ISSN 2616-5902 Vol. 8, Issue 6: 26-34, DOI: 10.25236/AJBM.2026.080604

Leading Enterprises' Green R&D Investment and Its Impact on Regional Energy Conservation and Emission Reduction

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Abstract: *Achieving carbon peak and carbon neutrality goals hinges on promoting green development, and enterprises, especially leading enterprises, are important micro-level drivers of regional energy conservation and emission reduction. Using panel data of listed companies ranked top ten by total assets in western China from 2013 to 2023, this paper empirically examines the impact of green R&D investment of leading enterprises on regional energy conservation and emission reduction and its mechanisms by constructing a two-way fixed effects model. The results show that: (1) green R&D investment of leading enterprises significantly reduces carbon emission intensity and energy consumption intensity in western China, and this conclusion remains robust after replacing the core explanatory variable (number of green invention patent applications) and the dependent variable (enterprises' own carbon emissions); (2) green R&D investment promotes energy conservation and emission reduction through multiple channels including technological progress effect, clean energy substitution effect, industrial structure upgrading, and green technology innovation; (3) in terms of economic significance, a 1% increase in green R&D investment reduces regional carbon emission intensity by about 0.0032% and enterprises' own carbon emissions by about 2.02%, with the enterprise-level effect being more direct and stronger. This study enriches the micro-macro integrated analytical framework of green R&D investment and regional environmental performance, and reveals the "bellwether" and "radiation source" role of leading enterprises in the green transformation of western China. The findings provide empirical evidence and policy references for formulating differentiated green innovation incentive policies, precisely cultivating green leading enterprises, and achieving the dual goals of "development" and "carbon reduction" in western China.*

Keywords: *Leading Enterprises, Green R&D Investment, Energy Conservation and Emission Reduction, Western China*

1. Introduction

Climate change is the most serious challenge to sustainable human development, and actively addressing climate change has become a global consensus. Currently, global climate governance has entered the implementation phase of the Paris Agreement, with 136 countries and regions having proposed or preparing to propose carbon neutrality targets (Tan Xianchun, Green Finance Reform). As a responsible major country, China pledged in 2020 to "peak carbon emissions by 2030 and achieve carbon neutrality by 2060" and incorporated this into its overall plan for ecological civilization construction. Achieving the dual carbon goals depends on high-quality economic development, with green development as the breakthrough[1]. The core of green development lies in increasing green R&D investment to stimulate technological innovation-driven energy structure optimization and resource use efficiency improvement. In this context, enterprises, as the main actors in market economic activities, energy consumption, and carbon emissions, have become key leverage points for society-wide energy conservation and emission reduction. To comply with various command-and-control and market-based incentive policies introduced by the government, enterprises generally increase green R&D investment in order to improve energy efficiency and reduce pollution emissions.Green R&D investment refers to the part of R&D investment related to environmental protection and green product development, which directly affects green technology innovation capability and corporate competitive advantage [2].

Against this grand background, western China serves as a national strategic energy resource guarantee base, an ecological security barrier, and a destination for industrial transfer. The success of its green and low-carbon transformation directly affects the overall national "dual carbon" strategy. Western China is

ISSN 2616-5902 Vol. 8, Issue 6: 26-34, DOI: 10.25236/AJBM.2026.080604

generally characterized by "abundant coal, poor oil, and scarce gas", and its industrial structure has a high proportion of energy, chemical, raw material and other heavy industries, leading to energy consumption per unit of GDP and carbon emission intensity that have long been higher than the national average, facing the dual pressures of "development" and "carbon reduction". However, challenges and opportunities coexist: the new round of western development strategy emphasizes "taking a new path of ecological priority and green development", and a number of major clean energy bases have been located in western China. In this process, enterprises are important micro-level actors in achieving energy conservation and emission reduction.

Nevertheless, heterogeneity among enterprises objectively exists. "Leading enterprises" in various industries usually have strong capital strength, powerful R&D capabilities, extensive market influence, and high social responsibility. Compared with ordinary enterprises, leading enterprises' green R&D investment is not only larger in scale and more sustainable, but also has more significant technology spillover and demonstration effects. So, what is the relationship between leading enterprises' green R&D investment and energy conservation and emission reduction in western China? How does their green R&D investment affect the level of energy conservation and emission reduction in western China? Currently, existing research has paid insufficient attention to these questions. Answering them not only has important theoretical value but also provides scientific decision-making basis for governments to formulate differentiated green innovation incentive policies and precisely cultivate green leading enterprises to drive regional low-carbon transformation, bringing new ideas for achieving carbon neutrality.

2. Literature Review

With the increasing visibility of climate change and other environmental issues and the proposal of carbon neutrality goals, examining corporate green development has become a major research focus for scholars both domestically and internationally. As early as 1991, Porter and others proposed the "Porter hypothesis", stating that properly designed environmental regulations can stimulate firms' "innovation compensation effect", thereby achieving both environmental and economic performance improvements. Subsequently, scholars began to focus on the perspective of R&D investment stimulating the innovation compensation effect to study its impact on green development. Lan Zirui and Sun Zhenqing found that existing R&D expenditure has a positive effect on green productivity in the light industry sector, but green environmental R&D is the key breakthrough for future low-carbon development. Pedro explored the dynamic relationship between green innovation and internal and external R&D practices of firms, showing that both internal and external R&D efforts strengthen green innovation activities. Chang Qing et al., using data from Chinese industrial enterprises, found that corporate R&D investment significantly and positively affects the green technology content of exports. Wang Zhixin et al. argued that imperfect market development and insufficient corporate R&D investment reduce China's total factor carbon emission performance. Juan Carlos Bárcena-Ruiz concluded from a social perspective that only when firms pay attention to both environmental social responsibility and coordinate R&D investment will they save energy, reduce emissions, and reduce environmental damage. Zhao et al. proposed that R&D investment significantly improves green governance efficiency [3]. Li Guangyong et al. proved that China's energy-saving and environmental protection R&D investment does not crowd out total R&D investment [4].

In addition, some scholars support the "compliance cost" argument, believing that R&D investment increases carbon costs and upstream embodied carbon. Wang Zhao et al., using industrial structure upgrading as a mechanism, explored the relationship between R&D investment and carbon emissions at the national and regional levels, concluding that increased R&D investment raises carbon emissions but significantly promotes industrial structure upgrading[5]. Xie Ronghui, based on provincial panel data from 2002-2010, found that green technology innovation induced by environmental regulation has a "crowding-out effect" on production resources, thus hindering green productivity growth. Zhao Junmei et al., respectively from the national, eastern, central, and western regions, elaborated the relationship among R&D investment, energy consumption structure optimization, and carbon emissions, finding that increased R&D investment raises carbon emissions but also significantly promotes energy consumption structure optimization [6]. Ahmad et al. constructed a simple dynamic endogenous green growth model to explain how "periodic green R&D stock" affects green economic growth and pollution emissions, with the difference between desired green R&D stock and current stock causing cyclical fluctuations in green innovation [7]. Yin Baoqing et al., dividing the upgrading level of "Made in China" into three dimensions – carbon productivity of the export sector, technology content of export products, and industrial height – and based on provincial panel data from 30 Chinese provinces, found a "U-shaped" relationship between

ISSN 2616-5902 Vol. 8, Issue 6: 26-34, DOI: 10.25236/AJBM.2026.080604

green R&D investment and the upgrading level of "Made in China" [8]. They pointed out that green technology innovation requires substantial human and physical capital inputs and cannot significantly improve firm productivity in the current period, so firms face high R&D risks.

As research on R&D investment deepened, scholars turned their focus to green R&D investment, which is more sensitive to climate change, and it gradually became a key area of corporate R&D. Hamamoto first defined the part of R&D investment increase induced by environmental regulation as green R&D investment [9]. Yan Qing and Yin Baoqing, by measuring green technological progress using a sample of 30 Chinese provinces from 2002-2018, found that green technology innovation measured by green R&D investment significantly and positively promotes green technological progress [10]. Qi Jie, Han Botang et al., using 29 Chinese regions as samples, compared the effects of independent green technology innovation, international spillovers, and provincial spillovers on total factor productivity, technological change, and efficiency change in eastern, central, and western China. Tian Hongna, using a threshold regression model, found that government subsidies significantly stimulate green R&D investment in pharmaceutical manufacturing enterprises[11]. Yin Baoqing et al., using provincial-level sample data from 30 Chinese provinces, empirically tested the "U-shaped" relationship between green R&D investment and the upgrading level of "Made in China". Xiao Yuanfei found that green R&D investment helps resource-based industries climb the value chain, with productivity being an important mechanism[12].

Currently, only a small number of scholars have studied the relationship between green R&D investment and energy conservation and emission reduction. Wu Hongbo et al. deeply analyzed the mechanism of green R&D investment on firm high-quality development and concluded that green R&D investment significantly promotes firm high-quality development. Henriques and Borowiecki, taking Europe, North America, and Japan as research objects, showed that technological progress has a long-term inhibiting effect on carbon emissions. Cai Ning et al., based on provincial panel data from 2005-2011, found that three types of technological innovation – endogenous innovation efforts, local innovation spillovers, and foreign technology introduction – have significant positive effects on industrial energy conservation and emission reduction efficiency. Costinot pointed out that targeted increases in green R&D investment not only promote energy conservation and emission reduction but also increase voice in the global green value chain[13]. Li Jinyue and Wang Qiuyue, based on new geographical economics and using a spatial Durbin model, empirically found that green R&D investment significantly increases carbon productivity, and also showed that both provincial green R&D investment and carbon productivity in China exhibit significant spatial agglomeration effects[14]. Zhang Cuiju and Zhang Zongyi showed that technological progress induced by foreign investment and science and technology expenditure significantly reduces carbon emission intensity[15]. Jiao Jianling et al., constructing an inter-provincial technology spillover network based on geographical economic distance, proved that direct inter-provincial R&D spillovers have a significant inhibiting effect on carbon emissions at the national level[16]. Cui Yanjuan et al. empirically found that green R&D investment improves firm total factor productivity, mainly for high-tech firms. Grübler and Messner (1998), based on learning curves, argued that increasing R&D investment and enhancing technological learning ability help achieve emission reduction targets. In addition, some scholars have focused on green total factor productivity to explore the impact of green technological progress on energy use and carbon emissions[17].

In summary, the existing literature on green R&D investment and regional energy conservation and emission reduction provides useful references for this study, but there are also the following deficiencies. First, most existing studies are limited to a single macro or micro level, for example, discussing the impact of technological progress on the macro environment from a macro perspective, or focusing on the impact of corporate green innovation on corporate carbon emissions from a micro perspective. There is a lack of systematic research that refines micro-level corporate green innovation to corporate green R&D behavior and that integrates corporate green behavior and regional environmental effects. Second, current research on green R&D investment mostly covers all enterprises or is limited to specific industries such as industrial enterprises or energy enterprises, neglecting the special characteristics of regional leading enterprises in terms of resources, technology, and influence. Their "bellwether" and "radiation source" roles have not been fully revealed. Moreover, most existing studies focus on the whole country, lacking specific research on western China, which faces dual pressures of development and carbon reduction and urgently needs research related to regional green and low-carbon development. Filling these research gaps will not only help build an integrated analytical framework for micro-macro green development but also provide theoretical support for achieving the dual carbon goals and promoting high-quality corporate development.

ISSN 2616-5902 Vol. 8, Issue 6: 26-34, DOI: 10.25236/AJBM.2026.080604

3. Research Hypotheses and Model Construction

3.1 Research Hypothesis

Green R&D investment of leading enterprises and energy conservation & emission reduction in western China. Green R&D investment is a strategic investment for enterprises to build green dynamic capabilities and obtain sustainable competitive advantages. Through green R&D, enterprises can reduce energy and raw material costs, improve production efficiency, and at the same time meet increasingly stringent environmental regulations and avoid environmental risks. First, by increasing green R&D investment, enterprises develop more efficient boilers, motors, lighting systems, building insulation materials and other energy-saving equipment; develop more advanced end-of-pipe treatment technologies such as desulfurization, denitrification, dust removal, and carbon capture and storage (CCS); and upgrade process optimization technologies such as intelligent control systems and industrial internet to optimize production processes. Through these technological progress effects, energy consumption per unit of output is directly reduced. Second, green R&D investment has a clean energy substitution effect. Increased investment in renewable energy technologies such as solar, wind, hydrogen, and biomass reduces energy costs, improves efficiency and stability, thus replacing fossil energy and achieving energy conservation and emission reduction at the source. Third, increased green R&D investment by leading enterprises drives the formation of green technology industrial chains in the region, such as photovoltaic industrial clusters and wind power equipment manufacturing bases, generating R&D agglomeration effects and spillover effects, and promoting green and low-carbon development in the region through their own demonstration effects, thereby reducing environmental pollution and energy consumption and achieving regional sustainable development.

Leading enterprises usually possess abundant financial resources, top-tier R&D talent, and strong organizational capabilities. These heterogeneous resources constitute the basis for their large-scale, high-risk green R&D. Essentially, this is an act of internalizing negative externalities: through green R&D investment, leading enterprises transform social costs such as environmental pollution into private benefits such as efficiency improvement, cost savings, and green brands. Due to their huge production scale, the total energy savings and emission reductions brought about by the application of green technologies are also huge, forming a significant scale emission reduction effect. This energy conservation and emission reduction effect is particularly valuable for western China. Because the market mechanism in western China is relatively imperfect and environmental protection infrastructure is relatively weak, the strategic behavior of leading enterprises has a stronger demonstration and guiding role. Their green R&D not only directly applies to their own production processes, reducing their own energy consumption and emissions, but more importantly, sets a “technical benchmark” and “behavioral paradigm” for green development in the entire region, helping western China achieve the dual goals of “development” and “carbon reduction”.

The green R&D behavior of leading enterprises drives industrial structure upgrading through “signal effects” and “real effects”. On the one hand, their technological successes in emerging green energy fields attract supporting enterprises to cluster, leading the formation of green industrial clusters. On the other hand, leading enterprises, as industrial chain leaders, impose green standards and technical requirements on their upstream suppliers, forcing many small and medium-sized traditional enterprises to transform, while spilling advanced energy-saving and emission-reduction technologies to traditional advantageous industries such as energy, chemicals, and metallurgy in the region, increasing technology intensity and added value, thereby raising the green level of the entire regional industrial chain. At the same time, green R&D activities themselves generate demand for productive services such as green technology consulting, carbon trading services, green finance, and environmental monitoring, thus cultivating and strengthening the regional green service industry and promoting the evolution of industrial structure towards “servitization and high-end development”. The “structural dividend” brought by industrial structure upgrading – a rising proportion of low-energy-consumption, low-emission high-tech industries and modern services, and a declining proportion of high-energy-consumption, high-emission traditional heavy industries – naturally reduces the region’s overall energy consumption and emission intensity. In addition, green R&D investment directly translates into green technology innovation (e.g., green patents, low-carbon processes, energy-saving products), and these innovation outcomes continuously improve energy efficiency and reduce emissions in production and consumption stages, forming long-term environmental performance improvement through technological accumulation.

Based on the above analysis, this paper proposes the following research hypothesis: Green R&D investment of leading enterprises has a significant positive impact on energy conservation and emission reduction in western China.

3.2 Model Construction

The data for the variables in this study come from the China Statistical Yearbook, China Science and Technology Statistical Yearbook, and China Energy Statistical Yearbook for relevant years. Enterprise data are sourced from the CSMAR database. In addition, based on data availability and validity principles, this paper takes leading enterprises in western China from 2013 to 2023 as the research object, using listed companies on the Shanghai and Shenzhen A-share markets in western China as the initial sample, and performs the following filtering: (1) exclude financial industry firms; (2) remove companies in special treatment status (ST, *ST); (3) delete samples with missing key variables. A two-way fixed effects model is constructed to empirically study the specific impact of green R&D investment on regional energy conservation and emission reduction.

3.2.1 Green R&D Investment

According to Hamamoto (2006), the part of R&D investment increase induced by environmental regulation is defined as green R&D investment. The specific measurement method refers to Yin Baoqing et al. (2018).

1) Construct an econometric regression model for green R&D investment induced by environmental regulation:

$$ln(RD)_{i,t}=\beta+\theta_1\ ln(REG)_{i,t-1}+\theta_2 RDS_{i,t}+\theta_3\ ln(VA)_{i,t}+ind+year+\varepsilon_{i,t} \tag{1}$$

where RD is enterprise R&D investment; REG is an environmental regulation variable – considering data quality and its correlation with income level, following Lu Yang's study, it is calculated as operating revenue per employee; RDS is government R&D subsidies received by the enterprise; VA is enterprise net profit. The estimated coefficients are used as weights to calculate the amount of green R&D investment.

2) green R&D .According to the elasticity of R&D investment with respect to environmental regulation intensity, the amount of green R&D investment is calculated using equation:

$$GRD_{i,t}=\theta_1\times[\frac{REG_{i,t}-REG_{i,t-1}}{REG_{i,t-1}}]\times RD_{i,t} \tag{2}$$

3.2.2 Regional Energy Conservation and Emission Reduction Indicators

The logarithm of total energy consumption of each province in western China from 2013 to 2023 is selected to measure the level of energy saving (lnec). The logarithm of carbon emissions of each province (lnpcmiss) is selected to measure the level of carbon emission reduction.

Total energy consumption (ec) refers to the sum of various energies consumed by all industries and households in a certain economic region during a certain period. It includes primary energy such as raw coal, crude oil, natural gas, hydropower, nuclear power, wind power, solar energy, and biomass energy; secondary energy such as washed coal, coke, gas, electricity, heat, refined oil products and other products generated from the processing and conversion of primary energy; and other fossil energy, renewable energy, and new energy. Renewable energy such as hydropower, wind power, solar power, geothermal energy, and biomass energy refers to the part obtained by people through certain technical means and used as commercial energy.

Total energy consumption is calculated through comprehensive energy balance accounting, i.e., compiling an energy balance sheet. Primary and secondary energy cannot be double-counted. Calculation formula: Total energy consumption = final energy consumption + energy processing and conversion loss + energy loss.

3.2.3 Definition of Leading Enterprises and Western China

Referring to Ye Zhenyu and Zhuang Zongwu (2022), leading enterprises are defined as the top ten listed companies by total assets in each province (city) of western China. Referring to Liu Zhiyong et al. (2018), western China includes Inner Mongolia, Guangxi, Sichuan (including Chongqing), Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang.

ISSN 2616-5902 Vol. 8, Issue 6: 26-34, DOI: 10.25236/AJBM.2026.080604

4. Empirical Results Analysis

4.1 Benchmark Regression

Column (1) for carbon emissions shows that the coefficient of lngrd is -0.00364, significant at the 1% level. After adding control variables in column (2), the coefficient becomes -0.00321, still significant at the 1% level (t = -2.902). This indicates that a 1% increase in green R&D investment of leading enterprises reduces carbon emission intensity in western China by about 0.0032%. For energy consumption: in columns (3) and (4), the coefficients of lngrd are -0.00364 and -0.00332 respectively, both passing the 1% significance test. This shows that green R&D investment also significantly reduces energy consumption intensity.

These results verify the research hypothesis that green R&D investment of leading enterprises has a significant positive impact on energy conservation and emission reduction in western China. The economic implication is that leading enterprises, through technological R&D, improve energy efficiency, promote clean energy, and generate green technology spillovers, effectively inhibiting regional carbon emissions and energy consumption growth. Although the absolute value of the coefficient is small, considering the huge base of energy consumption in western China, the total effect on energy conservation and emission reduction is considerable.

Table 1.Benchmark regression

VARIABLES	(1) lnpcmiss	(2) lnpcmiss	(3) lnec	(4) lnec
lngrd	-0.00364***	-0.00321***	-0.00364***	-0.00332***
		(-2.902)	(-3.385)	(-3.411)
pgdp		-0.250**		-0.241**
		(-2.165)		(-2.377)
tbr		5.493***		6.648***
		(3.447)		(4.743)
fdi		4.607***		4.521***
		(11.43)		(12.75)
dens		-0.00255***		-0.00210***
		(-9.676)		(-9.066)
Constant	9.27***	18.91***	9.277***	8.786***
	(126.7)	(126.7)	(567.2)	(66.95)
Fixed year	Yes	Yes	Yes	Yes
Fixed industry	Yes	Yes	Yes	Yes
Observations	901	901	901	901

t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.2 Robustness Tests

To ensure the reliability of the benchmark regression results, this paper conducts robustness tests from two perspectives: replacing the core explanatory variable and replacing the dependent variable.

4.2.1 Replacing the core explanatory variable

To avoid potential measurement errors in the original measure of green R&D investment, this paper replaces the core explanatory variable with the number of green invention patent applications (ginpa) of leading enterprises, following Liu Jinru et al. (2019). Green invention patents more directly represent the substantive output of corporate green technology innovation, and their number is less affected by short-term financial fluctuations, making them more robust. The benchmark model is re-estimated with ginpa replacing the original lngrd. The results are shown in Table 2.

Table 2 shows that after replacing the explanatory variable, the coefficient of ginpa is -0.00376, significant at the 1% level. This means that a 1% increase in the number of green invention patent applications of leading enterprises reduces regional carbon emission intensity (eci) by about 0.0038%.

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Compared with the coefficients of lngrd in the benchmark regression (-0.00321 to -0.00364), the sign, significance, and magnitude are highly consistent, further confirming that the inhibiting effect of green R&D investment on carbon emissions is robust.

Table 2. Robustness test

VARIABLES	eci
ginpa	-0.00376***
	(-4.610)
Control variable	Yes
Observations	891
R-squared	0.780

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.2.2 Replacing the dependent variable

In the benchmark regression, the dependent variables are the logarithm of provincial carbon emissions (lnpcmiss) and the logarithm of total energy consumption (lnec). To test whether the conclusion depends on macro-aggregated data, and to further examine the direct impact of green R&D investment on leading enterprises' own carbon emissions, this paper replaces the dependent variable with the logarithm of leading enterprises' own carbon emissions (lncmiss).

Table 3 shows that after replacing the dependent variable with enterprise-level carbon emissions, the coefficient of lngrd is -0.0202, highly significant at the 1% level (t = -6.892). This indicates that a 1% increase in green R&D investment of leading enterprises reduces their own carbon emissions by about 2.02%. Compared with the elasticity coefficient for provincial carbon emissions in the benchmark regression (-0.00321), the enterprise-level emission reduction effect is significantly larger, which is expected: green R&D investment directly acts on the enterprise's own production technology and energy structure, so its marginal impact on the enterprise's own carbon emissions is more direct and stronger; while provincial carbon emissions are also affected by other non-leading enterprises, household activities, and other complex factors, so the elasticity coefficient is relatively smaller. Nevertheless, both are significantly negative, indicating that green R&D investment of leading enterprises effectively promotes energy conservation and emission reduction at both the macro regional level and the micro enterprise level. The control variable results are basically consistent with the benchmark regression, and the model R^2 is 0.462, indicating good explanatory power. Therefore, after replacing the dependent variable, the core conclusion remains robust.

Table 3.Robustness test

VARIABLES	lncmiss
lngrd	-0.0202***
	(-6.892)
Control variable	Yes
Observations	901
R-squared	0.462

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5. Conclusions and Policy Implications

Using sample data of leading enterprises in western China from 2013 to 2023 and constructing a two-way fixed effects model, this paper empirically analyzes the impact of green R&D investment of leading enterprises on regional energy conservation and emission reduction. The main conclusions are as follows.

First, green R&D investment of leading enterprises has a significant positive impact on energy conservation and emission reduction in western China. Leading enterprises, through R&D of energy-efficient equipment, promotion of clean energy technologies, and generation of green technology spillovers, effectively inhibit regional carbon emissions and energy consumption growth, verifying the applicability of the Porter hypothesis in western China.

Second, the energy-conservation and emission-reduction effect of leading enterprises' green R&D investment is achieved through multiple mechanisms. Theoretical analysis shows that the green R&D behavior of leading enterprises directly reduces energy consumption and emissions through technological progress effects, clean energy substitution effects, and scale emission reduction effects; on the other hand, it drives industrial structure upgrading through "signal effects" and "real effects", and translates directly into green technology innovation (e.g., green patents, low-carbon processes, energy-saving products), forming long-term environmental performance improvement. The synergy of these direct and indirect mechanisms makes leading enterprises a key pivot in the green transformation of western China.

Third, the influence of control variables reveals the complexity of energy conservation and emission reduction in western China. Increases in per capita GDP and population density significantly reduce carbon emissions and energy consumption, indicating that economic development and population agglomeration contribute to environmental performance. In contrast, technology market turnover and foreign direct investment are significantly positively correlated with carbon emissions and energy consumption, suggesting that western China may have a "pollution haven" effect and that technology transactions may flow mainly to non-green sectors. This provides a warning for western China to optimize its foreign investment attraction strategy and technology market development direction.

Based on the above findings, to further leverage the driving role of leading enterprises' green R&D investment in energy conservation and emission reduction in western China, this paper proposes the following policy recommendations.

First, precisely incentivize green R&D of leading enterprises to exert the "bellwether" effect. Local governments should increase financial subsidies and tax incentives for green R&D of leading enterprises, especially in energy-rich areas, to fully utilize their technology spillover and demonstration effects.

Second, take leading enterprises as the core to promote green upgrading of industrial structure. The government supports leading enterprises in building demonstration projects for green supply chains, encourages them to spill over green technologies into traditional advantageous industries such as energy and chemicals, metallurgy, and building materials, and leverages their green businesses—including new energy and energy-saving equipment—to foster the development of green industrial clusters.

Third, western China should, taking into account its own energy endowment of "abundant coal, poor oil, scarce gas", focus on supporting clean energy substitution technologies and clean and efficient coal utilization technologies, following a dual-track emission reduction path of clean and efficient coal use and new energy.

Through these multi-dimensional and actionable policy packages, western China can fully leverage the "technical benchmark" and "behavioral paradigm" role of leading enterprises, solve the dual dilemma of "development" and "carbon reduction", and contribute to the national goal of carbon peak and carbon neutrality.

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