Differentiated Paths of Regional Green Development Driven by Industrial Enterprise Innovation

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Abstract: A fundamental shift in the regional development pattern is crucial to achieving a comprehensive green transformation in China. Currently, innovation-driven green development is a significant strategic option for regional development. As the main body of innovation and the basic unit of regional composition, enterprises have a profound impact on the development of regional economy, society, ecology, and other aspects. However, considering China's vast territory and significant regional differences in natural environment and industrial structure, it's necessary to further explore the specific impact paths of regional green development driven by enterprise innovation. Therefore, taking industrial enterprises as an example, based on the panel data of 30 provinces in China from 2016 to 2020, this study verifies the impact of industrial enterprise innovation on the regional green development level by constructing a parallel multiple mediating effect model and dividing the economy into eastern, central, and western regions to discuss the specific impact paths. The results show that industrial enterprise innovation has a significant positive effect on regional green development level, via different influencing paths in each region: (1) The eastern region improves the regional green development level by narrowing the urban-rural income gap; (2) The central region improves the regional green development level by reducing resource dependence; and (3) The western region raises the regional green development level by improving the rationalization of industrial structure.

Keywords: Industrial enterprise innovation, Regional green development level, Differentiation paths, Mediating effect

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1. Introduction

China is the world's largest energy producer and consumer, and also the largest carbon emitter. Carbon emissions and economic growth have not yet been decoupled, and green transformation has a long way to go. The fundamental transformation of the regional development model is the key to the country's overall green transformation. China has introduced a series of policies to accelerate the layout of green development of the eastern region represented by the Beijing-Tianjin-Hebei region, the Yangtze River Delta, and the Guangdong-Hong Kong-Macao Greater Bay Area super-large urban agglomerations, as well as the central and western regions†. At the same time, the connotation of development has already gone beyond the single concept of economic growth, and has formed an organic combination with economic, social, and environmental development. At the Fifth Plenary Session of the 18th CPC Central Committee, "green development" was established as one of the five major development concepts in China. Behind the change of development concept is the further call for innovation-driven development, which means that it is necessary to speed up the use of scientific and technological innovation to solve development problems, strengthen development advantages, and get out of development difficulties.

At present, China's innovation resources are constantly gathering for enterprises. As the main body of scientific and technological innovation, enterprises' innovation activities increasingly need to assume their due responsibilities for global sustainable development, overall human welfare improvement, and social and cultural progress (Verganti, 2008; Stoneman, 2010). At the same time, enterprises also play a major role in regional green transformation. Through innovation in products, processes, and technologies, they can promote improvement in efficiency of energy utilization and pollution emissions, and can improve the overall level of the regional green development. Industrial enterprises with the characteristics of large pollutant emissions, high environmental sensitivity, and sufficient development potential for green innovation are particularly important (Wang, 2019). The existing literature has provided many references at the level of innovation and green development, but there is still a lack of direct evidence and path research on the impact of industrial enterprise innovation on the regional green development level. Considering that China has a vast territory and significant heterogeneity in economic development level, resource endowment, and industrial structure among different regions (Yi, 2018), the differentiated paths of regional green development need to be explored urgently.

Against the above background, this study will focus on the following issues: Can industrial enterprise innovation affect regional green development? How does industrial enterprise innovation affect the regional green development? This study selects the eastern, central and western regions for empirical test, aiming to identify the specific mechanism of industrial enterprise innovation to improve the regional green development, and provide suggestions for green transformation and development in different regions.

2. Literature review

2.1 Theory of green development

Green development emphasizes the systematic, overall, and coordinated development of the economic system, social system, and natural system (Hu, 2014), that is, good economic benefits, high social equity, and a beautiful ecological environment. Regional green development is an important carrier of green development, its current research mainly focuses on three aspects. (1) Development pattern. Most research takes the Yangtze River Economic Belt, the eastern region, and the whole country as typical constituencies to explore the characteristics of spatial and temporal evolution. Generally speaking, the efficiency of green development is inverted U-shaped along temporal dimension (Xu, 2021). The green development level in the downstream region is better than that in the middle region and the upstream region: The green development level in the eastern region is usually better than that in the central region and western region (Yang, 2023). (2) Measurement of regional green

† The *Action Plan for Carbon Dioxide Peaking Before 2030* emphasizes that the Beijing-Tianjin-Hebei region, Yangtze River Delta, Guangdong-Hong Kong-Macao Greater Bay Area, and other regions should take the lead in promoting the comprehensive green transformation of economic and social development. The *Opinions of the Central Committee of the Communist Party of China and the State Council on Promoting High-quality Development in the Central Region in the New Era* pointed out that we should focus on building a beautiful central region with green development and adhere to shared development. The *Guiding Opinions of the Central Committee of the Communist Party of China and the State Council on Promoting the Development of the Western Region in the New Era to Form a New Pattern* points out that we should strengthen the construction of beautiful western regions and accelerate the green development of western regions.

development. Part of the existing literature focuses on measuring the regional green development level by index method. This method often constructs a multi-dimensional comprehensive evaluation index system, and uses the step-by-step equal weight method (Liu, 2017), principal component analysis (Liu, 2022), and entropy method (Wu, 2017) to determine the weight of each index. The index setting is generally around three aspects, namely ecology (environment, resources), production (economic/quality growth), and life (social welfare), as shown in Table 1. Another focus is on measuring the efficiency of regional green development by efficiency method. This method often uses the input-output DEA model (Wang, 2019), emphasizing the acquisition of as much economic output as possible at the lowest cost of resources and environment. (3) Influencing factors. Empirical analyses investigate the impact of various factors on regional green development around scientific and technological innovation (Martinez, 2021), financial development (Liu, 2022), industrial structure (Li, 2017), environmental regulation (ling Guo, 2017), and so on.

2.2 Theory of enterprise innovation and green development

Under the post-Schumpeterian innovation paradigm, the connotation of innovation is incorporated into the dimensions of society and environment, and new theories such as responsible innovation and open innovation are proposed (Stilgoe, 2020; Chesbrough, 2003). The innovation policy has also shifted from the traditional economic growth paradigm to the social-technical system, turning to the innovation policy objectives of fairness, inclusiveness, greenness, openness, sharing, friendliness, narrowing gap of wealth, and sustainable development. Many scholars have confirmed the role of innovation in green development. By improving the efficiency in resource utilization (Martinez, 2021; Khan, 2023), reducing pollution emissions (Tabrizian, 2019), achieving energy substitution (Irandoust, 2016), and narrowing the development gap between regions (Kijek, 2022), it can promote the coordinated development of economic, social, and ecological composite systems (Hu, 2014). As the main body of innovation, enterprises' innovation activities exist in the socialized production process of the interaction between endogenous ability and the external environment (Xie, 2021), which can have a comprehensive impact on themselves and the external environment.

The existing research on industrial enterprise innovation affecting regional green development mostly integrates industrial enterprise innovation with green development, highlighting the concept of green innovation in industrial enterprises (Xie, 2021), and carries out in-depth research on the strategy, process and capability of green innovation in industrial enterprises, such as industrial enterprises' end-of-pipe control, green product innovation, green process innovation, green steering and so on (Brown, 2019; Peng, 2021). However, more frequently, this perspective addresses innovation results within the enterprise, including the green innovation impact on the enterprise's financial performance (Xie, 2021). Centered on the interactive perspective of industrial enterprise innovation and regional development, most of the existing research focuses on regional innovation and regional economic development. For example, Zheng

Table 1: Measurement dimensions of regional green development level

First-level indicator dimension	Source
Resource utilization; Environmental governance; Environmental quality; Ecological protection; Growth quality; Green life; Public satisfaction.	*Green development index system*
Greening degree of economic growth; Carrying potential of resources and environment; Government policy support.	*2019 China Green Development Index Report-Regional Comparison*
Eco-environmental quality; Environmental governance capacity; People's well-being; Economic green development.	*Evaluation index system of green development in Qinghai-Tibet Plateau*
Resource utilization; Environmental governance; Green life; Quality growth.	Wu *et al* (2017)
Green environment; Green life; Green production; Green Deal.	Liu (2017)
Environmental governance; Emission consumption; Social welfare; Economic growth.	Liu *et al* (2022)
Resource utilization; Environmental governance; Ecological protection; Green economy.	Xu *et al* (2021)

(2021) found that R&D investment by industrial enterprises can promote regional innovation output. It must be pointed out that research on the relationship between industrial enterprise innovation and regional green development is still weak, and there is less literature proving the directness of the role of industrial enterprise innovation on the green transformation of regional economic structure and the improvement of regional green economic efficiency. Although some scholars have also portrayed the regional green development level from the green innovation of industrial enterprises, such as Wang (2019) *et al*, who measures the regional green innovation performance in terms of the transformation efficiency of green innovation by the industrial enterprises and the green innovation output benefits, such research is still mostly focused on the green innovation outputs rather than exploring the impact path.

3. Research hypothesis

3.1 Industrial enterprise innovation and regional green development

Industrial enterprise innovation is one of the endogenous driving forces to enhance the level of regional green development and an important factor in breaking the pressure of regional green development. First, industrial enterprise R&D investment is the material basis for guaranteeing the continuous innovation of their own technology and the constant introduction of new products. This can both influence the innovation capacity of industrial enterprises themselves and promote the increase of regional average productivity, accelerating the optimization of regional resource allocation. Second, the agglomeration of innovative talents brought about by industrial enterprise innovation can not only guide enterprises to carry out green production, but also help local residents to accept the concept of environmental protection and promote green consumption (Xu, 2021). Third, the innovation output of industrial enterprises essentially increases the overall knowledge stock of the region, which can improve regional competitiveness and economic development level. This has led to the improvement of regional development efficiency from a lower level to a higher one, and the improvement of green economic efficiency (Anokhin, 2019) as well. For example, more high-tech jobs are provided, which is beneficial to social welfare. Fourth, the innovation environment provides institutional safeguards for industrial firms to innovate and encourages industrial firms to engage in innovative practices, the spillover effects of which are beneficial to regional development. In particular, the innovation of "energy saving, pollution reduction and carbon reduction" carried out in the links between source substitution, process control and end-of-pipe treatment can directly increase the benefits of regional green development.

Hypothesis 1: Industrial enterprise innovation has a positive impact on the improvement of regional green development level.

3.2 Industrial enterprise innovation, rationalization of industrial structure and regional green development

Industrial enterprise innovation is the micro unit to realize the overall industrial upgrading. Internally, innovation has improved the production efficiency as well as the resource utilization efficiency of industrial enterprises, positively promoted the expansion of industrial scale, and changed the output ratio of the whole industry in the region. It has a significant role in promoting the upgrading of capital industries, technology-intensive industries, and labor-intensive industries (Matsuzaki, 2021). Externally, the industrial enterprise innovation often requires cross-enterprise or even cross-industry cooperation. The deepening of the correlation helps to realize the complementarity of technological innovation, so that the level of specialization and socialization of industrial enterprises can be improved, and the proportion of output can be adjusted to achieve the rationalization and upgrading of industrial structure (He, 2019).

At present, China's emission reduction effect is brought about by the shift of production factors from agriculture and industry to service industry (Li, 2017). The process of industrial structure rationalization is precisely the process of reshaping the existing industrial portfolio relationship to high-quality development. First of all, the green transformation of manufacturing industries with high energy consumption and high pollution can directly promote the regional green development. Subsequently, the transformation of the manufacturing industry can drive the development of new energy industries, producer services (such as energy conservation and environmental protection services, high-tech services) and other low-energy and low-emission industries. In turn, it will improve the overall resource allocation efficiency of the region, reduce carbon emissions, and optimize the energy consumption structure, so as to achieve the results of improving the regional green development level (Gu, 2022). Finally, the rationalization of industrial structure has good benefits for the stable growth of the regional economy.

Hypothesis 2: The rationalization of industrial structure plays an intermediary role in industrial enterprise innovation and regional green development.

3.3 Industrial enterprise innovation, regional resource dependence, and regional green development

Industrial enterprises can effectively improve the supply efficiency of traditional energy and clean energy in the R&D of key technologies and major equipment such as those for energy exploitation and utilization. These innovations can also enrich the diversity of regional resources. At the same time, through innovation, industry enterprises can help eliminate backward technology in production, especially technological innovation in energy conservation bias, which can effectively reduce energy consumption under the condition of constant non-energy factors and output (Khan, 2023), and drive regional development to get rid of resource dependence and move towards technology dependence. In addition, the investment of industrial enterprises in innovative personnel can accelerate the substitution of primary labor force (Pfeiffer, 2001), and the innovation of process can support waste recycling and multiple energy utilization.

In the short term, relying on resources may be able to achieve rapid development. However, in the long run, the resources on which development depends will gradually dry up, and high resource dependence will bring about simplification, primary and non-sustainable development, which is contrary to the regional green development goals (Shao, 2013). At the same time, high resource dependence often leads to regional super-heavy economic structure, which is an important cause of resource waste, high energy consumption and serious environmental pollution (Fan, 2022).

Hypothesis 3: The regional resource dependence plays an intermediary role in industrial enterprise innovation and regional green development.

3.4 Industrial enterprise innovation, urban-rural income gap, and regional green development

Entrepreneurs are the main force of innovation and prosperity. In the long run, industrial enterprise innovation can have a positive effect on its own economy and regional economy, increase local government revenue, and then expand the government's distributable resources. The government then uses the resources obtained to give back to relatively low-income people and relatively underdeveloped areas in the form of transfer payments and social welfare expenditures to narrow the income gap (He, 2019). At the same time, industrial enterprise innovation can bring knowledge spillover effects, and employees can improve their skills and income levels through "learning by doing" on a certain basis (Ryu, 2005). Farmers' application of agricultural tools produced by enterprises can promote the transformation of modern and efficient production mode in rural areas. This can also reduce the risk of agricultural production, extend the industrial chain, increase the added value of agricultural products so as to increase the market competitive advantage, and help farmers increase production and income.

The urban-rural income gap is a response to the degree of regional equity. First, narrowing the urban-rural income gap is conducive to the harmonious and stable development of local society. Second, the income gap will increase regional carbon dioxide emissions and pollutant output, and damage the local environment (Hao, 2016). Third, the urban-rural income gap will lead to the loss of rural labor force, especially with difficulty in retaining high-quality talents, hence resulting in relatively low population remaining in the rural area, and low environmental awareness in the local region. In order to address the problem that normal agricultural activities are difficult to carry out due to insufficient manpower, measures such as increasing pesticides and fertilizers are often adopted, which can easily cause pollution of regional soil and water sources (Ma, 2022). On the contrary, narrowing the urban-rural income gap can increase human capital investment in rural areas, affect external technology absorption, resource utilization efficiency, *etc*., thus promotes the decoupling of economic growth from air pollution (Zhang, 2022).

Hypothesis 4: The urban-rural income gap plays an intermediary role in industrial enterprise innovation and regional green development.

Based on the above analysis, an analytical framework for the impact of industrial enterprise innovation on regional green development is constructed (Figure 1).

4. Research methods and index design

4.1 Model design

This study used the mediation effect test method to construct a parallel multiple mediation model (such as formulae 4.1 to 4.3) (Preacher, 2008). The Bootstrap test method was used to empirically study the differentiated paths of industrial enterprise innovation in different regions

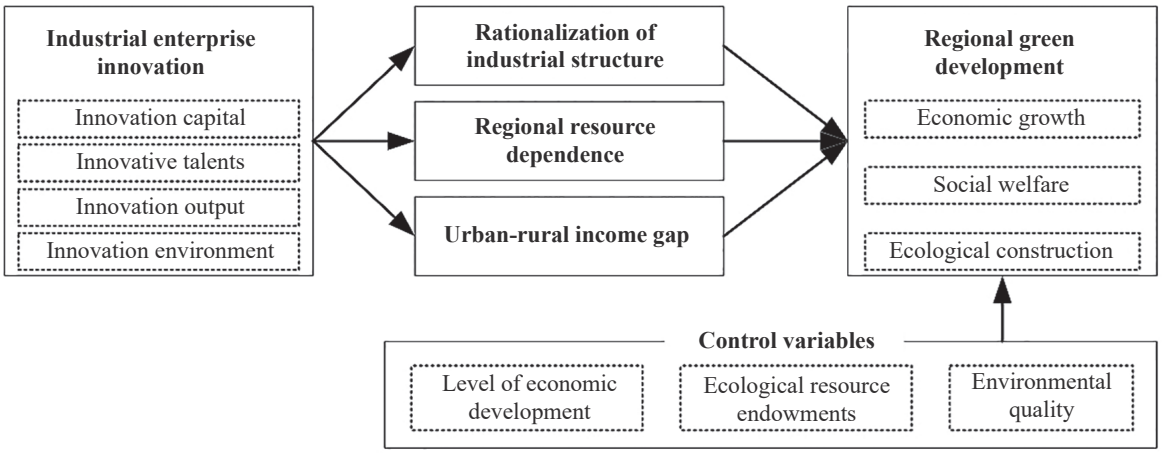


Figure 1: Parallel multiple mediation model of industrial enterprise innovation affecting regional green development

affecting the respective regional green development level, and the robustness test was also carried out. The number of Bootstrapping samples was set to 5000.

GDL_{it} is the explained variable, that is, the level of regional green development; EI_{it} is the explanatory variable, that is, the innovation index of industrial enterprises in each region; M_{it} is the mediating variable. It can be any of the following (each defined as described in section 4.2.3): the industrial structure rationalization *IS*, the resource industry dependence *ID* or the urban-rural income gap *UR*; Z_{it} is the control variable. It can be any of the following (each defined as described in section 4.2.4): the level of economic development *ED*, the ecological resource endowment *EE*, and the environmental quality *EQ*. The subscript character *i* represents different provinces, and *t* represents different years; the coefficient α_0 is a constant term, α_1 is the influence degree of core explanatory variables on the explained variables, α_2 is the influence of different mediator variables on the explained variables, δ_i is the fixed effect of enterprises, θ_t is the fixed effect of time, γ is the influence degree of control variables, and ε_{it} is the residual term.

$$GDL_{it} = \alpha_0 + \alpha_1 EI_{it} + \gamma \sum Z_{it} + \delta_i + \theta_t + \varepsilon_{it} \quad (4.1)$$

$$M_{it} = \alpha_0 + \alpha_1 EI_{it} + \gamma \sum Z_{it} + \delta_i + \theta_t + \varepsilon_{it} \quad (4.2)$$

$$GDL_{it} = \alpha_0 + \alpha_1 EI_{it} + \alpha_2 M_{it} + \gamma \sum Z_{it} + \delta_i + \theta_t + \varepsilon_{it} \quad (4.3)$$

4.2 Variables design

4.2.1 Explained variable

Regional green development is a comprehensive concept, which needs to realize the connotation of the coordinated development of an economic-social-ecological complex system. Based on the generalized definition of green development and the existing evaluation index system results (Liu, 2022; Wu, 2017), this study considered the availability of data and the representativeness of variables, and finally constructed the evaluation index system of regional green development level from the three dimensions of "economic growth, social welfare, and ecological construction". Economic growth is measured by retail consumption level, urbanization level and regional GDP. Social welfare is measured by the low-carbon travel level, medical level and educational level. Ecological construction is measured from the perspective of energy consumption, waste discharge and environmental protection. Among them, waste discharge highlights waste gas discharge, whilst environmental protection highlights the role of the government, which is measured by the *per capita* park green area, as shown in Table 2.

In order to highlight the balanced and coordinated characteristics of green development, the step-by-step equal weight method was used to distribute the weights. That is, the weight of the first-level indicators is 1/3. In the second-level index, the weight of the index to the first-level index is 1/m (m is the number of indicators under the first-level index). Similarly, the weight of the third-level indicators to the second-level indicators is 1/n (n is the number of indicators under the second-level indicators). Therefore, the final weight of the index is 1/3mn. The negative indicators are processed by reciprocal positive processing, and the data of each index layer are standardized by Min-Max to eliminate the influence

Table 2: Evaluation index system of regional green development

	First-level	Second-level	Indicator measurement	Attribute
Regional green develop-ment	Economic growth	Retail consumption level	Total retail sales of social consumer goods (Bn)	Positive
		Urbanization level	Urban population density (P/km²)	Positive
		Regional GDP	Urban GDP (Bn)	Positive
	Social welfare	Low-carbon travel level	Public transport vehicles per 10,000 people (units)	Positive
		Medical level	Health technical personnel per thousand population by region (P)	Positive
		Educational level	Education funds (W)	Positive
	Ecological construction	Energy consumption level	Electricity energy consumption of the whole society (TWH)	Negative
		Waste discharge level	Sulfur dioxide emissions (t)	Negative
		Environmental protection level	Per capita public green area (m²/P)	Positive

of variable dimension and variation range. The specific formula is given as (4.4), where y_i represents the value of each three-level index after processing.

$$GDL = \sum_{i=0}^{10} \frac{1}{3mn} \times y_i \quad (4.4)$$

4.2.2 Explaining variable

The industrial enterprise innovation is the result of the joint action of internal innovation activities and external innovation environment, and it is difficult to describe its real situation with a single index. 1) In the internal innovation activities layer, it should include R&D investments, innovation processes and innovation outputs (Dewangan, 2014). However, considering both R&D investments and innovation activities can be characterized by innovative capital and innovative talents, to avoid redundancy, new dimensions are no longer introduced in this study. The results of innovation activities are innovation outputs, which are used to describe the results of innovation transformation and benefit generation. 2) In the external innovation environment layer, it refers to the external support for regional industrial enterprises to carry out innovation activities, in which we highlight the government's support for industrial enterprise innovation.

Therefore, this study measures the innovation capital, talent, output and environment of industrial enterprises. Specifically, the innovation capital of industrial enterprises is represented by the expenditure on R&D of industrial enterprises above state designated scale. Innovative talents are represented by R&D personnel full-time equivalent of industrial enterprise above state designated scale. The innovation output takes into account the long cycle of patents from application, disclosure to authorization, and is represented by the number of patent applications of industrial enterprises above state designated scale. The innovation environment is measured in a ratio, where the numerator is the number of industrial enterprises benefiting from the policies (represented by "additional deduction policy" and "tax preferential policy for high-tech enterprises") and the denominator is the number of industrial firms. Here all the firms counted in the numerator and the denominator must have carried out innovation activities. Thus, we can directly reflect the supportive effect of the policy from the level of industrial enterprises above state-designated scale.

On the basis of the Min-Max standardization of each index, the innovation capital, talent, output, and environment values of industrial enterprises are weighted and summed by equal weights. Finally, the results of industrial enterprise innovation (EI) are obtained.

4.2.3 Mediating variables

Industrial structure rationalization *IS*. It refers to the balance of demand and supply structure of various industrial sectors with input-output relationships. The rationalization of industrial structure is often measured by the degree of deviation between industrial structure and employment structure (Dong, 2020). The formula is as below,

$$IS = \sum_{i=0}^{3} \left| \frac{Y_i/L_i}{Y/L} - 1 \right| = \sum_{i=0}^{3} \left| \frac{Y_i/Y}{L_i/L} - 1 \right| \quad (4.5)$$

where Y and L represent output and employment respectively, and represents the primary, secondary and tertiary industries. The larger is the IS value, the higher the mismatch between the output and employment structure of the tertiary industry in the region, the lower the labor productivity, and the lower the economic benefits of the industrial structure – that is, the more unreasonable the industrial structure. On the contrary, the smaller is the IS value, the higher the degree of rationalization of industrial structure.

Resource industry dependence *ID*. It refers to the degree of dependence on resource-based industries for regional development. In this study, the proportion of the number of employees in the mining industry to the total number of employees is used for reference (Fan, 2022). According to the statistical basis of the existing industry by the China Bureau of Statistics, the mining industry (GB/T 4754-2017) can cover all kinds of primary industries related to natural resources in a relatively comprehensive way. This index can also better reflect the preference and dependence of regional employment structure on resource industries.

Urban-rural income gap *UR*. It refers to the income gap between the urban and rural populations, reflecting the degree of social equity and social welfare effects. In this study, the Theil index is used to measure the urban-rural income gap (Wang, 2007). The smaller the Theil index is, the more equitable the regional social development is. The formula is as follow,

$$dis_t = \sum_{j=1}^{2} \left(\frac{p_{jt}}{p_t}\right) \ln\left(\frac{p_{jt}}{p_t}\Big/\frac{z_{jt}}{z_t}\right) = \left(\frac{p_{1t}}{p_t}\right) \ln\left(\frac{p_{1t}}{p_t}\Big/\frac{z_{1t}}{z_t}\right) + \left(\frac{p_{2t}}{p_t}\right) \ln\left(\frac{p_{2t}}{p_t}\Big/\frac{z_{2t}}{z_t}\right) \quad (4.6)$$

where j = 1 or 2 denote urban and rural areas respectively, z_{jt} denotes the number of urban (j = 1) or rural (j = 2) population in period t, z_t denotes the total population in period t, p_{jt} denotes the total income of urban (j = 1) or rural (j = 2) (the product of urban [rural] population and per capita income), and p_t denotes the total income in period t.

4.2.4 Control variables

In order to avoid endogenous problems caused by missing explanatory variables, the following three control variables are introduced: level of economic development, ecological resource endowment, and environmental quality.

1) The level of economic development (ED) has a positive impact on economic growth. Economically developed regions often have more complete social construction, but the level of environmental protection will decline first and then rise with economic development. Therefore, the symbol of this indicator needs to be estimated by empirical results. This study uses the natural logarithm of *per capita* GDP to measure the level of economic development.

2) Ecological resource endowment (EE) symbolizes the ecological resource base and positively affects regional environmental construction, but it is a limiting factor for the level of economic development. If we can promote the construction of ecological industrialization and industrial ecology, we can realize the transformation from “lucid waters and lush mountains” to “mountains of gold and silver”, and simultaneously improve the level of regional economic growth and overall green development. Therefore, the symbol of this indicator needs to be estimated by empirical results. Forest coverage was selected for characterization.

3) The worse the environmental quality (EQ) is, the more unfavorable it is to ecological construction and sustainable economic growth. The PM2.5 concentration was used to reflect this control variable. This part of the data comes from the Atmospheric Composition Analysis Group of Washington University in St. Louis, and the ecological environment bulletin of the provincial ecological environment department.

4.3 Data description

This study used panel data. The 13th Five-Year period from 2016 to 2020 was used as the time interval. This period is the five years with the greatest improvement in ecological environment quality in Chinese history, and also the five years with the best development of ecological environment protection. Excavating the experience of regional green development in this period can provide support for further development.

Taking 30 provinces in China (Xizang, Hong Kong, Macao and Taiwan are excluded due to data availability) as the basic measurement unit in this study. Considering the similarities and differences in the technical level of industrial enterprises and regional resource endowments among regions, we divided the 30 provinces into three regions. The eastern region covers Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan, totaling 11 provinces

(municipalities). The central region covers Heilongjiang, Jilin, Shanxi, Anhui, Jiangxi, Henan, Hubei, and Hunan, totaling eight provinces. The western region includes Sichuan, Chongqing, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, Guangxi, and Inner Mongolia, totaling 11 provinces (autonomous regions/ municipalities).

All data come from the *National Enterprise Innovation Survey Yearbook*, the *China Statistical Yearbook*, the *Urban Construction Statistical Yearbook*, the *China Social Statistical Yearbook*, the *China Environmental Statistical Yearbook*, and the National Bureau of Statistics database. The data have no missing values and pass the collinearity test. The statistical results are shown in Table 3.

5. Results

5.1 The impact of industrial enterprise innovation on regional green development level

In this part, the collected data were analyzed, and the direct impacts of industrial enterprise innovation on regional green development were tested.

Figure 2 shows the calculated results of green development level and industrial enterprise innovation in each region. From the level of green development on the left side, it can be seen that from 2016 to 2020, the eastern region continued to rank first and was the only region above the national average. In addition, both the regional green development level and the national green development level are on the rise, and the green development level is stable. From the perspective of regional balanced development, the gap of green development level among the eastern, central, and western regions has gradually narrowed. From the trend chart of the industrial enterprise innovation on the right side, it can be seen that the regional industrial enterprise innovation is similar to the level of regional green development level, showing a decreasing order in the eastern, central, and western regions. The eastern and central regions are higher than the national average, and all regions showed an overall upward trend.

Based on the previous theoretical analysis and model construction, the regression results in Table 4 intuitively show the overall impact of industrial enterprises on the regional green development level. From the second column, we can know that industrial enterprise innovation significantly affects the regional green development, and positively promotes regional green development at a significant level of 1%, with a specific coefficient of 0.235. Hypothesis 1 holds. In the eastern and central regions, industrial enterprise innovation also has a positive effect on regional green development, and the specific impact coefficients are 0.199 ($P < 0.01$) and 0.379 ($P < 0.05$), respectively. But the calculated impact is not statistically significant for the western region. Combined with Figure 2,

Table 3: Statistical table of core variables

	Name	Number	Mean	Min	Max	standard d.	VIF
GDL	Regional green development	150	0.2651	0.1372	0.4857	0.0827	
EI	Industrial enterprise innovation	150	0.1972	0.0100	0.9691	0.1719	1.761
IS	Rationalization of industrial structure	150	1.5928	0.5369	3.0051	0.5795	2.734
ID	Regional resource dependence	150	0.0067	0.0101	0.0477	0.0088	1.374
UR	Urban-rural income gap	150	0.0804	0.0183	0.2183	0.0354	3.896
EE	Ecological resource endowments	150	35.1538	4.8700	66.8000	18.2535	1.418
EQ	Environmental quality	150	33.3093	9.5661	68.1768	11.0324	1.396
ED	Level of economic development	150	10.9801	10.2182	12.0086	0.3927	2.719

Note: The dependent variable GDL does not require a VIF test. When the VIF value is less than 10, it means that there is no need to worry about multicollinearity.

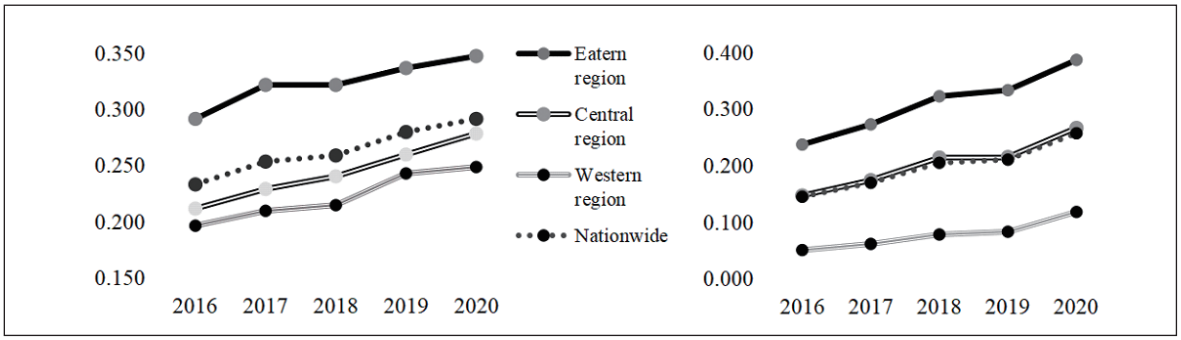


Figure 2: The average value of regional green development level (left) and industrial enterprise innovation (right) from 2016 to 2020

the possible reason is that the innovation level of industrial enterprises in the western region is generally low, and hence the increase in production efficiency caused by technology is low, therefore it is not strong enough to play a supporting role. By further observing the significance of the control variables in the western region, we can see that the variable indicating economic development level in the western region has a positive impact on the regional green development at a significant level of 1%. This means that the higher the level of economic development, the higher the level of green development in the west. In fact, the rapid increase in the level of green development in the western region in the past five years is also largely due to the rise of economic growth indicators.

5.2 Results of the mediating effect test

In this part, this study chooses to use the Bootstrap method to directly test the significance of the mediating effect "a*b". If the coefficient of the fourth column in Table 5 does not contain 0 in the 95% confidence interval, it means that there is a mediating effect. The overall test results are shown in Table 5.

5.2.1 Robustness test

In order to ensure the credibility of the results and test the stability of the results in Table 5, this study further uses two methods to carry out the robustness test.

Method one adjusts the explanatory variables. In addition to the number of patent applications, the process and product innovation of industrial enterprises is also a typical innovation output, which is the key performance of technology transformation. Therefore, the "number of patent applications" in the original indicator is replaced by "the number of industrial enterprises in the region to achieve product or process innovation" or "the total number of enterprises in the region". Method two increases the control variables. In general, the better the infrastructure construction is, the higher the efficiency of regional green development. Therefore, the level of

Table 4: Regression results of industrial enterprise innovation and regional green development level

GDL	Nationwide	Eastern region	Central region	Western region
EI	0.235***(7.611)	0.199***(4.716)	0.379**(3.221)	0.163(1.534)
EE	0.003***(3.676)	0.074***(3.736)	-0.092***(-3.502)	-0.001(-0.245)
EQ	-0.009*(-1.399)	0.116***(3.563)	-0.067*(-1.753)	-0.015*(-1.154)
ED	0.081***(6.040)	0.081**(3.139)	0.111**(2.945)	0.075***(3.865)
Constant	-0.780***(-4.944)	-1.424***(-3.837)	-0.256(-0.548)	-0.508**(-2.451)
R^2	0.615	0.634	0.546	0.376
F	46.015	16.956	8.163	5.908
N	150	55	40	55

Note: Given in parentheses are the values of t; and the asterisk(s) indicate the range of P-value: *(p<0.01), **(p<0.05), and ***(p<0.01).

Table 5: The mediating effect test results of each region

Influence path	a	b	a*b (95% BootCI)
Eastern region			
EI=>IS=>GDL	-0.1550	-0.0437	[-0.0059, 0.0396]
EI=>ID=>GDL	-0.0037**	0.9832	[-0.0425, 0.0255]
EI=>UR=>GDL	**-0.0234*** **	**-3.8480*** **	**[0.0362, 0.1812]**
Central region			
EI=>IS=>GDL	-2.7087***	0.0501	[-0.3212, 0.0366]
EI=>ID=>GDL	**-0.0697****	**-4.1351*** **	**[0.0892, 0.5073]**
EI=>UR=>GDL	-0.0654	0.0964	[-0.0712, 0.0232]
Western region			
EI=>IS=>GDL	**-3.7886***	**-0.0275****	**[0.0036, 0.2597]**
EI=>ID=>GDL	-0.0046	2.6799*	[-0.1064, 0.0495]
EI=>UR=>GDL	-0.0256	0.6149	[-0.1074, 0.032]

Note: *(p<0.01), **(p<0.05), and ***(p<0.001). The first column in the table shows three possible paths for the three regions. The exact result of each region needs to be checked to see whether the interval range shown in the fourth column of the table includes 0; and if not, the path of the region is established. The smaller the value of mediating variable is, the greater the impact is. Therefore, when "a" is negative, it means "promotion".

infrastructure is introduced as a new control variable. Referring to Liu J (2022), this study also selects the *per capita* road area to measure the level of infrastructure. The robustness test results from the two methods are good.

The significance of the core explanatory variable coefficient and the intermediary paths results are basically consistent with the results of Table 5, which confirms the rationality of the research. Due to the limitation of the length of the article, the robustness results are not displayed in the text.

5.2.2 The differentiated paths of eastern, central, and western regions

(1) The eastern region: narrow the urban-rural income gap.

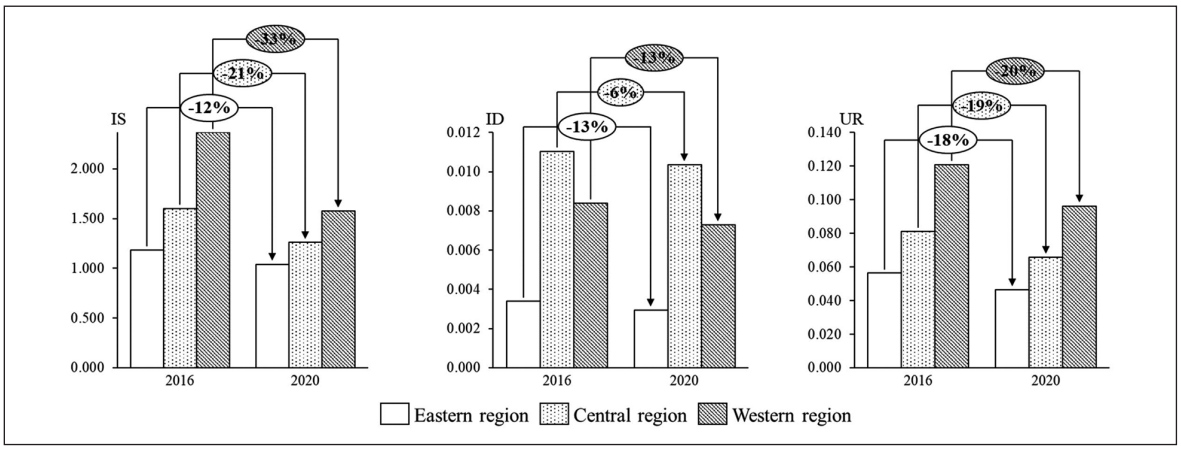
The influencing path of the urban-rural income gap in the eastern region has passed the mediating effect test. Its range of a*b under the 95% confidence interval is [0.0362, 0.1812], excluding 0; a and b coefficients are both negative, which means that industrial enterprise innovation in the eastern region has improved the regional green development level by narrowing the income gap between urban and rural areas.

Specifically, first of all, the industrial enterprises in the eastern region narrowed the urban-rural income gap with a coefficient of 0.0234 ($P < 0.01$). According to the previous UR calculation results of this study, the Theil index in the eastern region decreased by 18% in five years. This is commendable because the base of the coefficient in the eastern region is relatively low. In this case, it is still basically the same as the decline of 19% and 20% in the central and western regions, which reflects the contribution of the eastern region to narrowing the urban-rural income gap (Figure 3). Furthermore, the narrowing of the income gap between urban and rural areas has further improved the level of regional green development at a significant level of 1%, with a coefficient of 3.848. This is mainly due to the reduction of the income gap, which has brought about the improvement of social welfare and the fair and stable development of the regional economy, accounting for 70% of the growth of the green development level in the eastern region.

(2) The central region: reducing resource dependence.

The influencing path of reducing resource dependence in the central region has passed the mediating effect test. Its range of a*b under the 95% confidence interval is [0.0892, 0.5073], excluding 0; a and b coefficients are both negative, which means that industrial enterprise innovation in the central region has improved the level of regional green development by reducing resource dependence.

Specifically, first of all, the industrial enterprises in the central region reduced resource dependence with a coefficient of 0.0697 ($P < 0.05$). Combined with Figure 3, it can be seen that the resource dependence has decreased



(Note: The values from 2016 to 2020 are calculated. Limited by the length of the article, only the values of the first year and the last year are shown.)

Figure 3: The optimization range of IS, ID and UR in each region from 2016 to 2020

by 6% in five years. The core reason why the value in the central region is lower than the eastern and western regions is that the overall employment-population in the central region has fallen too much, reaching 20%, which is much higher than the corresponding rate of 6% in the eastern region and 5% in the western region. Furthermore, the reduction of resource dependence in the central region has significantly improved the level of regional green development, with a coefficient of 4.1351 ($P < 0.01$). This is mainly due to the improvement of social welfare, accounting for 56% of the growth of green development level in the central region. In addition, it can be seen from Table 6 that the central region promotes the rationalization of industrial structure through industrial enterprise innovation at the significance level of 1%, with a coefficient of 2.7087, but it fails to produce significant benefits for the improvement of green development level.

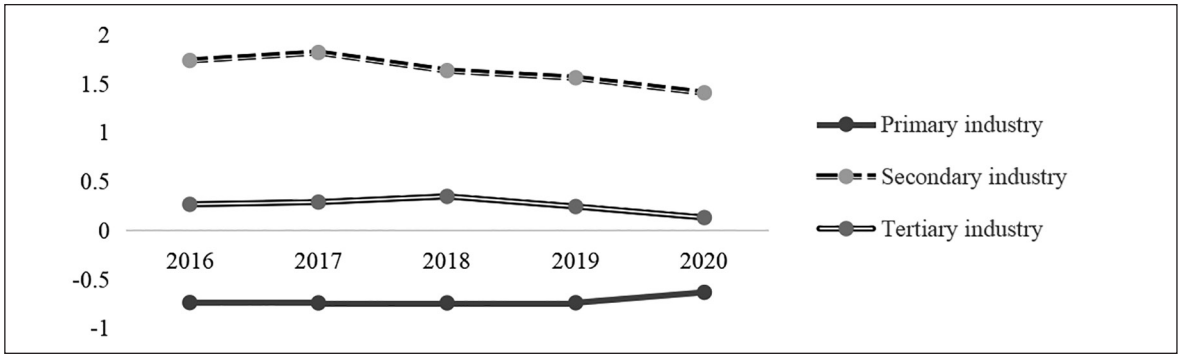
(3) The western region: improve the rationalization of industrial structure.

The influencing path of improving the rationalization of industrial structure in the western region has passed the mediating effect test. Its range of a*b under the 95% confidence interval is [0.0036, 0.2597], excluding 0; a and b coefficients are both negative, which means that industrial enterprise innovation in the western region has improved the level of regional green development by improving the rationalization of industrial structure.

Specifically, first of all, the industrial enterprises in the western region optimized the industrial structure with a coefficient of 3.7886 ($P < 0.01$). Combined with Figure 3, it can be seen that the industrial structure of the western region showed an overall improvement trend from 2016 to 2020. Its rationalization index decreased from 2.366 to 1.577, a decrease of 33%, which was much higher than the decrease of 12% in the eastern region and 21% in the central region. In the process of dissecting the deviation degree of the three industries in the western region in more detail, we find that although the value for the secondary industry is high, basically within the range of [1.52.0] (see Figure 4), it is also showing a downward trend year by year. Furthermore, the optimization of industrial structure rationalization in the western region has significantly improved the regional green development level, with a coefficient of 0.0275 ($P < 0.05$).

6. Discussion

Regional paths to green development are diverse. This study supports the confirmation of this well-established notion. Distinguishing from previous regional perspectives, in contrast, this study innovatively starts with the enterprises as the innovation subject and explores what role industrial enterprise innovation can play in the green development of different regions. We show that industrial enterprises in the eastern region promote social equity and harmonious development through narrowing the urban-rural income gap in order to enhance regional green development. The central region improves the level of regional green development by reducing its dependence on heavy resources. In the western region, the rationality of the industrial structure is optimized to achieve economic growth and regional green development.



(Note: The closer the value is to 0, the lower the deviation of the industry is.)

Figure 4: The deviation degree of the three industries in the western region from 2016 to 2020

Combining theory with the reality of the situation, we analyze the circumstances leading to the results. All results are traceable.

(1) The eastern region. The distribution of industrial enterprises in the eastern region is very characteristic. In addition to being scattered in towns and cities, a large number of well-established rural industries have been formed in the countryside. As noted in expert reports, the industrialization of rural areas in the developed coastal regions has been achieved, and employment in secondary and tertiary industries at the doorstep is common. The innovation of industrial enterprises in the eastern region empowers rural areas to expand production and increase income by utilizing technology and equipment, and moreover, the innovation of industrial enterprises in rural regions can directly promote rural development and narrow the income gap between urban and rural areas. In addition, urban and rural development in the eastern region is not only relatively balanced, but also relatively high-income, which is reflected in the economic and social efforts of the region to enhance people's well-being and improve the quality of life. Take facts as an example, China's central authorities issued a guideline on building the eastern province of Zhejiang into a demonstration zone for achieving common prosperity. We are also concerned that as seen in the Bootstrap test results, the marginal income of regional green development through the rationalization of industrial structure and reduction in resource dependence is low. Both two mediating variables failed to produce a statistically significant promoting role. This is largely due to the high level of innovation of industrial enterprises in the eastern region, the proportion of technology-intensive industries is larger than that of the central and western regions, and the market openness is high. As the highland of China's intelligent manufacturing development, the industrial structure there entered the track conducive to carbon emission reduction and green development earlier, which was also confirmed in the early research of Zhang Y G (2021).

(2) The central region. The central region is rich in resource elements and is an important energy supply guarantee area in China. In particular, energy production and energy-intensive industrial enterprises represented by Shanxi, Heilongjiang, Jilin and Henan provinces account for a large proportion. In the previous results, we found that the innovation of industrial enterprises in the central region has reduced regional resource dependence. There are two reasons for this. On the one hand, the innovation of industrial enterprises in the central region has optimized the technology of energy extraction and deep processing, and improved the efficiency of energy use. On the other hand, the innovation of industrial enterprises has accelerated the pace of building a "modern industrial system supported by advanced manufacturing industries" in the central region, and has led to the formation of diversified development of technology-intensive and labor-intensive industries, which can further get rid of the dependence on a single energy resource. The optimization of energy structure directly brings clean and environmental benefits, and the government can also transfer the funds originally used for resource exploitation to social construction such as medical care, education, transportation, *etc*., which improves the social welfare of the region. This is one of the reasons why the social level of green development in the central region has made significant progress. We are also concerned that in the Bootstrap test results, the optimization of the industrial structure in the central region has failed to achieve results

in promoting regional green development. China has issued a series of policy documents on promoting the high-quality development of the central region in the new era, which emphasizes the need to adhere to innovative development, promote the transformation and upgrading of traditional industries, as well as the deep integration of advanced manufacturing and modern service industries in the same direction. However, at the current stage of development, the *status quo* of the central region's high dependence on the secondary industry remains unchanged, and the phenomenon of convergence in industrial structure remains unresolved. This will also be a direction that the central region needs to work on in the future.

(3) The western region. In the western region, the level of industrial structure is lower. Combined with Figure 4, it is not difficult to find that the secondary industry of the western region shows the *status quo* of insufficient employment absorption and low labor productivity. The innovation of industrial enterprises enhances the net growth of employment, prompting the redundant personnel in the primary industry to transfer to the secondary and tertiary industries, thus alleviating the contradiction of the solidified industrial structure in the western region. In fact, from the policy point of view, in 2010, the State Council issued the *Guiding Opinions on Undertaking Industrial Transfers in the Central and Western Regions*, and in 2016, the National Energy Administration issued the *Guiding Opinions on Energy Work in 2016*, which proposes the gradient transfer of high-energy-consuming industries from the eastern region to the western region. This has, to a certain extent, enhanced the overall level of technological innovation of industrial enterprises in the western region, and improved the proportion of original output or the quality of output, while at the same time driving the benign development of new energy industries and so on. However, it should be noted that, due to the overall low level of innovation of industrial enterprises in the western region, scientific and technological human resources, market-oriented institutional construction, and many other aspects are far lagged behind compared with those in the eastern and central regions (Wang, 2019). The improvement of regional green development level also benefits more from the regional economic growth and social welfare brought by industrial development, rather than ecological construction. It is worth mentioning that although the reduction in the income gap between urban and rural residents in the western region is the largest among the three regions, it does not have a significant impact on regional green development due to its low real income, which is consistent with the findings of Wang (2021).

Although there are important discoveries revealed by these studies, there are also limitations. First, the study divides China into three regions, but in fact, the provinces in each region, and even the finer-grained administrative divisions in each province, have differentiated green development paths that adapt to local characteristics. Second, the impacts of each influencing factor in the real social environment are complex. Our current selection of mediating variables may need to consider their possible coupling effects on each other. In further studies in the future, the paths results under the interaction effects can be further dissected.

7. Conclusion

Based on the relevant data of the 30 provinces in the 13th Five-Year Plan period, this study establishes a parallel multiple intermediary model on the basis of constructing the evaluation index system of regional green development level. Through basic regression and Bootstrap test, this paper focused on the influence paths of industrial enterprise innovation on green development in different regions. Industrial enterprise innovation has a significant impact on the improvement of regional green development level. However, the western region has not yet significantly promoted regional green development due to the overall low level of industrial enterprise innovation. At the same time, the study found that there is heterogeneity in the impact paths of industrial enterprise innovation in each region. The rural industrial foundation in the eastern region is relatively good, and the overall income level of urban and rural areas is relatively high. It can improve the level of regional green development by narrowing the income gap between urban and rural areas, mainly to improve social welfare and promote social equity. The central region is rich in resources. Industrial enterprise innovation realizes regional green development by reducing resource dependence, which is mainly based on ecological construction and social welfare improvement. The innovation of industrial enterprises in the western region promotes regional green development by improving the rationalization of industrial structure, which is mainly based on the improvement of economic growth.

Regional implementation of green development has been a general consensus. It is necessary to adhere

to innovation-driven green transformation and give full play to the main role of enterprises. However, due to the different situations in different regions, local governments should combine the resource endowment advantages and institutional environment of each region, and formulate and implement relevant action plans and measures according to local conditions under the overall national policies of "carbon peaking and carbon neutrality" and "high-quality development." The eastern region should take advantage of the innovation and development advantages of industrial enterprises and further strengthen the measures such as nurturing agriculture by industry. And it should further promote the development of new rural industrialization, and narrows the income gap between urban and rural areas to create a model of social justice. The central region should face up to the advantages and limitations of resources, promote the development of traditional industrial enterprises to be intelligent, green and service-oriented in accordance with the Strategy for the Rise of Central China, and build a base of energy raw materials to form an integrated energy hub. The western region should grasp the dual tasks of catching up with development and green transformation, accelerating the transformation and layout of industrial enterprises to encourage industries, and further supporting the optimization and upgrading of industrial structure in the western region. At the same time, in this process, the western region should give full play to the guiding role of the government in scientific and technological innovation and improve the industrial supporting system.

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