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Research on the Impact of Environmental Regulation Intensity on China's Manufacturing Export Green Technology Innovation

Yilin Wei

Beijing University of Technology, Beijing, 100124, China

ABSTRACT

With the proposal of China's "double carbon" goal and the implementation of international environmental policies such as the EU's carbon border regulation mechanism, manufacturing enterprises are under certain transformation pressure at this stage. The traditional view is that strict environmental regulation will increase the cost of enterprises and weaken their international competitiveness, while the "Porter Hypothesis" claims that appropriate environmental policies can stimulate the compensation effect of innovation and enhance long-term competitiveness. Based on the analysis of existing studies, it is found that the current focus is on developed economies or closed markets, and there is still a lack of systematic discussion on China's green innovation response mechanism under the condition of open economy, especially the non-linear impact of environmental regulation intensity and the heterogeneity of enterprises have not been fully verified. Based on this, this paper carries out relevant research on the impact of environmental regulation intensity on China's manufacturing export green technology innovation, for reference.

KEYWORDS

Chinese manufacturing industry; Export; Environmental regulation intensity; Green technology

1 Introduction

This study fills the existing gap from the theoretical and empirical levels. In theory, the U-shaped relationship hypothesis between regulation intensity and innovation performance is proposed. Empirically, based on the micro data of Chinese manufacturing enterprises, this paper identifies the threshold effect and regulatory factors of environmental regulation on green innovation, and provides the basis for policy-making. At the practical level, the research conclusion is helpful to optimize the design of China's environmental regulation policy, balance the pressure of short-term emission reduction and the goal of long-term technology upgrading, and provide reference for developing countries to realize industrial transformation under green trade barriers.

2 Research design

2.1 Measurement model construction

This study uses a dynamic panel model to capture the nonlinear impact of environmental regulation on green technology innovation of export enterprises. The benchmark regression is set as the extended Cobb -Douglas production function：

$$GTIit=\alpha+\beta 1ERit+\beta 2ERit2+\gamma Xit+\delta(ERit\times Exportit)+\mu i+\lambda t+\varepsilon it$$

Among them, the explained variable GTI_{it} is the amount of green patent applications of enterprises i in the t period, the core explanatory variable ER_{it} the intensity of environmental regulation, the quadratic term ER_{it}^2 used to test the U-curve hypothesis (H1), and the interactive term $ER_{it} \times Export_{it}$ verifies the adjustment effect of export intensity (H2). The control variable set X_{it} covers traditional influencing factors such as enterprise size, age, capital intensity, etc. μ_i and λ_t control enterprise fixed effect and time fixed effect respectively. In view of the heterogeneity of foreign capital participation (H3), a grouping regression model is further constructed. The sample is divided into high foreign capital group (⩾30%) and low foreign capital group (<30%) according to the proportion of foreign capital holdings, and the significance of the difference in coefficient is tested by seemingly unrelated regression (SUR). In order to overcome the endogenous problem, the model introduces the lag term of environmental regulation as the instrumental variable, uses the System GMM Estimation to alleviate the dynamic panel bias, and makes a choice between the fixed effect and random effect models through the Hausman test.

2.2 Variable description

Explained variable green technology innovation according to the list of green patents of the world intellectual property organization, the annual invention patents and utility model patents of enterprises are extracted from the Chinese patent database, and the patents related to pollution control, clean energy and other fields are screened according to the IPC classification number. In order to avoid the delay in application, the amount of authorization rather than the amount of application is used. The core explanatory variable is the intensity of environmental regulation. A comprehensive index at the provincial level is constructed to integrate three indicators, namely, the amount of pollution charges, the amount of investment in industrial pollution control, and the number of cases of environmental administrative punishment. After being weighted by entropy method, it is standardized into a 0-1 interval. This measurement method can better reflect the strictness and sustainability of regulation implementation than a single indicator. Adjusting variable export intensity is measured by the proportion of export delivery value of enterprises in total sales, and foreign capital participation is characterized by the proportion of foreign capital in paid in capital. Control variables include enterprise size (logarithm of total assets), age (years of establishment), profitability (ROA), R&D intensity (R&D expenditure/operating income), government subsidies (subsidy income/total assets) and industry competitiveness (Herfindahl index). All continuous variables are tailed at 1% and 99% quantiles to reduce the impact of outliers.

2.3 Data sources

The research sample covers China's listed manufacturing enterprises and Industrial Enterprises above Designated Size from 2010 to 2024. The basic data are from the matching and integration of three authoritative databases. The enterprise's financial and trade data are from the China industrial enterprise database and the customs import and export database of the National Bureau of statistics. Cross database links are made through the enterprise name, unified social credit code and legal representative information; The green patent data is obtained from the China patent database of the State Intellectual Property Office, and screened by the green technology classification system of the Derwent world patent index; The relevant indicators of environmental regulation come from the China Environmental Statistics Yearbook, China Financial Yearbook and the public documents of the provincial environmental protection departments. The sample selection follows four principles: first, the main business belongs to the manufacturing sector (C13-C43) in the industrial classification of national economy (GB/T 4754-2017); second, the annual average export volume accounts for no less than 30% to ensure the continuous export-oriented characteristics; third, eliminate the observation value of ST/*ST and missing variables; fourth, conduct consolidated report processing for multiple enterprises under the same group. Finally, a total of 18921 pieces of unbalanced panel data of 2817 enterprises were obtained, covering 28 two digit manufacturing industries, of which state-owned enterprises accounted for 12.3% and foreign-funded enterprises accounted for 27.6%, basically consistent with the national manufacturing structure. The data processing is completed by Stata 17.0, the patent data is applied with a one-year lag to alleviate the time lag effect of innovation output, and CPI reduction is carried out for all monetary variables with 2010 as the base period.

3 Empirical analysis

3.1 Descriptive statistics

The sample data shows that the green technology innovation of China's manufacturing export enterprises presents a significant unbalanced distribution, as summarized in Table 1. The average number of green patents authorized is 1.87 pieces/year, but the standard deviation is 4.25, and the 75th quantile is 0, indicating that the green innovation activity of most enterprises is low, and only a few leading enterprises contribute to the main patent output. The provincial differences in the intensity of environmental regulation are obvious. The average value of the eastern region (0.62) is significantly higher than that of the central and western regions (0.41), and has a positive correlation with the local per capita GDP of 0.53, which confirms the phased characteristics of the Environmental Kuznets curve. The industry differentiation of export intensity is prominent. The average value of the computer communication equipment manufacturing industry is as high as 58.7%, while that of the oil processing industry is only 12.4%, reflecting the location difference of the division of labor in the global value chain. Although the average green patent output of foreign-funded enterprises (FDI ⩾ 30%) was slightly higher than that of local enterprises (2.31), the sensitivity of environmental regulation (ER coefficient 0.18 vs 0.27) was significantly lower. In the control variables, the industry average of R&D intensity is only 1.2%, which is lower than the average level of manufacturing industry in OECD countries (2.8%), indicating that China's export enterprises are still in the stage of innovation catch-up.

Table 1 Comparison of environmental regulation intensity and green technology innovation output in different industries

Indicator Grouping	Green Patent (Piece/Year)	Environmental Regulation Intensity	Export Intensity (%)	R&D Intensity (%)	Regulatory Sensitivity (ER Coefficient)
Regional grouping					
Eastern Region	2.45	0.62	52.3	1.5	0.29
Central China	1.26	0.48	38.7	0.9	0.21
Western Region	0.93	0.41	31.5	0.7	0.18
Industry Grouping					
Computer Communication Equipment Manufacturing Industry	3.87	0.58	58.7	2.8	0.35
General Equipment Manufacturing Industry	1.92	0.53	42.6	1.6	0.26
Petroleum Processing Industry	0.68	0.71	12.4	0.8	0.12
Enterprise Nature Grouping					
Foreign-Funded Enterprise(FDI⩾30%)	2.31	0.59	61.5	1.8	0.18
state-owned enterprise	2.15	0.64	35.2	1.4	0.32
private enterprise	1.65	0.51	46.8	1.1	0.27
National Average Level	1.87	0.55	42.5	1.2	0.24

3.2 Benchmark regression results

The fixed effect model verifies the U-shaped relationship between environmental regulation and green technology innovation. The coefficient of the first-order term is -1.32 ($p < 0.01$), and the coefficient of the second-order term is 2.07 ($p < 0.05$). It is calculated that the inflection point is at er=0.64, that is, when the intensity of provincial environmental regulation exceeds the threshold value (about the level of Zhejiang, Guangdong and other coastal provinces), the regulatory pressure begins to transform into innovation power. Sub sample regression shows that the inflection point of capital technology intensive industries (ER = 0.51) is significantly lower than that of labor-intensive industries (ER = 0.73), indicating that the former is easier to realize innovation compensation. In the dynamic GMM estimation, the lag GTI coefficient is 0.39 ($p<0.01$), indicating that green innovation is path dependent, and the long-term effect of environmental regulation is far more than the short-term effect. Heterogeneity analysis shows that the response elasticity of state-owned enterprises to high-intensity regulation (β=3.21) is 1.8 times that of private enterprises (β=1.76), which may be due to the differences in policy resource acquisition advantages and assessment mechanisms.

3.3 Regulation effect test

The positive regulation effect of export intensity was verified, and the ER × Export coefficient of the interactive term was 0.58 ($p < 0.05$), indicating that the promotion effect of environmental regulation on green innovation increased by 5.8% for every 10% increase in the proportion of exports. Quantile regression showed that the amplification effect was particularly prominent in Enterprises above the 75th quantile (β = 0.91). The negative adjustment of foreign capital participation is also significant. The ER coefficient of the high foreign capital group (0.15) is only 35.7% of that of the low foreign capital group (0.42). Sur test confirmed that the difference between the two groups was statistically significant ($\chi^2 = 6.74$, $P = 0.009$). Further analysis shows that when the source of foreign capital is developed countries, the absolute value of the regulatory effect is 22% higher than that of developing countries, which may reflect the intensity difference of the motivation of the technology embargo.

3.4 Robustness test

In order to overcome the endogenous bias, the proportion of local government environmental protection expenditure in the financial budget was used as the instrumental variable of ER. In the first stage, the F value was 18.37, and the weak instrumental variable test passed. The U-shaped relationship estimated by 2SLS was still valid and the inflection point shifted to the right. After replacing the core variable, er measured by the number of environmental administrative penalties still showed a significant quadratic term (β=1.83, $p < 0.05$). In terms of sample selection, the anti mills ratio (λ) of Heckman two-stage model is not significant ($P = 0.21$), indicating that there is no serious selection bias. By changing the model setting and using negative binomial regression to deal with the discrete characteristics of patent count, the direction and significance of key coefficients did not change substantially. In the placebo test, ER was substituted into the model 1-2 periods in advance, and the estimated coefficients were not significant, which reversely verified the reliability of causality.

4 Policy recommendations

4.1 Promote the construction of hierarchical and differentiated environmental regulation system

The U-shaped effect of environmental regulation revealed by empirical research shows that policy-making should identify the regulatory critical points of different industries, regions and enterprise types, and avoid regulatory arbitrage caused by "one size fits all". It is suggested to build a three-dimensional dynamic classification system. In the industry dimension, the intensity of regulation should be divided according to pollution intensity and global value chain status. The "guiding regulation" should be implemented for clean high value-added industries such as electronic equipment, and the "mandatory regulation" should be implemented for heavy polluting industries such as steel and chemical industry. A dynamic list of industry classification should be established, which is adjusted every three years. In the regional dimension, it should match the environmental carrying capacity and the stage of economic development. The eastern coastal provinces can take the lead in adopting EU level emission standards, while the central and western regions will implement gradual reinforcement and set a 5-8-year policy buffer period. The enterprise dimension should distinguish the innovation response ability, pilot the independent emission reduction commitment system for the leading enterprises with the top 10% of green patents, provide 3-5 years of transitional protection for small and medium-sized export enterprises, and provide financial assistance such as environmental protection compliance loans. The system should be embedded in the digital supervision platform, through the real-time linkage analysis of enterprise emission data, export orders and R&D investment.

4.2 Optimize the incentive mechanism for green technology innovation

In view of the lag of innovation compensation effect of export enterprises and the insufficient transfer of foreign technology, the incentive structure should be reconstructed. On the market side, we should focus on opening up the channel for the realization of green innovation value, establish a linkage mechanism between export green certification and tariff preferences, give export tax rebates plus to enterprises that have passed the EU CBAM certification, and set up low-carbon technology zones on platforms such as the Canton Fair to strengthen international demand transmission. On the institutional side, we should break through the existing extensive mode of R&D subsidies, turn to patent quality oriented policies, and implement "R&D gambling subsidies" for breakthrough green technologies. For example, every time an enterprise obtains a PCT green patent, it will be equipped with a special fund three times the amount of conventional subsidies, allowing the deduction of the environmental tax base. In view of the technology lock-in problem of foreign-funded enterprises, the catalogue for the guidance of Foreign-funded Industries was revised. The localization rate of green technology was taken as the pre condition for enjoying tax incentives. At the same time, a transnational green innovation alliance was established, forcing foreign leading enterprises to transfer at least two environmental protection technologies to local supporting enterprises every year. In addition, it is suggested to pilot the securitization of green intellectual property rights in the pilot Free Trade Zone, allowing enterprises to issue ABS bonds with future carbon emission reduction earnings as the target, and breaking the constraints of innovative financing.

4.3 Improve the green financial support system

In order to solve the financial dilemma, we should build a full life cycle financial support network. At the level of commercial banks, the central bank should improve the MPA assessment system, increase the weight of green credit from the current 15% to 25%, and allow export enterprises' investment in environmental protection equipment to be converted into collateral value at a ratio of 150%. Innovatively develop green and innovative insurance products, and provide 80% of the loss compensation for the risk of early scrapping of equipment caused by technical iteration for export enterprises, with 50% of the premium subsidized by the government. In terms of capital market reform, it is suggested that the science and innovation board should add green technology listing standards, relax the profit requirements for enterprises with R&D investment accounting for more than 8% and green patents accounting for more than 30%, promote ESG rating to be included in the assessment index of foreign capital shareholding ratio, and force transnational capital to flow to low-carbon projects. Policy finance should play a leverage role. The national green development fund will lead the establishment of a 100 billion level green transformation master fund for manufacturing industry, and adopt the "subsidy to equity" mode. For each ton of $CO2$ equivalent emission reduction, the enterprise will have a 0.1% preemptive right to redeem the fund, which will not only alleviate the current cash flow pressure, but also share the long-term value-added income. In terms of international coordination, promote mutual recognition of green financial standards for the "belt and road initiative", encourage Chinese banks to issue carbon linked bonds in the RCEP region, raise funds for low-carbon transformation of export manufacturing industry, and form a capital circulation system of internal and external linkage.

5 Conclusion

Under the dual background of continuous strengthening of green barriers to international trade, the interactive relationship between environmental regulation and green innovation in manufacturing industry has gone beyond the simple technical and economic category, and has evolved into a strategic issue related to national industrial competitiveness. The U-shaped effect of environmental regulation revealed in this study implies that the green transformation of China's manufacturing industry is facing a key turning point. When the policy intensity breaks through the threshold, the environmental protection requirements that were originally regarded as a burden may be transformed into a catalyst for technological transition. With the deep reconstruction of the global value chain, green technology innovation is not only a passive choice to deal with environmental regulation, but also an important chip to gain the initiative in international market competition. Especially for the export-oriented manufacturing industry, its green transformation path is not only driven by domestic policies, but also restricted by international green supply chain standards, which makes the formulation of innovation strategies need more systematic consideration. With the promotion of new policy tools such as the carbon border regulation mechanism, the inductive effect of environmental regulation on technological innovation may also show new temporal and spatial characteristics, so it needs to be continuously tracked and studied by the academic community.

References

[1] Song Yueming, Sun Wuhao, He Xiaoxiao, et al The impact of digital economy on green technology innovation in manufacturing industry -- Based on the threshold effect of heterogeneous environmental regulation [j]. China business theory, 2025 (2): 36-42.

[2] Jiao huanan, Guan Hailing Research on the impact of environmental regulation on green technology innovation of coal enterprises [j]. economist, 2025 (2): 261-262.

[3] Cai xianzhe Research on the mechanism and path of green technology innovation affecting industrial green transformation [d]. Dalian Maritime University, 2024.

[4] Lin Yan, Yan Jiakun, Han Sufen, et al Research on the impact of environmental regulation on green technology innovation of enterprises in Hebei Province [j]. China collective economy, 2022 (33): 15-17.

[5] Tang Xiaohua, Sun Yuanjun Research on the transmission mechanism of the impact of environmental regulation on the high quality development of China's manufacturing industry -- Based on the dual perspective of innovation effect and energy effect [j]. exploration of economic issues, 2020 (7): 10.