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Procedia Computer Science 221 (2023) 106–112

Procedia Computer Science

www.elsevier.com/locate/procedia

10th International Conference on Information Technology and Quantitative Management

Assessment on the Economic, Social and Environmental Benefits of Power Grid Investment under the New Development Paradigm

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Abstract

With the construction of the new power system, power grid investment has been directly related to the realization of the "dual carbon" goal and the cultivation of new business forms, new technologies and new models. Under the new development paradigm, how to evaluate the comprehensive benefits of power grid investment has become a key issue for national macroeconomic regulation and enterprise investment strategy. Based on the important statements on the new development paradigm made by President Xi Jinping, this paper built an evaluation index system for the economic, social, and environmental benefits of power grid investment under the new development paradigm, evaluated the benefits quantitatively and qualitatively by using the CGE model, input-output model and data envelopment analysis model, providing decision reference for government and power grid enterprises.

Keywords: New development paradigm; Power grid investment; Economic benefits; Social benefits; Environmental benefits

1. Introduction

Since September 2020, Chinese President Xi Jinping has proposed to accelerate the establishment of a new development paradigm featuring dual circulation, which takes the domestic market as the mainstay while letting domestic and foreign markets boost each other on multiple occasions. As President Xi Jinping said, we need to make big efforts to expand domestic demand, enhance the momentum of development, and smooth domestic circulation to build the new development paradigm[1]. With the promotion of the strategic goal of "dual carbon" and the construction of new electric power system, the electric power field has gradually become the main battlefield to promote carbon emission reduction. New industries and new technologies are emerging constantly, and the reform of electric power system and mechanism is accelerating, which plays a key role in building a new development paradigm. As a platform and hub for energy resource allocation, the power grid is closely related to upstream power generation enterprises, downstream power users, power equipment manufacturing and other supporting industries. The driving power of power grid investment to upstream and downstream investment is significantly stronger than other links. However, as the energy authorities are more strict in the management of power grid planning investment and the approval of new

10.1016/j.procs.2023.07.016

power grid investment and the expectation of the society to reduce energy consumption costs and release the dividends of the reform of the electric power system is increasing, the operating pressure of grid enterprises is prominent, and the investment ability is significantly weakened. How to achieve precision investment has become an important problem for grid enterprises. Clarifying the overall economic and social benefits of power grid investment is not only conducive to national macro-control, but also conducive to power grid enterprises to better fulfill their political, economic and social responsibilities.

At present, the analysis of power grid investment benefit mostly stays at the project level, and the analysis of macro-level benefit under the new development paradigm is little. Jin Zhibo (2022) took the maximum comprehensive benefit during the planning period as the goal, taking into account the constraints of investment capacity, the relationship between projects and other constraints, and established the investment timing optimization model of power grid planning projects, aiming to provide reference for achieving accurate investment in infrastructure projects[2]. Tan Yudong (2021) proposed a transmission network project investment benefit evaluation method based on the improved matter-element extension model in view of the fuzziness of the evaluation results and the subjective error of the evaluation index weighting[3]. Wang Ronghua (2020)constructed the unit output efficiency benefit index model of different types of planned investment projects for provincial power grid based on the requirements of transmission and distribution electricity price reform[4].

First, this paper establishes evaluation index system of power grid investment benefit under the new development paradigm. Second, the paper synthesizes CGE model, input-output model and other multiple models as the evaluation model and method. Third, the paper analyzes and evaluates the external impact of power grid investment from the perspective of economic, social and environmental impact. Finally, the paper puts forward some relevant suggestions.

2. Evaluation index system of power grid investment benefit under the new development paradigm

2.1. Impact mechanism analysis

To build the new development paradigm, we need to focus on the following three areas. First, we should continue to expand domestic demand as the strategic basis. Second, we need to comprehensively step up scientific and technological innovation and import substitution, foster independent growth drivers, build industrial and supply chains that are independent, controllable, safe and reliable, and reshape new industrial chains. Third, we need to deepen supply-side structural reform, develop a national unified market, and coordinate development among regions to smooth the circulation of supply and demand, the market, and urban-rural and regional cycles.

Under the dual requirements of the new development paradigm and the "dual carbon" goal, the investment of power grid enterprises focuses on building a smart grid with a strong structure, improving the intrinsic safety level of power grid, the quality of excellent services and the ability to absorb clean energy, accelerating the innovation of key technologies of energy internet, and promoting the deep integration of power grid and digital technology. In general, power grid investment mainly includes infrastructure construction, promoting technological innovation and improving service level. It plays a significant role in promoting regional economic growth, driving employment, driving the growth of upstream and downstream industries, promoting regional coordination, promoting the development and utilization of new energy, and reducing carbon dioxide emissions. Under the new development paradigm and "dual carbon" strategic objectives, it is reflected in expanding domestic demand, increasing growth drivers, smoothing circulation and promoting green. See Figure 1 for specific conduction mechanism.

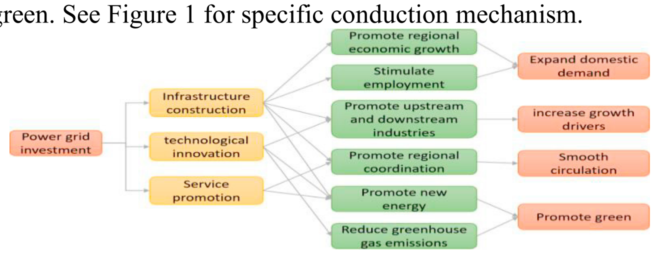

Fig. 1.Grid investment benefit conduction path diagram under the new development paradigm

2.2. Indicator system

The power grid investment benefit evaluation index system under the new development paradigm is composed of four dimensions: expanding domestic demand, increasing kinetic energy, smoothing circulation and promoting green. There are 16 specific indicators in total. See the table below for the specific indicator system.

Table 1. Benefit evaluation index system of power grid investment under the new development paradigm.

Level-1 indicator	Level-2 indicator	Level-3 indicator	Interpretation of level-3 indicator
Expand domestic demand	Promote economic growth	GDP added value	power grid investment drives the overall GDP added value
		Contribution rate to GDP growth	the contribution rate of power grid investment to GDP growth
	Stimulate employment	Increase in employment	the increase of jobs caused by grid investment
Increase growth drivers	Drive the growth of related industries	Scientific research and technology services Metal products, machinery and equipment repair services special equipment General equipment Other manufacturing Instruments and Apparatuses Communication equipment, computers and other electronic equipment	the growth of upstream and downstream industrial chain driven by power grid investment
Smooth circulation	Optimize resource allocation	Change of trans-regional transport capacity	the change of transmission capacity of trans-regional channel caused by UHV investment
	Improve business environment	Changes in infrastructure power supply capacity	the improvement of infrastructure level brought by grid investment
	Promote coordinated development	Changes in differences in urban and rural power supply services	the difference level change in average outage time and voltage qualification rate of rural and urban customers caused by grid investment
Promote green	Improve environmental efficiency	Evolution of national and regional environmental efficiency	the change of national and regional environmental efficiency
	Promote CO_2 emission reduction	CO_2 emission reduction	CO_2 emission reduction effect through promoting the use of new energy

3. Evaluation model and method of power grid investment benefit under the new development paradigm

This study coupled a variety of energy technology models and energy economic models, and established a comprehensive benefit evaluation model of power grid investment that reflects the characteristics of the new development paradigm and the gradual internalization of environmental costs and other energy transformation characteristics, providing methods and tools for the value evaluation and strategic decision-making of power grid investment. Combining the calculation of indicators in the four dimensions of expanding domestic demand, increasing growth drivers, smoothing circulation and promoting green, this study coupled the dynamic computable general equilibrium model, input-output model and data envelopment analysis model.

3.1. Computable general equilibrium model

The dynamic computable general equilibrium model (CGE) is adopted to establish a quantitative evaluation model of power grid investment driving GDP growth and employment to measure the benefits of power grid investment in expanding domestic demand[5-6]. The model mainly includes 28 production departments, including 3 resource recovery departments, 4 pollution control departments, 4 resource industry departments and 17 traditional production departments. The model includes six types of production factors - labor, land, capital, energy resource assets, non-energy resource assets and environmental assets. Resource assets are used by resource recovery departments and resource industry departments.To build the new development paradigm, we need to focus on the following three areas. First, we should continue to expand domestic demand as the strategic basis. Second, we need to comprehensively step up scientific and technological innovation and import substitution, foster independent growth drivers, build industrial and supply chains that are independent, controllable, safe and reliable, and reshape new industrial chains. Third, we need to deepen supply-side structural reform, develop a national unified market, and coordinate development among regions to smooth the circulation of supply and demand, the market, and urban-rural and regional cycles.

3.2. Input-output method

The input-output method is based on the industrial correlation theory to analyze the backward and forward correlation effects of industrial investment, which is currently a relatively mature industrial correlation effect analysis method[7-8]. In the framework of input-output model, the production of a sector has two effects on the economy. The increase in production of department j requires more raw materials to drive the production of upstream industries, which is called backward linkage. The increase in the output of sector j increases the number of goods that can be provided to other industries as inputs, which is conducive to the expansion of production in other industries using the products of industry j as raw materials, known as forward correlation.

The backward correlation of the power industry reflects a relationship between the power industry and the upstream industry, which can be considered by the direct consumption coefficient of the power industry to other industries. The larger the consumption coefficient, the stronger the dependence of the power industry on other industries, and the greater the pulling effect on other industries. The direct backward correlation coefficient formula is expressed as:

$$\alpha_{ij} = \frac{x_{ij}}{X_j}, \quad (i, j = 1,2,\ldots n) \tag{1}$$

α_{ij} is the direct consumption coefficient, x_{ij} is the value of the products consumed by department j in the production process, and X_j is the total output of department j.

The backward correlation of the power industry reflects a relationship between the power industry and the upstream industry, which can be considered by the direct consumption coefficient of the power industry to other industries. The larger the consumption coefficient, the stronger the dependence of the power industry on other industries, and the greater the pulling effect on other industries. The direct backward correlation coefficient formula is expressed as:

$$h_{ij} = \frac{x_{ij}}{Y_i}, \quad (i, j = 1,2,\ldots n) \tag{2}$$

h_{ij} is the direct distribution coefficient, and Y_i is the total output of the department i.

3.3. Data including analytical method

The Malmquist index in the data envelopment analysis method (DEA) represents the change of total factor productivity relative to the previous period. It can be used to study the technical form of more output and more input. It can better fit the panel data analysis and multi-input and output analysis, and it does not need to set the specific form and distribution of the production function, which has relaxed the theoretical constraints to a certain extent. This paper uses Malmquist index to evaluate the evolution of power grid investment environment efficiency in different periods. The form of Malmquist index is as follows:

$$M_i(x^{t+1}, y^{t+1}; x^t, y^t) = [\frac{D_{ci}^t(x^{t+1}, y^{t+1})}{D_{ci}^t(x^t, y^t)} \times \frac{D_{ci}^{t+1}(x^{t+1}, y^{t+1})}{D_{ci}^{t+1}(x^t, y^t)}]^{1/2} \tag{3}$$

Where x^t and y^t are input and output vectors of t period; D^t_{ci} (x^t, y^t) is the distance function value of the *i-th* decision-making unit under the production front in period *t*, representing the distance between the actual function value in period *t* and the front. Further, changes in total factor productivity can be decomposed into technical efficiency effect (*Effch*) and technical progress effect (*Techch*) in the following form:

$$M_i(x^{t+1}, y^{t+1}; x^t, y^t) = Effch \times Techch = [\frac{D_{ci}^{t+1}(x^{t+1}, y^{t+1})}{D_{ci}^t(x^t, y^t)}] \times [\frac{D_{ci}^t(x^{t+1}, y^{t+1})}{D_{ci}^t(x^t, y^t)} \times \frac{D_{ci}^{t+1}(x^{t+1}, y^{t+1})}{D_{ci}^{t+1}(x^t, y^t)}]^{1/2} \tag{4}$$

Among them, *Effch* is the change of technical efficiency from period *t* to period *t+1*, which measures the ability of the research object to maximize output with a certain input; *Techch* is the change of technology level, which represents the advance and retreat of the research object in technology. When the Malmquist index is greater than 1, it indicates that the total factor productivity is higher than the previous year, and when it is less than 1, it indicates that it is lower than the previous year. This paper mainly takes power grid investment and clean energy generation as input variables, and carbon emission reduction of power industry as output variables for calculation and analysis.

4. Result analysis

4.1. Benefits of expanding domestic demand

According to the CGE model, during the "Fourteenth Five-Year Plan" period, the grid investment scale of State Grid Corporation of China is 2.4 trillion yuan, which is expected to increase the total social output by about 10 trillion yuan, provide about 700000 jobs each year, and contribute about 0.4% to the annual GDP growth.

4.2. Benefits of increased growth drivers

Based on the national input-output table for 2005-2017, the calculation results show that the backward pull effect of electricity production and supply industry on the economy is far greater than the forward pull effect, that is, the support and pull effect of electricity consumption is far greater than that of electricity production process on China's economy. Under the new development paradigm, the driving mode of power grid investment to the economy and society will be comprehensively upgraded, mainly in the cultivation of new business forms and new models focusing on promoting clean energy. With the development of new business forms and new models related to the energy industry, the forward pull effect driven by power grid investment will gradually improve, that is, the pull effect of power production process on economic development will gradually highlight. According to the input-output model, from 2025 to 2035, electric power investment will drive higher growth in the output of communication equipment, computers and other electronic equipment, scientific research and technical services, and the long-term driving effect is stronger than the short-term.

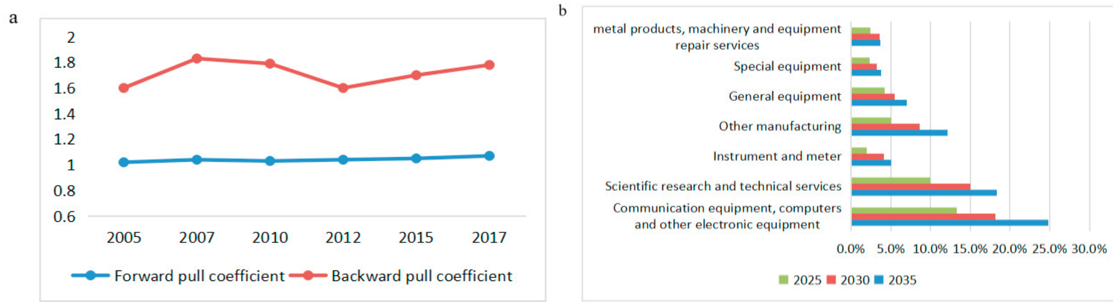

Fig. 2. (a)the forward and backward pull effect of electricity investment;(b) electricity investment on the output of related industries.

4.3. Benefits of smooth circulation

It is estimated that in 2025, the grid investment of the State Grid Corporation of China will increase the transmission capacity of the existing trans-regional channels by 35.27 million kilowatts, and the utilization hours of UHV DC channels will reach more than 4500 hours, an increase of 699 hours compared with 2020. In terms of infrastructure power supply capacity, it is expected that by 2030, the "share of heavy-load public distribution and transformation" in the operation area of State Grid Corporation of China will reach 0%, the "capacity of household distribution and transformation" will reach 6 kVA, and the "qualified rate of 10 kV line power supply radius" will reach 100%, achieving consistency between urban and rural areas. In terms of power supply quality, it is expected that the eastern, central and western regions will achieve urban-rural consistency by 2040.

4.4. Benefits of promoting green

From the perspective of environmental efficiency, in the middle and later stages of the "Fourteenth Five-Year Plan", grid investment has brought about continuous improvement in the environmental efficiency of the national power industry by promoting the development of clean energy and the substitution of electric energy. At the current technological level, the scale of power grid investment is sufficient, and technological innovation is the decisive factor to bring about changes in environmental efficiency. In the future, the improvement of environmental efficiency will be achieved mainly through promoting technological innovation. From the perspective of provinces, the environmental efficiency of various regions driven by power grid investment is constantly improving. The environmental efficiency of developed regions in North China and East China is generally higher than that of inland regions in the west.

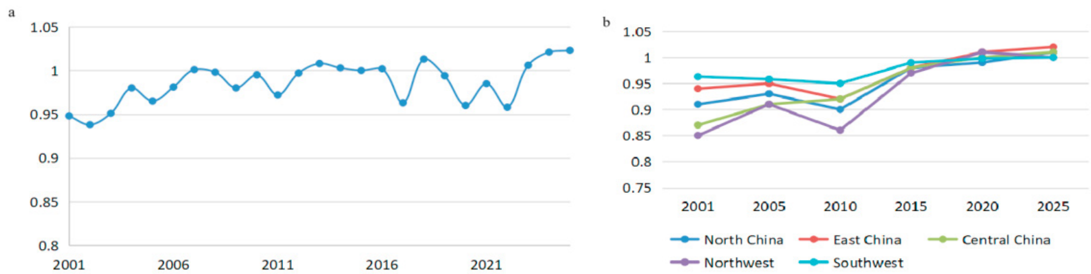

Fig. 3. (a) National environmental efficiency brought by grid investment;(b) Regional environmental efficiency brought by grid investment.

From the perspective of coordinated emission reduction, the driving effect of electricity production and consumption on the implicit carbon emissions of the whole society is far greater than that on the economy. Based on the input-output table data of 2005-2017 and the carbon emission data of sub-sectors, the impact of electricity production and consumption on the carbon intensity and electricity intensity of the whole society is calculated. From the perspective of backward pull, the current production of 1 unit of electricity will drive 5.7 units of carbon emissions and 1.1 units of social output. From the perspective of forward pull, consumption of 1 unit of electricity will drive 14.9 units of carbon emissions and 1.78 units of social output. During the "Fourteenth Five-Year Plan" period, the grid investment of State Grid Corporation of China will promote the cumulative clean replacement of coal of about 140 million tons in the power industry, and reduce carbon dioxide of about 380 million tons.

4. Conclusions and suggestions

With the construction of the new power system, power grid investment will play an important role in expanding domestic demand and cultivating new drivers. At the same time, power grid investment will narrow the gap between urban and rural infrastructure and power supply service level, improve the power transmission capacity across regions, and help smooth the domestic market cycle with the national allocation of energy elements. However, electricity production and consumption have a far greater pull on the implicit carbon emissions of the whole society than that on the economy. In the case that the power generation side has not fully realized the clean transformation, it is necessary to properly grasp the investment rhythm of electricity substitution to avoid the increase of the implicit carbon emissions of the whole society.

Acknowledgements

This work was supported by the Technology Project of State Grid Corporation, which is dedicated to researching multi-objective coordination theory and evaluation technology of new power system integrating energy security, economy and low carbon.

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