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Study on Macroeconomic Risk Exposure under the Background of Green and Low-carbon Transition

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Abstract

Promoting green and low-carbon transformation of economy and society is an important means for countries in the world to actively respond to global climate change.However, due to different national conditions, economic stages and economic structures of countries, the risks they face in the process of promoting green and low-carbon transformation are different. In this regard, this study takes China's provinces as the research objects, and studies the green and low-carbon transformation risks of each province according to the degree of provincial dependence on sunset industries in terms of foreign exchange earnings, fiscal taxes and employment wages. The results show that the mining and supply of fossil energy and the processing of non-ferrous metals are important sources of carbon emissions. In this regard, this paper puts forward some suggestions from the aspects of precise control of transformation risks, prevention of risks to achieve safe carbon reduction, and the main issues of "efficiency and fairness".

Keywords

Green and Low-carbon Transformation; Exposure to Risk; Input-output Model.

1. Introduction

Achieving the Sustainable Development Goals is a broad and profound economic and social systemic transformation. While promoting the low-carbon transformation of the economy to achieve green development, the transformation risks caused by uncertainties in policies, technologies and markets may also pose a threat to macroeconomic stability. In addition, the significant differences in the economic conditions of each province further aggravates the heterogeneity of transition risks at the provincial level. Therefore, it is of great practical significance to effectively identify and quantify transition risks and analyze their heterogeneity at the provincial level for preventing and resolving potential economic and financial risks and realizing high-quality economic development.

The "hard landing" of low-carbon transition tends to lead to stranded assets in carbon-intensive sectors, so research has focused on the financial risks driven by stranded assets of large fossil fuel companies, and the cascade effects on other sectors such as banking and stock markets [1] . However, financial instability is only one of the specific manifestations of macroeconomic risks. In addition, the above studies mainly focus on the sources and influence mechanism of transition risks. Based on this, this paper will quantitatively evaluate the potential scale of provincial transition risk, namely risk exposure, from a macro perspective, and pay more attention to the difference analysis of transition risk.

This paper estimates the potential transition risk exposure of each province from a macro perspective. Specifically, this paper first calculates the indirect carbon emission intensity of each industry to its upstream and downstream industries through Leontief inverse matrix and Ghosh model, and defines the sunset industry based on it. Compared with the existing literature, the possible marginal contributions of this paper mainly include the following: (1) multi-

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dimensional macroeconomic exposure analysis. This paper assesses the transition risk exposure from three dimensions: external risk, fiscal risk and socio-economic risk, comprehensively assessing the vulnerability and risk of each province in the transition process. (2) Estimate transition risk exposure based on input-output model. By using China's multi-regional input-output tables to assess the direct and indirect dependence of provinces on high-carbon emission industries, this paper pays more attention to the economic linkages between industries. (3) Application of economic resilience. Economic resilience is introduced in the analysis of transition risk exposure, which is used to describe the adaptive capacity of provinces to green transformation, so as to more accurately assess vulnerability.

2. Literature Review

2.1. Transition Risk Exposure and Economic Resilience

Generally speaking, risk comes from "uncertainty". Relatively specific risks such as transition risks come from "uncertainties" brought about by low-carbon economic policies, technological innovation and changes in consumer investors' preferences[2]. First of all, whether the climate policy is divided according to the degree of instrument enforcement or whether it is based on the criteria of market mechanism, it may lead to the shrinkage of the collateral or asset value of various economic entities, and evolve into systemic risks after multiple effects such as financial acceleration effect or amplification of financial frictions. Secondly, driven by factors such as corporate social responsibility, investors' attention, and improving their own market competitiveness, market players will actively carry out green technology innovation. Finally, in the context of green and low-carbon transformation, investors have significant green preference. Investors' green preference can reduce the credit spread and financing cost of enterprises with good green performance, enhance the value of enterprises, and stimulate enterprises to disclose carbon information to a certain extent.

The existing literature has fully studied the possible macroeconomic shocks caused by transition risks. In the process of promoting transformation, some regions may need to import raw materials or capital to put into production to achieve the transformation goal[3], How to balance the balance of payments and control the risk exposure depends on the adaptive capacity and coping strategy of each region[4].

The government sector also faces a balancing act. Through mainstream climate policies such as carbon pricing, green subsidies, and green infrastructure construction, the government can effectively promote the green transformation of the economy. On the one hand, although carbon pricing policy has no direct fiscal cost, it may reduce real GDP by increasing energy cost; On the other hand, for the provinces whose fiscal revenue is heavily dependent on sunset industries, green subsidies and green infrastructure construction will increase government expenditure and reduce fiscal revenue at the same time. In addition to the right policy mix, Chen et al. pointed out that the effectiveness of fiscal expenditure stimulus depends on the popularity of green skills[5]. However, while low-carbon industries put forward technical requirements for workers, they may also have an impact on regional employment and wage levels[6].

2.2. Transition Risk Exposure Measurement Methodology Literature

At present, there are many methods for measuring climate transition risk exposure, and the specific methods used to measure climate transition risk are also different due to different research objectives. As climate transition risks are highly uncertain, FSCO particularly advocates the use of scenario analysis to measure climate risks. Compared with the stress testing method based on historical data, the scenario stress testing method not only has certain forward-looking advantages, but also attaches importance to extreme situations and can

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provide tail risk information for decision makers. Battiston et al. used the network-based stress test method to study how climate policy risks propagate within the financial system[1].

In terms of macro analysis models, the Integrated Assessment model and its derived models such as DICE, RICE and PAGE have been widely used in climate assessment due to their comprehensiveness, flexibility and strong policy orientation. In their study of the impact of emission reduction restrictions on fossil fuel production in different regions, McGlade et al. constructed a single comprehensive assessment model that included the quantity, location, and nature of fossil energy reserves and resources[7].

In addition, the Input-Output Model, which was early applied in the fields of carbon footprint migration research, industrial chain and industrial output research, has gradually been applied in the field of risk exposure measurement. Compared with other calculation models, the input-output model can capture the complex connection of various sectors in the economic system, quantify the risk transmission mechanism, and reveal the characteristics of systemic risks through multi-sector linkage analysis. The purpose of this paper is to measure the risk exposure of provinces in the process of promoting green and low-carbon economic transformation from the macroeconomic level. Therefore, considering the research purpose and existing research literature, the input-output model is the most appropriate in the macro analysis model, which can comprehensively evaluate the impact of transformation risks while It intuitively reflects the differences in the transition risk exposure of each province, which has important reference value for the implementation of low-carbon transformation in each province.

3. Model and Data Sources

Input-output models are used to analyze industrial interdependence within an economy or between different economies. Based on the basic IO model, the developed multi-regional input-output model is more widely used to analyze the relationship between industries in different regions, which is also an important tool for the analysis of low-carbon transition. In addition, combined with the research objectives, this paper measures the economic resilience at the provincial level by constructing an index system and using the entropy weight-TOPSIS method.

The main data for the macroeconomic risk measurement of green transformation in this paper come from China's multi-regional input-output table of CEADs[8, 9], The monetary input-output information of 42 economic sectors in 31 provinces and the carbon dioxide emission inventory of various industries are completed through the statistical yearbooks of each province for the data not included in the input-output table during the calculation process.

3.1. Carbon Emission Intensity and High Energy Consumption Industries

To calculate upstream indirect emissions, in addition to taking into account the carbon emissions content of direct inputs, it is also necessary to take into account the carbon emissions content of all inputs that produce these direct inputs. The column vector of the total output of each province and industry including direct and indirect is equal to the intermediate input and the column vector of final demand (Y). The intermediate input is obtained by multiplying the technical coefficient matrix (A) with the column vector of the total output (x), which can also be written as:

$$\boldsymbol{X} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{Y} \tag{1}$$

In Equation (1), $\boldsymbol{L} = (\boldsymbol{I} - \boldsymbol{A})^{-1}$ is the inverse Leontief matrix.

Before analyzing the macroeconomic risk exposure of provinces in the process of green and low-carbon transformation, it is first necessary to define the sunset industry. Therefore, this

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paper first calculates the direct and indirect carbon emission content of each province and each industry.

$$e_i^{direct} = \frac{Emission_i}{x_i} \tag{2}$$

In Equation (2), $Emission_i$ is the carbon dioxide emissions of industry i, and x_i is the total output of industry i.

Continue to define backward (upstream) inter-carbon emission intensity:

$$e_i^{backward} = \hat{e}\boldsymbol{L} - \hat{e} \tag{3}$$

In Equation (3), L is the Leontief inverse matrix, and $\hat{e}$ is the e_i^{direct} diagonalized matrix.

In addition to backward (upstream) carbon intensity, it is also necessary to determine the carbon emissions resulting from the use of goods and services produced by the industry under consideration.

$$\begin{cases} \boldsymbol{e_i^{forward}} = \boldsymbol{G}\hat{e} - \hat{e} \\ \boldsymbol{G} = (\boldsymbol{I} - \boldsymbol{B})^{-1} \end{cases} \tag{4}$$

In Equation (4), G is the Ghosh matrix and B is the direct output coefficient.

Based on the level of direct, backward indirect and forward indirect carbon emission intensity, sunrise and sunset industries can be defined.

3.2. External Risks

External exposure refers to the ratio of the foreign exchange generation of sunset industries to the total foreign exchange generation, and this indicator indicates the amount of foreign exchange lost if the province stops the export trade of products of sunset industries. It can be achieved by the following calculation:

$$\begin{cases} \boldsymbol{\alpha} = \boldsymbol{i^T}[\boldsymbol{A^\alpha}(\boldsymbol{1} - \boldsymbol{A})^{-1}] \\ \boldsymbol{A^\alpha} = \boldsymbol{A}\odot(\boldsymbol{1} - \boldsymbol{D}) \end{cases} \tag{5}$$

In Equation (5), i is the column vector with each element equal to 1, D is the virtual matrix with the inter-provincial internal relationship equal to 1 and the rest equal to 0, and ⊙ represents the multiplication of elements. The calculated result α is the row vector reflecting the direct and indirect inputs.Before calculating the net foreign exchange output of each industry in each province, it is also necessary to calculate the amount of foreign exchange generation per unit of output of each industry in each province. Therefore, the net foreign exchange output by industry production unit after deducting direct and indirect inputs outside the province is calculated as follows:

$$Netfc_{ij} = exp_{ij}(1 - \alpha_{ij}) \tag{6}$$

In Equation (6), $Netfc_{ij}$ is the net foreign exchange generation of industry i in province j, exp_{ij} is the foreign exchange generation of industry i in province j per unit of output, and α_{ij} is the proportion of foreign inputs in industry i in province j.

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Finally, the macroeconomic risk exposure of the green and low-carbon transformation of the economy in the external risk is as follows.

$$EXexposure_j^S = \frac{\sum_{i\in S}(Netfc_{ij}x_{ij})}{\sum_i(Netfc_{ij}x_{ij})} \tag{7}$$

Where S is the set of all sunset industries in the considered country.

3.3. Financial Exposure

Fiscal exposure is used to reflect the impact of promoting green and low-carbon economic transformation on provincial fiscal revenue, and then reflect the dependence degree of provincial fiscal revenue on sunset industries.

$$X^n = (1 - A^n)^{-1}Y^n \tag{8}$$

Where $A^n = d^n \odot A$, $Y^n = d^n \odot Y$, d^n are column vectors, representing the effective shares of all sectors excluding sunset industries: for sunset industries, $d^n = 0$; For completely non-sunset industries, $d^n = 1$; For sectors that may include sunset industries, d^n depends on the proportion of non-sunset industries within the industry. The Leontief matrix is re-estimated to measure the importance of non-sunset industries to the economic system.

In addition, the tax part of the government's fiscal revenue can be regarded as consisting of two parts: the production tax (t_{ij}^{Produ}) and the wage profit tax ($t_{ij}^{earning}$). The production tax can be defined as the tax generated per unit of output. In addition to the production tax, the wage profit tax is as follows:

$$t_{ij}^{earning} = \frac{ProTaxes}{Profits}\frac{Profits_{ij}}{x_{ij}} + \frac{WageTaxes}{Wages}\frac{Wages_{ij}}{x_{ij}} \tag{9}$$

In Equation (9), $ProTaxes$is the total corporate income tax, $Profits$ is the total corporate surplus, and $Profits_{ij}$ is the corporate surplus of industry i in province j; $WageTaxes$ is the total personal income tax, $Wages$ is the total remuneration of workers, and $Wages_{ij}$ is the remuneration of workers in industry i in province j.

Finally, we calculate the fiscal exposure of each province to the green and low-carbon transformation of the economy:

$$\begin{cases} Fexposure_j^S = 1 - \frac{\sum_i t_{ij}^{total}x_{ij}^n}{\sum_i t_{ij}^{total}x_{ij}} \\ t_{ij}^{total} = t_{ij}^{product} + t_{ij}^{earning} \end{cases} \tag{10}$$

3.4. Socio-economic Exposure

First, we calculate the wage contribution share of sunset industries:

$$\begin{cases} Wexposure_j^S = 1 - \frac{\sum_i salary_{ij}x_{ij}^n}{\sum_i salary_{ij}x_{ij}} \\ salary_{ij} = \frac{wages_{ij}}{x_{ij}} \end{cases} \tag{11}$$

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Finally, the contribution of sunset industries to social employment is calculated:

$$\begin{cases} EMexposure_j^S = 1 - \frac{\sum_i job_{ij} x_{ij}^n}{\sum_i job_{ij} x_{ij}} \\ job_{ij} = \frac{Employment_{ij}}{x_{ij}} \end{cases} \quad (12)$$

4. Analysis of Results

4.1. Define Sunset Industries

According to the above research design, the direct and upstream and downstream indirect carbon emissions of each industry are obtained, and the carbon emission intensity is divided according to this standard. The specific results are as follows:

Table 1. Define sunset industries

	Low upstream emissions	Upstream medium emissions	High upstream emissions
Low downstream emissions	Education; Textile clothing shoes and hats; Leather down and its products wood processing products and furniture; Public administration, social security and social organization; Real estate; Communication equipment, computers and other electronic equipment; Health and social work	Technical services; Water conservancy, environment and public facilities management; Construction; Food and tobacco; Special purpose equipment; Scientific research	Agriculture, forestry, animal husbandry and fishery products and services
Downstream medium discharge	Electrical machinery and equipment; Culture, Sport & Recreation; Information transmission, software and information technology services; Instrument and meter	General purpose equipment; Resident services, management and other services; Metal products; Accommodation and catering; Transportation equipment	Non-metallic mineral products; Chemical products; Wholesale and retail; Paper printing and cultural and educational sporting goods
High downstream emissions	Other manufactured products; Finance; Water production and supply	Gas production and supply; Oil and gas extraction products	Production and supply of electricity and heat; Metal smelting and calendering processing products; Transportation, storage and postal services; Coal mining and selection products; Petroleum, coking products and nuclear fuel processing products; Metal mining and selection products; Leasing and business services; Non-metallic ore and other ore mining products; Metal products, machinery and equipment repair services

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4.2. Foreign Exchange and Fiscal Risk Exposure

Based on the defined sunset industries, by calculating their ability to create foreign exchange and increase fiscal revenue, this paper analyzes the dependence degree of each province on the sunset industries in terms of foreign exchange and fiscal revenue, so as to better evaluate the macroeconomic risk exposure that each province may face in the process of promoting green and low-carbon economic transformation.

The horizontal axis of Figure 1 shows the financial risk exposure of each province, which is measured by the dependence degree of each province's fiscal revenue on the sunset industry; The vertical axis represents the foreign exchange exposure of each province, measured by the share of foreign exchange earnings of sunset industries in each province. The color scale on the right is the economic resilience of each province, and the value from high to low indicates that the economic resilience is from weak to strong.

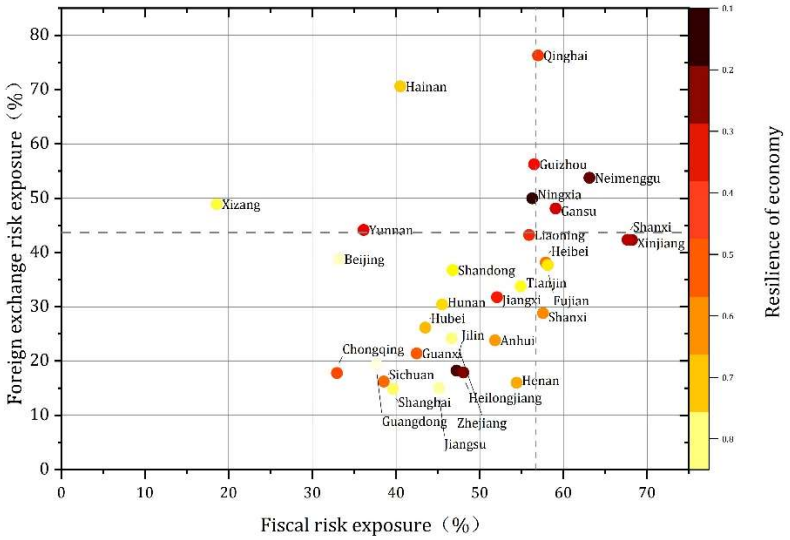

Figure 1. Distribution of foreign exchange fiscal risk exposure

Secondly, from the perspective of fiscal risk, the provinces that are easy to receive the impact degree of transformation in fiscal revenue are the provinces on the right of the dotted line of the vertical axis, namely Qinghai, Guizhou, Ningxia, Liaoning, Hebei, Fujian, Shanxi, Gansu, Inner Mongolia, Shanxi and Xinjiang. The dashed line is the third quartile and divides the graph into four regions. Provinces located in the upper right corner are more vulnerable to the negative impact of transition in terms of foreign exchange and fiscal revenue, while provinces located in the lower left corner are relatively less exposed to macroeconomic risks in terms of foreign exchange and fiscal revenue.

4.3. Socio-economic Risk Exposure

Socio-economic risk exposure can be reflected by employment and wage levels, but it is obviously not possible to comprehensively evaluate the vulnerability of a province at the socio-economic level only based on the dependence of the province on the sunset industry at the two levels of job creation and wage payment. In addition to significant differences in geographical location, natural resources and other aspects, population age structure, labor quality and even regional culture may also have heterogeneity in the socio-economic risk exposure faced by provinces in the process of promoting green and low-carbon economic transformation. Therefore, this section considers the dependence of provincial employment and wages on sunset industries, It also combines the economic resilience of each province for comprehensive

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analysis. The vertical axis shows the direct and indirect dependence of each province on employment creation by sunset industries, and the horizontal axis shows wages.

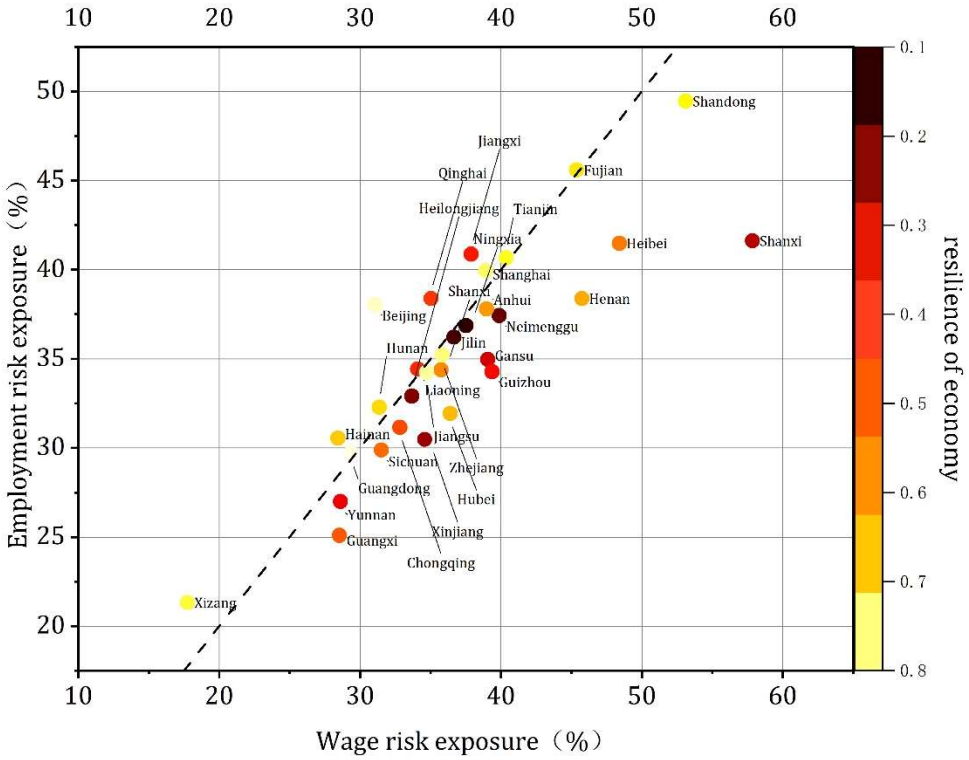

Figure 2. Socioeconomic risk exposure

In the figure, the provinces in the upper right heavily rely on sunset industries in providing jobs and paying wages, such as Shandong, Shanxi, Fujian, Shanxi and Hebei. The dotted line in the figure is the 45° line, indicating that wages are equivalent to the employment share. The provinces above the dotted line, such as Beijing, Qinghai, Jiangxi and Hainan, have a high degree of dependence on sunset industries in terms of employment, but do not rely on sunset industries in terms of wages. The opposite is true for the provinces below the dotted line, such as Shandong, Hebei, Shanxi, Henan, Guizhou, and Guangxi, which provide fewer jobs in sunset industries but have higher wages.

5. Conclusion and Suggestions

5.1. Conclusion

The results show that: 1) The mining and supply of fossil energy and the processing of non-ferrous metals are important sources of carbon emissions, but there are certain differences in the emission links. Metal and mineral products, chemical products and agriculture, forestry, animal husbandry and fishery products and services have high carbon emission intensity mainly in the upstream; The mining and processing of coal, oil, natural gas and other fossil energy as well as the production and supply of water mainly generate carbon emissions during the use of downstream industries. 2) There are significant differences in the degree and type of dependence of each province on sunset industries. In the process of analyzing the economic resilience of each province, it is found that although some provinces have high risk levels, their economic resilience is relatively strong, which means that their vulnerability in the actual transition process may be lower than that of the provinces with similar risk levels but poor resilience. 3) Finally, this paper finds that the level of risk exposure is closely related to the

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economic and industrial structure formed by early development. Provinces with high levels of risk exposure are mainly concentrated in northwest China and North China and often have relatively rich fossil energy resources. In their early development, they relied on rich mineral resources to promote economic development while forming a structural system dominated by heavy industry. Therefore, they are facing greater risk exposure today when the development concept changes and advocates low-carbon transformation. Most provinces in South and southwest China benefit from diversified economic structures, thus taking the lead in promoting green and low-carbon economic transformation. Although the economic structure of the provinces in central China, East China and Northeast China is relatively diversified, they still have a considerable scale of sunset industries as economic support, so they will also face certain transformation risks.

5.2. Suggestions

(1) Determining the path of green and low-carbon economic transformation requires precise control of transformation risks. For provinces with large exposure to external and total output risks, they can actively promote industrial upgrading, diversify product export structure, improve resource utilization efficiency and other aspects to determine their own transformation path. For provinces with high exposure to social and economic risks, they can promote green and low-carbon economic transformation through vocational and technical training, breaking through employment information barriers, improving social welfare and other policies. On the one hand, the government of China's provinces has always played an important role in promoting the process of economic transformation. Financial support plays an important role in guiding capital, stimulating technological innovation, optimizing resource allocation and other aspects; On the other hand, the large exposure of fiscal risk means that the sunset industry is an important source of government fiscal revenue, and promoting the green and low-carbon transformation of the economy represents the reduction of fiscal revenue.

(2) While preventing risks and achieving safe carbon reduction, it is also necessary to focus on "efficiency and fairness." Precise risk control solves the efficiency problem in the process of pollution reduction and carbon reduction, but the equity problem in the transition process should also be paid attention to. Under the background of the change of development concept and the advocacy of green economic development, the transformation difficulties faced by these provinces should be solved collectively. For example, a recognition mechanism based on historical responsibility and contribution should be constructed to compensate traditional energy producing areas that may suffer economic losses due to low-carbon transition by setting up special funds or providing financial transfer payments and other means; For the provinces affected by the transformation, local governments provide strong support for industrial transformation; Under the framework of coordinated regional development, the economy promotes cross-regional cooperation, and developed regions and traditional energy producing regions realize resource complementarity by establishing partnerships and contributing development opportunities. Such mutual assistance measures can not only provide a strong boost to the provinces with large exposure to transformation risks, but also play an important role in comprehensively implementing the new development concept and promoting high-quality economic development.

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