental protection and economic structural reform are the primary tasks for the sound and rapid development of China's economy. The “2020 Report on the Work of the Government” emphasizes that “we will endeavor to protect our blue skies, clear water and clean lands, and meet the goals for the critical battle of pollution prevention and control”. China's ecological environment has generally improved, but the problem of pollution discharge persists. According to the "2020 Global Environmental Performance Index Report", China's environmental performance index score is 37.3 points, ranking 120th in the world, down 21 places from 2016. Although China's total investment in environmental pollution control has risen year by year, its amount accounts for about 1.2% of GDP, far below the level of developed countries. It is not difficult to find that the efforts made by the central government in environmental protection have not achieved outstanding results (Shen et al., 2017). The reason is that local governments, as the executors of the central government's environmental protection policies, often obtain short-term economic benefits at the expense of destroying the ecological environment, driven by the economic performance evaluation (Li et al., 2014). In fact, the government is only the regulator of environmental issues, and enterprises are the main reason for pollution emissions. In order to pursue profits, enterprises seek loose regulatory behaviors of local governments in their pollution discharge decisions, while local governments relax environmental protection supervision for tax competition, and reach mutually beneficial win-win "private agreements" with enterprises under the national environmental protection framework. The fundamental strategy for preventing and controlling environmental pollution is to strengthen the self-discipline of enterprises in discharging pollutants. The key element is to stimulate the entrepreneurial spirit of environmental protection and encourage them to take the road of innovation-driven green development. This leads to thinking: How does entrepreneurship affect environmental pollution? This paper is of great practical significance in conducting research on this issue.

LITERATURE REVIEW

Entrepreneurship is a multi-dimensional concept, and its core content is mainly the innovation and entrepreneurial spirit of entrepreneurs. Among them, entrepreneurial innovation spirit refers to a quality, the courage to promote technological innovation, organizational innovation and market innovation of enterprises to improve production efficiency, reform business models, expand market space, and ultimately added value of enterprises. Furthermore, the entrepreneurial spirit also refers to an important quality of an entrepreneur seeking to start a business with the spirit of adventure and responsibility to the support and meet social needs and buildup self-value in life. At present, most scholars focus on the research of the relationship between entrepreneurship and regional economic development (Li, et al.,2009; Ma & Tao, 2019), corporate performance (Chen & Wei, 2010; Li, et al., 2019), financial development (Jiang & Teng, 2010; Cheng & Ma, 2019), total factor productivity (Li & Liu, 2020), etc., but there are few studies on entrepreneurship and environmental pollution. In theory, the technological innovation behavior of enterprises produced by entrepreneurial innovation spirit is closely related to the problem of environmental pollution. Technological innovation of enterprises can significantly and positively affect pollutant emissions (Li, et al.,2017). However, there is a certain threshold value for the level of technological innovation. When the level of technological innovation is low, it is often impossible to reduce environmental pollution (Chen, et al.,2019), which further verifies the inverted U-shaped hypothesis of technological innovation and environmental pollution of enterprises (Bai & Nie, 2017). At the same time, technological innovation has different types of pollutant emissions, among which the removal rate of industrial sulfur dioxide is more significant, while the effect on the comprehensive utilization rate of industrial water and industrial solid waste is limited (Wang & Xie, 2014). In addition, because of mutual causality, pollution reduction can also significantly and positively affect technological innovation behavior (Wang, 2014). We believe that the government should not rely on enterprises acting in good faith with regards to active emission reduction. Instead, it should promptly take relevant regulatory measures. The organic combination between policy and entrepreneurship in more efficient in realizing the integration of pollution prevention and cross-media supervision (Barry, 1999). In the absence of environmental regulation policies, corporate technological innovation behavior and pollutant emissions show a positive correlation, while under environmental regulation policies, corporate technological innovation behavior and pollutant emissions begin to show a negative correlation (Huang, et al., 2020). Entrepreneurship is also an effective means of addressing environmental degradation, instead of causing it (York & Venkataraman, 2010). Entrepreneurial behavior is conducive to improving social and environmental conditions (Cohen & Winn, 2007), and environmental resources are an important cause for entrepreneurial spirit (Dean & Mcmullen, 2007).

To sum up, the existing research has achieved a series of results, but there are still shortcomings: First, scholars' explanations of entrepreneurship are too simplistic and general, focused on macroscopic technological innovation behaviors, or focused on vague entrepreneurial behaviors, and do not fully address the essence of entrepreneurship. Second, there is still a lack of strong data demonstration and model explanation. In fact, corporate pollution reduction decisions are affected by many factors. The study of the impact of entrepreneurship on environmental pollution on the basis of controlling other factors needs further consideration. The marginal contribution of this paper lies in the construction of a general equilibrium model of pollutant emissions, the use of dynamic GMM model to empirically test the relationship between entrepreneurship and environmental pollution in 30 provinces in China, and a series of policy recommendations.

RESEARCH DESIGN

Theoretical model analysis

On the basis of the Copeland-Taylor model, and referring to the research ideas of Sheng B. and Lu Y.(2012) , a general equilibrium model including government control, output decisions and corporate pollutant discharge decisions is reconstructed to analyze the general linear relationship between entrepreneurship and environmental pollutant emissions.

Basic assumption

Assuming that the production mode of representative enterprises satisfies the characteristics of constant returns to scale, and there are only two inputs of capital and labor, according to the form of the Cobb-Douglas production function, we see:

$$P(K, L) = K^{\theta} L^{1-\theta} \quad (1)$$

We set up representative enterprises to produce two kinds of products: One is a green product *Y*, the production process does not emit pollutants; The other is the capital-intensive polluting product *X*, which emits pollutants *G* during the production process, which is bound to have a negative impact on society and the economy, resulting in a certain social cost. On the basis of clearly defined property rights and division of responsibilities, enterprises must pay opportunity costs σ such as pollution discharge fees, environmental taxes, and pollution discharge permit rights. In the process of pursuing profit maximization, arbitrarily discharging pollutants is not the optimal production choice. Instead, enterprises should dedicate some production resources to control pollutant emissions. Suppose that μ accounts for the proportion of all production resources spent on pollution control by enterprises. Then $0 \leq \mu \leq 1$. When μ=0, it means that the enterprise does not control pollution discharges, therefore the enterprise obtains potential output P . When $\mu \neq 0$, it means that the enterprise spends μ *resources* for pollution control , therefore the enterprise obtains the output of $(1-\mu)P$ and pollutant G is discharged concurrently as follows:

$$X = (1-\mu)P \qquad (2)$$

$$G = \varphi(\mu)P \qquad (3)$$

$$\varphi(\mu) = \frac{1}{T}(1-\mu)^{1/\theta} \qquad (4)$$

Where $\varphi(\mu)$ is the reduction function of pollution emissions with respect to μ. T represents the production technology which is the θ parameter, with a value between 0 and 1. According to the constant return to scale Cobb-Douglas, the production function form is as follows:

$$X = (1-\mu)P(K_X, L_X) \qquad (5)$$

$$G = \varphi(\mu)P(K_X, L_X) \qquad (6)$$

Among them, K_X and L_X represent the capital factor input and labor factor input of production X, respectively. Finally, according to (4), (5) and (6), the production functions of G and X can be represented as follows:

$$G = \frac{1}{T}(1-\mu)^{1/\theta}P(K_X, L_X) \qquad (7)$$

$$X = (TG)^{\theta}[P(K_X, L_X)]^{1-\theta} \qquad (8)$$

Enterprise production decision

From (8), it can be seen that the two core elements that determine the production of product X are pollutant G and the potential output P. Therefore there are two main approaches in the decision-making process of pursuing profit maximization: One is to choose the optimal ratio of capital input k and labor input l to control the the potential output P *and the unit production cost* c_p. The second is to select the combination of the optimal pollutant G and the potential output P on the basis of the given pollution opportunity costs σ and c_p to control the unit production cost c_x of the product X. The second is to control the unit production cost c_X of product X by selecting the optimal combination of pollutant G and potential output P on the basis of the established pollution opportunity cost σ and c_P. It is set as follows:

$$c_P(k,l) = min\{ka_{KP} + la_{LP}, P(a_{KP}, a_{LP}) = 1\} \quad (9)$$

$$c_X(\sigma, c^P) = min\{\sigma TG + c^P P, (TG)^\theta P^{1-\theta} = 1\} \quad (10)$$

In the above formula (9), a_{KP} and a_{LP} respectively represent the capital input and labor input of the unit potential output P, and the first-order premise to satisfy the above (9) is that the marginal rate of technical substitution TRS_{KL} is equivalent to the ratio of labor input l to capital input k, which is set as follows:

$$TRS_{KL} = \frac{\partial P}{\partial K_P} / \frac{\partial P}{\partial L_P} = l/k \quad (11)$$

Finally, the first-order optimal solution of (10) is solved as follows:

$$\frac{(1-\theta)TG}{\theta P} = \frac{c^P}{\sigma} \quad (12)$$

Enterprises' decisions regarding the sewage

If the unit price of product *X* is P_X, assuming that the market is perfectly competitive, the total revenue of the enterprise is equal to the total cost, and the following equivalence relationship can be represented as follows:

$$P_X X = c_P P + \sigma T \quad (13)$$

From (12) and (13), the total amount *G* of pollutant discharge can be represented as follows:

$$G = \frac{P_X X \theta}{\sigma T} \quad (14)$$

When $S = P_X X + P_Y Y$ represents the total production scale of the enterprise, and $\gamma = P_X X/(P_X X + P_Y Y)$ represents the production structure of the enterprise, then the total pollutant discharge *G* of the enterprise can be represented as follows:

$$G = \frac{S\gamma\theta}{\sigma T} \quad (15)$$

It can be seen from (15) that the four influencing factors of the enterprise's pollution discharge decisions are the output scale, output structure, pollution discharge cost and the level of technology. Finally, considering the logarithm of (15), there are:

$$lnG = lnS + ln\gamma + ln\theta - ln\sigma - lnT \quad (16)$$

The refinement of environmental protection technology mainly relies on independent R&D innovation and on technology introduction. The intrinsic motivation of independent R&D innovation drives the entrepreneurial spirit. If entrepreneurs truly comprehend the concept of green development, then in the process of pursuing profit maximization, they will strengthen their willingness to save energy and reduce emissions, give full play to the power of process innovation, increase investment in R&D , and reduce pollution control costs. Technology introduction is an important step for enterprises to incorporate technology, mainly relying on actual foreign direct investments. Therefore, the technical level function can be rewritten as follows:

$$lnT = \alpha_0 + \beta_1 lnE + \beta_2 lnfdi + \beta_3 lnrd + \varepsilon \qquad (17)$$

In (17), α_0 represents a constant. $\beta_i (i = 1,2,3) > 0$. ln*E* represents the logarithm of entrepreneurship. ln*fdi* represents the logarithm of technology introduction. ln*rd* represents the logarithm of R&D investment intensity. ε represents the random disturbance term. Finally, according to (16) and (17), $\omega_0 = ln\theta - \alpha_0$, ζ=-ε, the general linear model of entrepreneurship and pollution emissions can be obtained as follows:

$$lnG = \omega_0 + lnS + ln\gamma - ln\sigma - \beta_1 lnE - \beta_2 lnfdi - \beta_3 lnrd + \zeta \qquad (18)$$

It can be seen from (18) that entrepreneurship, foreign direct investment, and independent R&D can negatively affect the emission of environmental pollution, while the scale and structure of industrial output positively affect the emission of environmental pollutants.

Econometric Model Construction

According to the foregoing, the basic econometric model constructed in this paper is as follows:

$$lnP_{it} = \alpha_0 + \beta_1 lnEI_{it} + \beta_2 lnES_{it} + \beta_3 lnX_{control} + \varepsilon_{it} \qquad (19)$$

Where P_{it} represents the pollutant emissions of i province in t year. EI_{it} represents the entrepreneurial innovation in i province and in t year. ES_{it} represents the entrepreneurial spirit in province i and in t year. $X_{control}$ represents a series of control variables. α_0 represents a constant term. $\beta_i (i = 1,2)$ represents the estimated coefficient of the explanatory and control variables. μ_i represents the individual fixed effect of unobservable provinces. ε_{it} represents the random disturbance term.

Variable setting

Explained variable

General environmental pollutants mainly include industrial waste water, industrial waste gas and industrial solid waste, referred to as the industrial "three wastes". Existing literature has not yet formed a unified approach for the measurement of pollutant emissions. Some scholars have constructed a comprehensive index of environmental pollution for accounting (Xu & Deng, 2012), and some scholars have used a single index to conduct research (Yang, 2015; Jin & Wu, 2017). Although the comprehensive index of environmental pollution fully considers the diversity of pollutants, it shows more of the relative degree of pollutant emissions, rather than the absolute emission scale, and the strength of different pollutant emissions' is too subjective and one-sided. In addition, it makes more sense to use a single indicator to evaluate the scale of pollutant emissions. Considering that recently China's air pollution has reached a serious point, and that sulfur dioxide is the main pollutant of energy consumption and is an important cause of air pollution, in addition, the available data is thorough and easy to obtain, therefore this paper uses per capita industrial sulfur dioxide emissions (ln*SD*) to measure the degree of environmental pollution. Other variables are used for robustness testing.

Explanatory variable

Entrepreneurship is an intangible factor of production and the inner essence of an entrepreneur's ability to achieve enterprise management. Therefore, this paper mainly measures explanatory variables from the perspectives of innovation and entrepreneurial spirit. The connotation of entrepreneurship is a definition of micro-category. Enterprises are an important pillar of economic and social development. More and more scholars focus on measuring entrepreneurship from a macro perspective. Macro data indicators are, to a certain extend, the result performance of micro data (Li et al, 2009). First of all, patents are the product of corporate innovation activities. They reflect the entrepreneur's innovation cognition and intellectual property awareness, and are thus an important manifestation of the entrepreneurial innovation spirit. They are used by most scholars to measure the entrepreneurial innovation (Li, 2011). But because patent granting is relatively slow and easily affected by review mechanisms, it cannot reflect the most recent corporate innovation activities. Therefore, this paper uses the number of patent applications per 10,000 people (ln*EI*) to measure the entrepreneurial innovation. Secondly, entrepreneurial spirit is the intrinsic motivation for entrepreneurs to start businesses, practice emerging business models, and improve business management strategies. With the advent of the entrepreneurial boom, private enterprises have become the "strong engine" to promote social and economic development, and entrepreneurial spirit has been fully reflected in the scale of private enterprises. Scholars have represented the entrepreneurial spirit through indicators such as the number of employees in private enterprises and the number of private enterprise households (Li, 2013). Considering the availability and accuracy of data and the entrepreneurial vitality of entrepreneurs in a certain year in a certain region, the new value is more than the absolute scale, so this paper uses the number of new private enterprises (ln*ES*) to describe the entrepreneurial spirit.

Control variables

Generally speaking, the factors affecting environmental pollution are relatively complex. In order to ensure the consistency and stability of the estimated results, the following control variables are set in this paper: (1) Output scale (scal), represented by industrial added value per capita (employees). (2) Industry structure (indu), represented by the proportion of the added value of the secondary industry. (3) Government intervention (gove), represented by the proportion of industrial governance investment in GDP. (4) Technology introduction (fdi), represented by the proportion of actual foreign direct investment in GDP. (5) R&D intensity (rd), represented by the proportion of R&D expenditure of industrial enterprises in the main business income. (6) Urbanization rate (urba), represented by the proportion of urban population to the total population. (7) Population density (popu), represented by the ratio of resident population to administrative area. (8) Economic development (gdp), represented by real GDP per capita.

Data source description

The research object of this paper is 30 provinces in China (due to the serious lack of data in Tibet, Hong Kong, Macau and Taiwan of China, they were excluded), and the study time span considers 2006-2017. During this period, China's economy was in the stage of transition from industrialization to service industry. Entrepreneurship plays an important role, and the environmental quality is getting better and better, so it is worth doing research. The data come from China Environmental Yearbook, China Statistical Yearbook, China Science and Technology Statistical Yearbook and EPS database. In order to eliminate heteroscedasticity, all variables were turned into logarithms in order to enter the measurement equations. The specific descriptive statistical analysis is shown in Table 1.

Table 1 Descriptive statistical analysis of variables

Category	Variable	Symbol	Mean	Std. dev.	Minimum	Maximum
Explained variable	Per capita industrial sulfur dioxide (SO_2) emissions	ln*SD*	5.3136	0.8496	1.1142	7.1828
Explanatory variables	Patent applications per 10,000 people	ln*EI*	2.3296	1.2047	0.0087	5.0435
	The number of new private enterprises	ln*ES*	1.2285	1.1772	-3.2189	4.2348
Control variables	Output scale	ln*scal*	0.8405	0.6035	-0.9796	2.0882
	Industry structure	ln*indu*	3.8229	0.2114	2.9452	4.1190
	Government intervention	ln*gove*	0.2006	0.4681	-1.2069	1.4425
	Technology introduction	ln*fdi*	0.4527	1.0179	-3.2545	2.1031
	R&D intensity	ln*rd*	-0.3867	0.4630	-2.8453	0.4489
	Urbanization rate	ln*urba*	3.9498	0.2450	3.3125	4.4954
	Population density	ln*popu*	5.4361	1.2720	2.0264	8.2496
	Economic development	ln*gdp*	9.8781	0.4945	8.6634	11.1633

ANALYSIS AND RESULTS

Benchmark Estimate Analysis

First, this paper uses fixed-effects and random-effects models to carry out the statical analysis of the econometric model (19). Second, endogeneity problems arise due to the possible reverse causal relationship between entrepreneurship and environmental pollution. In order to solve the endogeneity problem, this paper incorporates the explanatory variables into the explanatory variables with a one-period lag to form dynamic panel data, and then uses the generalized method of moments (GMM) to estimate the econometric model (19). The GMM method is a method for estimating model parameters through moment conditions. Since this method does not need to determine the exact distribution of random error terms, it can allow heteroscedasticity and serial correlation of random error terms. Assumptions are relatively loose, so the estimation efficiency is high, consistent and unbiased, which can effectively alleviate the endogeneity problem. Common GMM estimation methods include Differential GMM (DIFGMM) and System GMM (SYSGMM). In order to ensure the stability of the estimation results, this paper adopts the DIFGMM method and the SYSGMM method to carry out dynamic estimation respectively (Table 2).

Table 2 Estimated results of the impact of entrepreneurship on environmental pollution

Variables	POOL	RE	FE	DIFGMM	SYSGMM
L1.ln*SD*				1.0315^{***}	0.8610^{***}
				(15.3837)	(22.4010)
Ln*EI*	-0.3159^{***}	-0.2454^{***}	-0.2175^{***}	-0.4156^{***}	-0.2131^{***}
	(-6.0261)	(-3.5477)	(-2.7039)	(-5.2672)	(-4.1947)
Ln*ES*	-0.1851^{***}	-0.0989^{***}	-0.0717^{*}	-0.0492^{***}	-0.0554^{***}
	(-5.4307)	(-2.7142)	(-1.8644)	(-3.5854)	(-4.2452)
Ln*scal*	0.1177	-0.4678^{***}	-0.7777^{***}	0.3030	0.1836
	(0.8050)	(-3.0392)	(-3.6477)	(0.9117)	(1.5822)
Ln*indu*	2.0908^{***}	2.6214^{***}	2.3193^{***}	0.8181^{**}	0.7835^{***}
	(6.8976)	(10.4841)	(7.2498)	(2.4306)	(3.1539)
Ln*gove*	0.3367^{***}	0.2173^{***}	0.1537^{**}	0.0601	0.2140^{***}
	(5.4328)	(3.5588)	(2.3543)	(1.5504)	(7.4672)
Ln*fdi*	-0.2126^{***}	-0.1329^{***}	-0.0947^{**}	-0.0741^{***}	-0.0367
	(-5.4916)	(-3.1163)	(-2.0639)	(-2.7425)	(-1.2399)
ln*rd*	0.1673^{**}	-0.0359	-0.0692	-0.2031^{***}	-0.1293^{***}
	(2.4756)	(-0.4990)	(-0.8445)	(-3.4333)	(-3.4459)
ln*urba*	0.2960	0.8665^{*}	0.8656	1.4461^{*}	-0.0980
	(0.6927)	(1.9169)	(1.4048)	(1.7285)	(-0.1373)
ln*popu*	-0.0011	-0.1221^{*}	-1.5871^{**}	1.3079	0.1360^{**}
	(-0.0288)	(-1.8816)	(-2.3845)	(1.1819)	(2.3939)
ln*gdp*	0.4023^{***}	0.7192^{***}	1.7788^{***}	0.0224	0.3173
	(2.6793)	(3.2118)	(3.8861)	(0.0305)	(1.2477)
constant	-6.8586^{***}	-13.4810^{***}	-14.6813^{**}	-15.7996	-5.5196
	(-2.7010)	(-5.4284)	(-2.0980)	(-1.1557)	(-1.5688)
AR(1)				0.0051	0.0072
AR(2)				0.3832	0.8152
Sargan test				0.9999	1.0000

In the table 2, the coefficients in brackets are *T* values. *, ** and *** represent the significance levels of 10%, 5% and 1%, respectively; AR(1), AR(2) and Sargan tests report P values; *POOL* represents mixed regressions, *RE* represents random effect, *FE* represents fixed effect; L_1. represents the explained variable lags one period. The following table is similar to this and will not repeat the description.

The know that the GMM estimates are consistently valid provided that there is no second-order or higher-order autocorrelation in the differences of the disturbance term, and that the instrumental variables are strictly exogenous and that there is no over-identification. Therefore, in this paper, the Arellano-Bond sequence autocorrelation test and Sargan over-identification test are carried out on the estimation results of DIFGMM and SYSGMM in Table 2. The results show that the P value of AR(1) is less than 0.1 and that the P value of AR(2) is greater than 0.1, indicating that there is only a first-order autocorrelation but no second-order or higher-order autocorrelation in the difference of the disturbance term. Sargan's over-identification test P value is 1.000, which is much larger than 0.1, indicating that all instrumental variables are valid and there is no over-identification problem. Therefore, the estimation results of DIFGMM and SYSGMM are consistent, effective and stable.

The results in Table 2 show that, the estimated coefficient of per capita industrial SO2 emission lag for the first period is significantly positive, indicating that the current per capita industrial SO2 is easily affected by the previous per capita industrial SO2 emission, indicating that per capita industrial SO2 emission has a certain cycle path dependence, therefore it makes more sense to use dynamic panel analysis. Judging from the results of the core explanatory variables, entrepreneurial innovation and entrepreneurship show a significant negative correlation with per capita industrial SO2 emissions, and that the negative intensity of the innovation spirit is greater, which indicates that entrepreneurial innovation and entrepreneurship can effectively alleviate the problem of environmental pollution. The reasons may be as follows: First, the entrepreneur's effective innovative spirit is the premise of the decision-making of enterprises' innovative behavior, which will guide enterprises to optimize the production process, manufacturing process and resource allocation of production services, develop green production technology, and improve the disposal and recovery rate of waste gas, to further reduce production costs and control the discharge of environmental pollutants from the source, which is conducive to alleviating environmental pollution problems; second, limited by the impact of entrepreneurial thresholds and market access mechanisms, the entrepreneurial spirit led by small and medium-sized enterprises is undoubtedly an important engine for expanding the private economy and optimizing the structure of emerging markets. It can effectively promote the transformation of traditional industries into emerging service industries, achieve supply-side structural reform of products, technologies and production capacity, vigorously promote pollution reduction, and improve air quality.

As for other control variables, since the SYSGMM method combining the differential matrix and the horizontal matrix can effectively solve the problem that DIFGMM may have with weak instrumental variables, the results are more reliable. Therefore, this paper mainly analyzes the estimated results of SYSGMM. The results show that: (1) There is a positive correlation between the output scale and per capita industrial SO2 emissions, indicating that the current industrial scale output in China is unreasonable. Blind and inefficient expansion of production not only aggravates the consumption of production resources, wastes more production costs, but also leads to a large number of environmental pollutants, causing serious environmental pollution problems. (2) The impact of industrial structure on per capita industrial SO2 emissions is significantly positive, indicating that the traditional industry-led secondary industry has intensified the consumption of energy such as coal, which will lead to serious environmental pollution problems. Therefore, optimizing industrial structure is very important for environmental pollution control. (3) Government intervention has a significant positive impact on per capita industrial SO2 emissions, indicating that the Chinese government's air control effect is not ideal at this stage. The main reason is that the government's inefficient investment in air control is quite common. Aggregating areas with heavy air pollution and ignoring areas with light air pollution will eventually lead to the rapid spread of environmental pollution, presenting the paradox of "more pollution will become more pollution". (4) Technology introduction can significantly negatively affect per capita industrial SO2 emissions, indicating that expanding foreign investment will be conducive to the international spillover of environmental protection production technology, which can drive the improvement of enterprises' green production technology and effectively alleviate China's environmental pollution problems. (5) The negative impact of R&D intensity on per capita industrial SO2 emissions indicates that with the increase of independent R&D funds, there is a higher possibility for Chinese enterprises' green technology innovation, which will drive the reduction of pollutant emissions. (6) Urbanization has a negative impact on per capita industrial SO2 emissions, but it is not significant. The possible reason might be that China is currently in the stage of new urbanization layout, therefore the new approach of intensive and sustainable development has alleviated environmental problems caused by the expansion of urbanization. (7) Population density has a positive impact on per capita industrial SO2 emissions, indicating that China's regional population density is relatively high, and private vehicles such as automobiles are over-aggregated. At the same time, it also drives the cluster development of the catering industry and construction industry, causing serious environmental pollution problems. (8) Economic development positively affects per capita industrial SO2 emissions and the 10% significance probability test indicates that China's economic development has not yet crossed the inflection point of the EKC curve, and that the negative environmental externalities brought about by economic development have not been effectively alleviated.

Robustness Analysis

In order to ensure the accuracy and stability of the conclusions of this paper, this paper mainly carries out the robustness tests from the following two methods: First, the explanatory variables are replaced. The discharge of industrial waste water (ln*WW*) is selected as the explanatory variable to carry out the estimation analysis again. Second, the core explanatory variables are recalculated. We re-measured the entrepreneurial spirit of innovation by the proportion of the sales revenue of new industrial products to the main business income. And re-measure the entrepreneurial spirit by the proportion of the number of private enterprises and individual employees to the total number of employees. The estimated results are shown in Table 3.

Table 3 *Robustness* test estimation results

Variables	(1)	(2)	(3)	(4)
L1.ln*SD*/L1.ln*WW*	0.8017***	0.8723***	0.8907***	0.8566***
	(8.9003)	(20.5217)	(14.8077)	(15.9682)
ln*EI*	-0.3238***	-0.0691	-0.2625***	-0.0403
	(-3.4169)	(-0.9466)	(-4.8846)	(-1.1427)
ln*ES*	-0.0262	-0.0451***	-0.1873	-0.4627***
	(-1.3042)	(-2.6282)	(-0.8765)	(-2.6779)
ln*scal*	0.5300***	-0.1820	0.0674	0.0648
	(2.5945)	(-1.2425)	(0.3090)	(0.2829)
ln*indu*	-0.2305	0.9056***	0.6685**	0.3741
	(-0.7309)	(3.1916)	(1.9673)	(0.7545)
ln*gove*	0.0804***	0.1729***	0.2127***	0.1734***
	(2.9674)	(4.9894)	(8.5621)	(5.9457)
ln*fdi*	-0.0578***	-0.0546*	-0.0251	-0.0538**
	(-2.7537)	(-1.8552)	(-0.8090)	(-2.0906)
ln*rd*	-0.0850**	-0.1843***	-0.1044	-0.1855***
	(-2.0880)	(-3.0450)	(-1.6377)	(-3.6278)
ln*urba*	0.0068	-0.8466*	0.6720	-0.5424
	(0.0143)	(-1.7198)	(0.7928)	(-1.0409)
ln*popu*	0.2460***	0.1053***	0.4699	-0.0748
	(2.7530)	(2.8480)	(0.7918)	(-0.2105)
ln*gdp*	-0.1034	0.5537***	0.5210	0.3761
	(-0.3209)	(3.4961)	(0.8859)	(0.7725)
constant	1.4178	-5.2971*	-11.3752	-0.5338
	(0.6237)	(-1.9426)	(-1.2280)	(-0.0900)
AR(1)	0.0002	0.0073	0.0054	0.0080
AR(2)	0.9746	0.1003	0.9785	0.1900
Sargan test	1.0000	1.000	1.000	1.000

In Table 3, (1) is the estimated result obtained after replacing the explanatory variable. (2) is the estimated result obtained after replacing only the explanatory variable of entrepreneurial innovation spirit indicator. (3) is the estimated result obtained after replacing only the explanatory variable of entrepreneurial spirit. (4) is the estimated result obtained after replacing the explanatory variable of the entrepreneurial innovation spirit and the entrepreneurial spirit respectively. The results show that there is no second-order autocorrelation in the SYSGMM disturbance term difference and that the instrumental variables are relatively stable. Although the significance level and the regression coefficient of the main core explanatory variables have changed, the direction of action remains the same, which further verifies the robustness of the conclusions of this paper.

Re-examination based on spatial effects

Considering the spacial nature of entrepreneurship affecting environmental pollution, entrepreneurship in a certain region may drive the imitation behavior of entrepreneurs in adjacent regions and have a certain impact on environmental pollution. This paper uses the spatial error model (SEM) and the spatial lag model (SLM) to analyze the static and dynamic characteristics of the impact of entrepreneurship on environmental pollution (Table 4).

Table 4 Estimation results based on re-testing of spatial effects

Variables	Static analysis		Dynamic Analysis	
	(1)	(2)	(3)	(4)
L1.ln*SD*			0.6556*** (9.9780)	0.6507*** (12.8411)
ln*EI*	-0.0550 (-0.9434)	-0.1282** (-2.2101)	-0.1074** (-2.0194)	-0.1135** (-2.2987)
ln*ES*	-0.0422 (-1.4903)	-0.0463* (-1.6731)	-0.0524* (-1.9402)	-0.0520** (-2.1787)
Spatial effects of variables	0.9105*** (39.2348)	0.6869*** (16.0549)	0.5290*** (6.8303)	0.4864*** (10.3905)
Spatial direct effect of ln*EI*		-0.1420** (-2.1215)		-0.1209** (-2.4286)
Spatial indirect effect of ln*EI*		-0.2699* (-1.9478)		-0.1055** (-2.2037)
Total spatial effect of ln*EI*		-0.4119** (-2.0431)		-0.2264** (-2.3794)
The spatial direct effect of ln*ES*		-0.0535* (-1.7798)		-0.0518** (-2.1643)
Spatial indirect effect of ln*ES*		-0.1023* (-1.6759)		-0.0450** (-1.9995)
Total spatial effect of ln*ES*		-0.1558* (-1.7364)		-0.0968** (-2.1257)
Control variables	YES	YES	YES	YES
R^2	0.1597	0.6125	0.7729	0.8194

In Table 4, since dynamic spacial models are often able to correct the deviation of static spacial models by separating the potential spacial factors, this paper mainly takes the estimated results of the dynamic spacial model as the criterion. The results in Table 4 show that the spatial effect coefficients of the variables all passed the 1% significance level probability test, indicating that environmental pollution has a certain spatial dependence. Under the premise of considering this spatial dependence, entrepreneurship can still negatively affect environmental pollution, indicating that entrepreneurship can improve environmental pollution, but it is easily affected by the negative externalities of environmental pollution in adjacent areas, and its effect changes. At the same time, local entrepreneurship can drive the model behavior of entrepreneurs in adjacent regions, which in turn indirectly affects environmental pollution in adjacent regions, resulting in a certain spatial spillover.

Re-examination based on the stage of economic development

Driven by technological innovation and industrial structure upgrading, China's economy is in the transitional stage of power transformation from an industrial economy to a service economy, and the quality of the ecological environment is showing a continuous improvement. Is there a difference in the impact? This issue requires further analysis. According to the proportion of China's secondary and tertiary industries, the stages of economic development are divided into two parts: industrialization and servitization. If the proportion of the secondary industry is higher than that of the tertiary industry, it indicates that the Chinese economy is in the stage of industrialization; if the proportion of the tertiary industry is higher than that of the secondary industry, it indicates that the Chinese economy is in the stage of servitization. According to statistical data, the proportion of China's tertiary industry has exceeded that of the secondary industry since 2012. Combined with the research time span, this paper defines 2006-2011 as the development stage of industrialized economy, and 2012-2017 as the development stage of service-oriented economy. The estimated results are shown in Table 5.

Table 5 Estimated results based on re-examination of economic development stage

Variables	Stage of industrialized economic development			Stage of service-oriented economy development		
	(1)	(2)	(3)	(4)	(5)	(6)
L1.ln*SD*		0.9894***	1.0127***		0.7738***	0.5332***
		(11.9163)	(24.0652)		(8.5432)	(8.6490)
ln*EI*	-0.0725	-0.0163	-0.0210	-0.2392	-1.5532***	-0.3182**
	(-1.6494)	(-0.5176)	(-0.6052)	(-1.3320)	(-7.8992)	(-2.3239)
ln*ES*	-0.0449**	-0.0616***	-0.0591***	0.1132	0.0152	0.3127***
	(-2.1350)	(-4.7600)	(-3.9188)	(1.5779)	(0.3283)	(4.7365)
Control variables	YES	YES	YES	YES	YES	YES

AR(1)	0.0562	0.0885	0.0156	0.0097
AR(2)	0.7855	0.9426	0.4506	0.6495
Sargan test	0.3079	0.9784	0.2785	0.9112

Table 5…

The results in Table 5 show that during the transition period of China's economy from the stage of industrialization to the stage of servitization, the role of entrepreneurial innovation in improving environmental pollution has shown a significant upward trend, while the negative effect of entrepreneurial spirit on environmental pollution has reversed into a positive promotion effect. The reasons might be as follows: First, with the rapid development of the knowledge economy and science and technology, China's innovation-driven development strategy has strengthened the innovative spirit of entrepreneurs, thereby triggering green production behaviors of enterprises, enabling enterprises to promote energy conservation and emission reduction, and continuously improve the effectiveness of environmental governance. Secondly, in the stage of industrialization, giving full play to the entrepreneurial spirit is a "strong engine" to increase the scale of private enterprises and optimize market structure, so as to achieve production capacity conversion and industrial structure upgrading, and effectively alleviate structural pollution. When the industrial economy is gradually transitioning to a service economy, the scale expansion of private enterprises leads to a marginal decrease in the environmental governance effect of market structure and production capacity conversion. At the same time, the disorderly expansion of private enterprises aggravates the loss of production resources. Therefore, the actual performance of entrepreneurial spirit may lead to certain environmental pollution. Hence, along with the structural transformation of the economic development mode, the connotation of entrepreneurship should be rationally considered.

CONCLUSIONS AND IMPLICATIONS

Based on the general equilibrium model of corporate pollution decision-making, using a panel statistics from 2006 to 2017 in 30 provinces in China, and using the dynamic GMM method to empirically test the impact of entrepreneurship on environmental pollution, this paper found that: (1) The relationship between entrepreneurship and environmental pollution presents a significant negative correlation and the greater negative strength of innovation spirit indicate that entrepreneurship can effectively alleviate the problem of environmental pollution. (2) Considering spatial dependency, the effectiveness of entrepreneurship in improving environmental pollution is affected by the negative externalities of environmental pollution in adjacent regions. At the same time, the local entrepreneurship can drive the imitation behavior of entrepreneurs in adjacent areas, and then indirectly affect the environmental pollution problems in adjacent areas. (3) China is in a transition period from an industrialized economy to a service-oriented economy. The role of the domestic innovation spirit in improving environmental pollution showed a significant upward trend, while the negative effect of entrepreneurial spirit on environmental pollution has reversed into a positive promotion effect.

According to the research conclusions, this paper puts forward four policy suggestions:

Firstly, create a good social environment and stimulate the enthusiasm of entrepreneurs for innovation and entrepreneurship. There is a need to optimize the legal environment that protects the legitimate business rights and interests of entrepreneurs, creating a fair, orderly, and fully effective market competition environment, creating an encouraging environment that tolerates failure and rewards achievements, and improving the services provided by the government. The spirit of innovation and entrepreneurship is rooted in fertile soil.

Secondly, the Chinese government needs to introduce supportive policies to encourage entrepreneurs to accelerate the pace of innovation and entrepreneurship. On the one hand, it is necessary to have loose financial policies, lower the threshold for innovation and entrepreneurship loans, and ensure that entrepreneurs' innovation and entrepreneurship funds are guaranteed. On the other hand, it is necessary to implement preferential fiscal and tax policies to reduce the fiscal and tax burden of innovation and entrepreneurship of small and medium-sized enterprises. At the same time, it is necessary to optimize a series of policies such as intellectual property rights and personnel training.

Thirdly, vigorously enhance entrepreneurs' awareness of innovation and entrepreneurship. Entrepreneurs are the backbone of social innovation and entrepreneurship activities. The key to cultivating entrepreneurial spirit is that entrepreneurs themselves need to strengthen their sense of urgency for innovation and entrepreneurship, actively cultivating their awareness of innovation and entrepreneurship, and constantly expanding their international vision. Be innovative, dare to start a business, invest energy and financial resources to seek development through innovation, and seek the improve future through entrepreneurship.

Fourthly, strengthen supervision and prevent entrepreneurial innovation and entrepreneurship risks. In order to encourage and promote the spirit of entrepreneurship, regulatory authorities at all levels should pay attention to the financial supervision of entrepreneurs' innovative and entrepreneurial activities, effectively control the risks of capital operation, and at the same time focus on the supervision of entrepreneurs' compliance operations, and urge entrepreneurs to improve their companies, build a governance system, perform social responsibilities, strengthen the disclosure of various business information, and accept external supervision by the public.

LIMITATIONS

The empirical research of this paper has the following limitations: First, scholars generally use enterprise data to represent entrepreneurship. However, this paper uses regional data to analyze the impact of entrepreneurship on environmental pollution, which lacks differential analysis of enterprises. Second, this paper analyzes the direct impact of entrepreneurship on China's environmental pollution, but does not explore the reasons and paths. Third, there is no analysis of the impact of foreign companies on Chinese companies' pollution emissions. In conclusion, this research has the possibility of further expansion.

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