Study on Regional Economic Effect of "West-East Power Transmission"

Kuang Xi *

Department of international Finance, Sun Yat-sen University, Guangzhou China

* Corresponding Author Email: kuangx5@mail2.sysu.edu.cn

Abstract. There is a certain mismatch between China's energy distribution and economic development. In this regard, the "West-East Power Transmission" project has optimized the allocation of China's power resources by exploiting the energy potential of the west. Based on the relevant economic data of 31 provincial administrative units in China from 1995 to 2018, combined with theoretical mechanism analysis, this paper hopes to explore the regional economic effect of "west point to East transmission" by designing a dynamic two-way fixed effect DID model divided into input and output areas. It is found that the policy of "power transmission from west to East" has no significant promoting effect on the whole, but has significant promoting effect on the economy of the import area in the medium and long term. In the input area, it mainly improves the output value of the tertiary industry and promotes the optimization of industrial structure. In addition, the heterogeneity robust estimators of de Chaisemartin and D 'Haultfoeuille were also used to estimate the policy effect at the input site, and the results were similar to those of dynamic TWFE.

Keywords: West-to-East Power Transmission; Regional Economy; DID; Dynamic TWFE; Heterogeneity Robust Estimators.

1. Introduction

Chinese energy structure shows a pattern of scarcity in the east and wealth in the west. The theoretical reserves and exploitability of hydraulic resources in the 10 provinces and cities in the west account for 82% and 72% of the country, respectively, and the reserved reserves of coal account for 39% of the country. However, the eastern coastal areas, as the vanguard of China's reform and opening up and the pioneer area of industrialization, are relatively short of natural resources such as coal, gas and hydraulic power. It is difficult to support the energy needs of its economy. "West-east power transmission" is a strategic measure to develop energy in the west and transfer it to the east in the form of electricity, so as to optimize the allocation of national power resources and develop the energy potential of China's vast territory and abundant resources.

The "West-east power transmission" project started at the end of the 20th century, and the main line was completed before 2010, and it is still being optimized and improved by 2022. Up to now, the construction of "west power transmission to the East" has been more than 20 years, and major lines have been completed one after another. Taking into account the reform of the tax sharing system in 1994 and the epidemic in 2019, this paper collected 24 years of panel data of 31 provinces or regions in China from 1995 to 2018, including the gross domestic product (GDP) of each province or region, the gross domestic product of the primary, secondary and tertiary industries, the number of regional employees, and the general budget expenditure of local finance. Consumer Price Index (CPI), data on the number of colleges and universities. Based on the analysis of the production theory model, we put forward three assumptions about the "West-east power transmission" policy: (1) "West-East power transmission" will promote the economic development of the import and export areas, and increase the GDP growth rate. (2) There should be a significant difference in the policy effect between the input and the output areas, and the GDP promotion effect of the input areas should be more significant. (3) The primary industry consumes less electricity, and the impact of "west-east power transmission" should also be smaller than that of the secondary and tertiary industries.

Through the design of a dynamic bidirectional fixed effect model, the research results show that if hypothesis (1) is rejected, although the "west-east power transmission" has a significant promoting

effect on the GDP of the input area in the medium and long term, the result on the output area is not significant, and the policy effect is limited in the output area. Hypothesis (2) cannot be rejected, the effect of the "west-east power transmission" policy is significantly different between the input area and the output area, and the economic promotion effect on the input area is significant. Hypothesis (3) cannot be rejected. In terms of input area, the output value of the primary industry may even have a negative effect after policy intervention, the promotion effect of the output value of the secondary industry is not significant, and the effect of the output value of the tertiary industry is even more significant than the policy effect of the total output value.

In terms of measurement methods, this paper chooses to use the staggered differential method to analyze the policy effect of "west-east power transmission". In China, Zhou Li 'an et al. (2005) was the first to study the effect of China's rural tax and fee reform policy by using the differentially applied method [1]. Huang Wei et al. (2022) found that in recent years, the number of literatures using DID also increased [2]. However, many researchers have gradually noticed the potential bias of staggered DID in the presence of heterogeneous processing effects. Liu Chong et al. (2022) sorted out this bias and summarized the cutting-edge heterogeneous staggered differential processing and estimation methods in the academic world [3]. This paper attempts to use the estimators proposed by de Chaisemartin and D 'Haultfoeuille (2020a, 2022a) together with traditional staggered DID to study the effect of the "west-to-east power transmission" policy [4].

In view of the fact that most scholars only consider the duality of power consumption and economic growth in their research, this paper introduces the policy effect of west-to-east power transmission to explain regional economic development differences, uses the multi-period differential model to make an empirical analysis of the regional economic growth effect and difference of west-to-east power transmission policy, and explores the relationship between economic development and power consumption intensity. It is of great significance to promote energy structure adjustment and economic structure optimization. Compared with the double difference proposed by Yang Xianming et al. (2022), this paper combined the estimators proposed by Chaisemartin and D 'Haultfoeuille (2020a, 2022a) on the basis of their bidirectional fixed-effect interleaved DID to try to deal with the potential bias caused by the heterogeneity of treatment effects. In addition, this paper will also study the influence of policies on different industries to explore the difference in the degree of influence of electric power development on the development of different enterprises.

2. Model Building and Solving

2.1. Model Assumption

As a product of the import and export areas and a factor of production, electricity promotes the economic development of the import and export areas. The progression mechanism is different. The "west-east power transmission" policy can theoretically stimulate the demand for electricity in the exporting areas and promote the western region. Investment in energy development, increase production capacity, reduce average cost, and drive the development of electric energy and supporting industries; while in input. The "west-east transmission" will increase the supply of electricity, reduce the price of electricity as a factor of production, and promote increased output. Relatively speaking, for the export area, only the power related industries will have more direct growth, while in the input area will push. The increase in the capacity of the electricity industry in the whole society. In summary, this paper proposes the following research hypotheses to be verified:

The "West-east transmission of electricity" will promote the economic development of both the import and export areas, and increase the GDP growth rate.

There should be a significant difference in the policy effect between the input and the output areas, and the GDP promotion effect of the input areas should be more significant.

The primary industry consumes less electricity, and the impact of "west-east power transmission" should also be smaller than that of the secondary and tertiary industries.

2.2. Data Description

Considering the reform of the tax sharing system in 1994 and the epidemic after 2019, this paper collected 24 years of panel data of 31 provinces or regions in China from 1995 to 2018, including the gross domestic product (GDP) of each province or region, the gross domestic product of the primary, secondary and tertiary industries, the number of regional employees, and the general budget expenditure of local finance. Consumer Price Index (CPI), data on the number of colleges and universities.

2.3. Static Bidirectional Fixed Effect (DID) Model

The recognition principle of the differential differential method is as follows: first observe the changes of the individuals in the treatment group before and after treatment, then observe the changes of the control group, that is, the untreated group, before and after treatment, and use the changes of the untreated group to estimate the potential state of the individuals in the treatment group after treatment. The difference between the two changes is the impact of the treatment on the individuals. In general, when DID is used for research, it is also necessary to add individual fixed effect and time fixed effect, which is the classic two-way fixed effect model. The static bidirectional fixed effect model assumes the following:

$$Y_{it} = \alpha + \beta(D_i \times T_t) + \theta \mathbf{X}_{it} + \sigma_i + \lambda_t + \varepsilon_{it} \quad (1)$$

Based on the scenario in this paper, Y_{it} is the provincial GDP, D_i is the group variable of the province, T_t is the time variable of policy implementation, $\mathbf{X}_{it}$ is the control variable at the provincial level over time, σ_i is the individual fixed effect, controlling the factors that do not change with time at the provincial level, λ_t is the time fixed effect, fixing the factors that change with time across provinces. The bidirectional fixed-effect model should be used by identifying the following assumptions:

2.3.1. Strict Exogenous Hypothesis

(1) There can be no interference factors that change with time; (2) The outcome variables of the past cannot affect the outcome variables of the current period; (3) Past variables cannot affect future processing states; (4) The current processing state cannot affect the future outcome variables. In general studies, this hypothesis is not much different from the parallel trend hypothesis, but strictly speaking, it is stronger than the parallel trend hypothesis [3].

2.3.2. Unanticipated Assumption

The outcome variable of an individual's period does not affect its future processing, that is, the individual does not anticipate whether it will receive processing in the future and change its behavior

2.3.3. Unit Processing Variable Value Stability Assumption

Whether different individuals are treated is independent of each other, and whether any individual is treated does not affect other individuals

2.3.4. Homogeneous Treatment Effect Hypothesis

The size of the treatment effect should be the same for different individuals and different times. This hypothesis is often ignored in traditional studies. In this paper, the subsequent estimators proposed by de Chaisemartin and D 'Haultfoeuille et al will attempt to deal with the problems caused by the consistency of treatment effects.

Hypothesis 4) is not taken into consideration in the basic regression of this paper. The policy of "transmission of electricity from west to East" is a long-term large-scale project, and its impact is long-term and dynamic. Therefore, in order to capture and explore the policy effects after multiple periods, the dynamic differential model is adopted in this paper, and the model is as follows:

$$Y_{it} = \alpha + \sum_{\tau=EW}^{-2} \beta_\tau\big(D_i \times \mathbf{1}(t - T_D = \tau)\big) + \sum_{\tau=0}^{\mathrm{BW}} \beta_\tau\big(D_i \times \mathbf{1}(t - T_D = \tau)\big) + \mathbf{X}_{it} + \sigma_i + \lambda_t + \varepsilon_{it} \quad (2)$$

2.4. Heterogeneity Problem Treatment

The above is a classic differentially applied process, but a study by deChaisemartin and D 'Haultfoeuille et al. found that heterogeneity in the differentially applied method significantly affects the effectiveness of the results. Based on the research results, this paper attempts to explore the heterogeneity problem more deeply.

In the bidirectional fixed-effect model, if there are only two sets and two periods of DID setting, the unbiased estimator of ATE (average treatment effect) can be obtained by TWFE only if the parallel trend hypothesis is satisfied, while in the multi-phase DID7, in addition to the parallel trend hypothesis, the non-heterogeneity hypothesis also needs to be satisfied. TWFE is an unbiased estimator of ATE only if the assumption that the treatment effect does not differ between different time points and different groups is satisfied (in dynamic difference, the assumption that there is no difference between different groups is satisfied), otherwise the heterogeneity problem will cause a large bias.

In the bidirectional fixed-effect model, if there are only two sets and two periods of DID setting, the unbiased estimator of ATE (average treatment effect) can be obtained by TWFE only if the parallel trend hypothesis is satisfied, while in the multi-phase DID7, in addition to the parallel trend hypothesis, the non-heterogeneity hypothesis also needs to be satisfied. Heterogeneity problems lead to biases in the calculation of weighted average treatment effects. If the hypothesis of no heterogeneity is met, that is, there is no difference in treatment effects among the groups, then the weight of treatment effects among the groups is equal and positive, that is, ATE is the simple average of treatment effects among the groups. However, due to the different processing effects between groups, the weight calculation of ATE may be biased or even negative. Sometimes negative weights can even lead to results that are contrary to reality. The following is an explanation of the effect of negative weights: TWFE is an unbiased estimator of ATE only if the assumption that the treatment effect does not differ between different time points and different groups is satisfied (in dynamic difference, the assumption that there is no difference between different groups is satisfied), otherwise the heterogeneity problem will cause a large bias.

The following formula is the calculation process of Average Treatment effect on the Treated group ATT, $\Delta_{g,t}$ is the average treatment effect of group g and period t, and $D_{g,t}$ is the treatment state of group g and period t.α is the average processing state of all (g,t) units, γ_g is the average processing state of group g, is the average processing state over time t, $\epsilon_{g,t}$ is the state residual, where $N_{g,t} = 1$.

$$\begin{cases} D_{g,t} = \alpha + \gamma_g + \lambda_t + \epsilon_{g,t} \\ w_{g,t} = \dfrac{\varepsilon_{g,t}}{\sum_{(g,t):D_{g,t}=1} \dfrac{N_{g,t}}{N_1}\varepsilon_{g,t}} \\ \beta_{fe} = \sum_{(g,t):D_{g,t}=1} \dfrac{N_{g,t}}{N_1} w_{g,t}\Delta_{g,t} \end{cases} \quad (3)$$

It can be seen that the hypothesis of no heterogeneity is difficult to meet in this study, because different provinces and regions have different natural conditions, economic conditions and social conditions, and the investment and construction process of west-to-east power transmission projects are also different, and the differences between regions are relatively large. For this reason, deChaisemartin and D 'Haultfoeuille's "Heterogeneity robust DID Estimators" were used to correct the bias caused by heterogeneity problems. In the stata package of did_multiplegt_dyn and

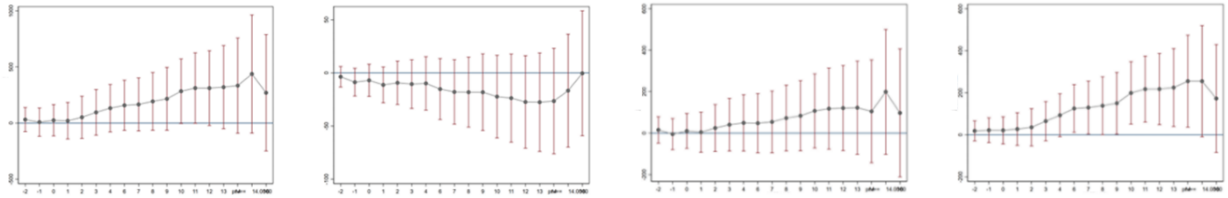
twowayfeweights, a new TWFE estimator is presented to avoid the heterogeneity caused by negative weights. Here's how the new estimator is calculated:

$$\begin{cases} \widehat{D_{g,t}} = \alpha + \beta X_T + \gamma t + \varepsilon_{g,t} \\ el_t = D_{g,t} - \widehat{D_{g,t}} \\ P_{g,t} = \dfrac{el_t \times mean(D_{g,t})}{mean(el_t \times D_{g,t})} \\ W_{g,t} = P_{g,t} \times \dfrac{D_{g,t}}{mean(D_{g,t})} \\ \beta_{fe} = \dfrac{\sum(W_{g,t} \times Y_{g,t})}{\sum W_{g,t}} \end{cases} \tag{4}$$

First, let $D_{g,t}$ perform multiple linear regression on X_T (control variable) and t (time dummy variable), subtract $D_{g,t}$ from the obtained expected processing state$\widehat{D_{g,t}}$, and obtain the residualel_t. Then the residual values el_t and $D_{g,t}$ are used to obtain the initial weight$P_{g,t}$, and the initial weights $P_{g,t}$ and $D_{g,t}$ are used to obtain the natural weight$W_{g,t}$. Finally, a new TWFE estimator is obtained by using the natural weight $W_{g,t}$ and the target variable$Y_{g,t}$. In this way, the heterogeneity caused by negative weight can be effectively avoided.

2.5. Interpretation of Result

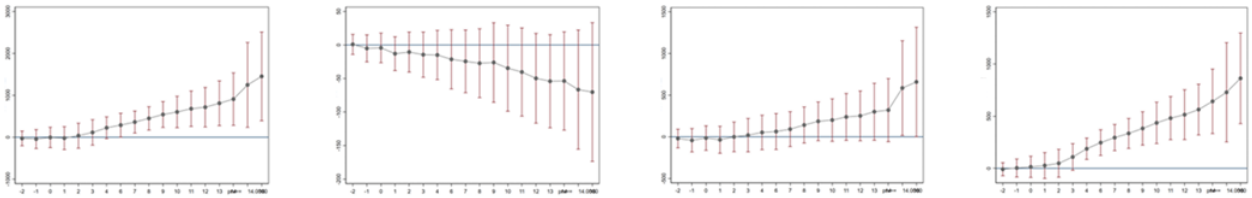
The difference of absolute policy time point between different provinces is too large, so the dynamic bidirectional fixed utility is relatively more suitable for the situation. Taking the policy occurrence point as the base point of the relative period, this paper selected the time window as the pre-2 period and the post-16 period to estimate the policy effect. The results are as follows:



a) total product. b) primary industry product. c) secondary industry product. d) tertiary industry product.

Fig 1. Overall dynamic policy effect (α=0.05).

We found that the economic effect brought by "west-east power transmission" is not obvious from the perspective of input and export areas. Except the tertiary industry, which has a significant positive effect in the medium and long term, the total output value and the output value of other industries are not significant. Therefore, we also perform regression according to the input and output classification, and the results are as follows:

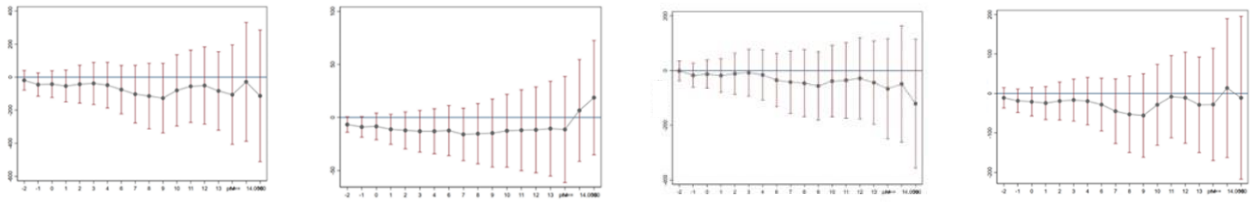


a) total product. b) primary industry product. c) secondary industry product. d) tertiary industry product.

Fig 2. Input dynamic policy effect (α=0.05).

From the results of the input site, the "west-east power transmission" has a significant promoting effect on GDP development in the medium and long term. After analyzing by industry, the promotion effect is mainly concentrated in the tertiary industry. Relatively speaking, the policy has a significant

promoting effect on the secondary industry only in the lag period of 15 years, while the effect on the primary industry is not significant. If the degree of significance is relaxed, it may even have a certain inhibiting effect.

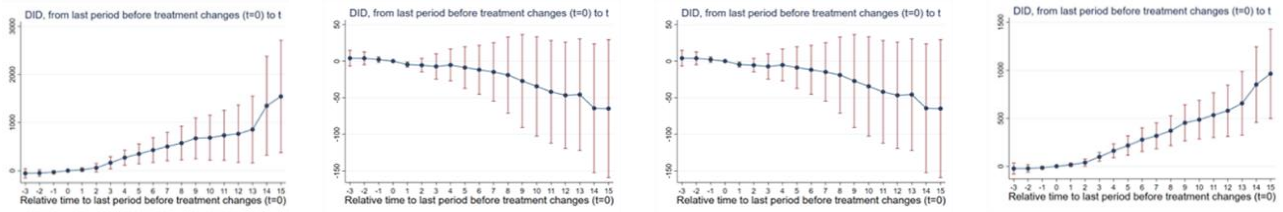


a) total product. b) primary industry product. c) secondary industry product. d) tertiary industry product.

Fig 3. Output dynamic policy effect (α=0.05).

From the results of the export area, the effect of the policy is not significant, indicating that the "west-east power transmission" policy has a small impact on the export area. In summary, the theoretical hypothesis can be judged. Hypothesis (1) is rejected. Although the effect of "West-east power transmission" on the GDP promotion of the input area is significant in the medium and long term, the effect on the output area is not significant, and the effect of political policies is limited in the output area. Hypothesis (2) cannot be rejected, the effect of the "west-east power transmission" policy is significantly different between the input area and the output area, and the economic promotion effect on the input area is significant. Hypothesis (3) cannot be rejected. In terms of input area, the output value of the primary industry may even have a negative effect after policy intervention, while the promoting effect of the output value of the secondary industry is not significant, and the effect of the output value of the tertiary industry is even more significant than the policy effect of the total output value. Therefore, this paper guesses that the policy of "power transmission from west to East" will promote the transformation of the industrial structure of the input area, and will be verified in the inference.

Combined with the results from the input site, we used the "Heterogeneity robust DID Estimators" of deChaisemartin and D 'Haultfoeuille to correct the deviations caused by heterogeneity. The output of did_multiplegt_dyn package is as follows:



a) total product. b) primary industry product. c) secondary industry product. d) tertiary industry product.

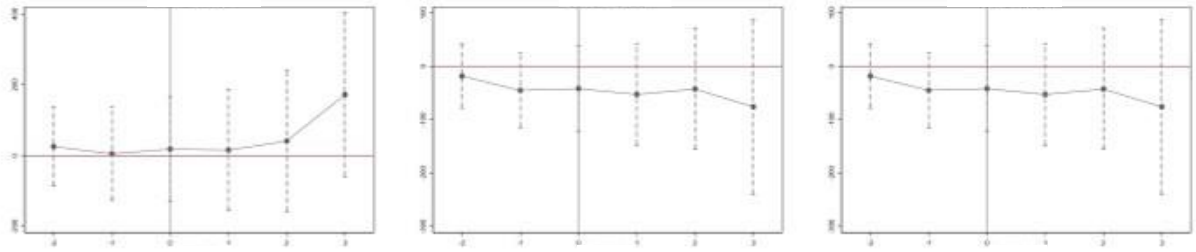
Fig 4. Input heterogeneity robust dynamic policy effect (α=0.05).

It can be found that the results of robust estimation of the heterogeneity of the policy effect at the input location are basically consistent with the above TWFE results. The policy has a significant promoting effect on the total output value and the output value of the tertiary industry in the medium and long term, while the effect on the output value of the primary industry and the output value of the secondary industry is not significant.

2.6. Parallel trend test

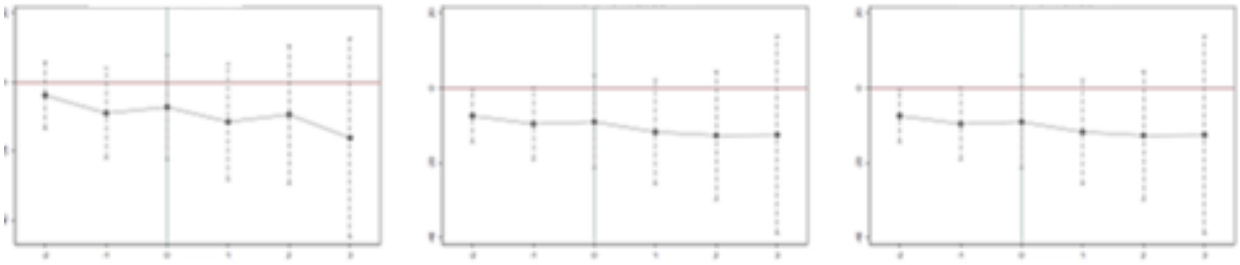
The parallel trend hypothesis is one of the basic identification assumptions of DID, which requires that the outcome variables of the prior control group and the experimental group have the same change trend. For different result variables R, this paper fixed the time window as three periods before and after, and set the three periods before as the base period. The following models were adopted respectively to conduct parallel trend tests:

$$R_{it} = \alpha + \sum_{-2}^{3} \beta_\tau \left(D_i \times \mathbf{1}(t - T_D = \tau) \right) + \theta \mathbf{X}_{it} + \sigma_i + \lambda_t + \varepsilon_{it} \quad (5)$$



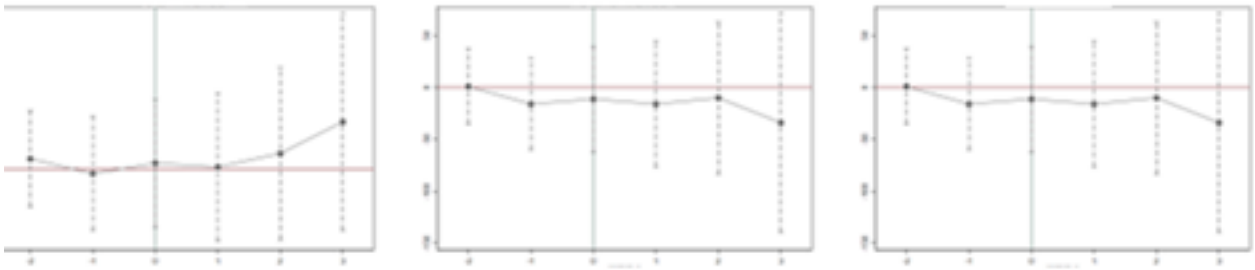
a) Entirety b) Input c) Output

Fig 5. Total product as the result variable.



a) Entirety b) Input c) Output

Fig 6. First product as the result variable.



a) Entirety b) Input c) Output

Fig 7. Secondary product as the result variable.

3. Summary

Based on the data of 31 provinces in China from 1995 to 2018, this paper uses the dynamic two-way fixed effect model DID to estimate the economic effects of the "West-east power transmission" policy by the input and output areas and the primary and secondary tertiary industries for the first time. Furthermore, deChaisemartin and D 'Haultfoeuille's "Heterogeneity robust DID Estimators" were used to correct the deviations caused by heterogeneity. The results show that in the input area, "west-to-east power transmission" has a significant promoting effect on GDP, mainly promoting the development of tertiary industry; in the export area, the policy effect of "west-east transmission of electricity" is not significant. This paper speculates that it may be because the industrial structure in the western region is backward and the proportion of output value of the secondary and tertiary industries is low, which limits the promotion effect of the policy. Through the analysis of the results,

this paper guesses that the "west-east delivery" policy has a certain role in promoting the transformation of the industrial structure of the input land. Therefore, this paper introduces the variable of industrial structure upgrading index, and then uses the dynamic two-way fixed effect model to evaluate the promoting effect of the policy on industrial structure transformation. The results show that in the input area, the policy of "power transmission from west to East" has a significant promoting effect on the upgrading of industrial structure, and can effectively play the continuous promoting role of industrial transformation and upgrading on economic growth.

In general, the "West-east power transmission" policy is a long-term project. Although its initial purpose has not been fully achieved in terms of results, and its contribution to the economic development of the western region is relatively limited, its economic promotion effect on the eastern power input region is very significant, and it can promote the transformation of industrial structure. On the whole, it optimizes the resource allocation in China. To a certain extent, it helped our country to break the bottleneck of economic development and promote sustained economic growth.

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