Economic Evaluation of Optical Fiber Composite Low-Voltage Cable Technology Application in China: An Input-Output Analysis

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OPLC (optical fiber composite low-voltage cable) technology is a common field of communication and power electronics technology, and it is an important means to realizing the energy Internet and the integration of four networks. As an infrastructure sharing technology, OPLC technology will fundamentally and substantially promote the sustainable development of China’s economy and environment. Taking typical OPLC projects in China as an example, the direct energy consumption of these projects is calculated by the life-cycle cost (LCC) analysis method and then compared with traditional projects that use only power technology or optical fiber. Based on the direct consumption of the project, the interaction between the intermediate sector and the total output variable under the traditional technology and OPLC technology was explored and compared by using the input-output (I-O) model and the structural decomposition model (SDA). The results showed that in 2015, technology substitution weakened the influence of 86% of industries on the upstream industry and weakened the demandsensitivity of 90% of industries to the downstream industry. In 2017, technology substitution reduced the industry’s influence over 86% of upstream industries. Short-term technology replacement will not increase the positive influence of each industry on the upstream industry, thus resulting in a negative impact of technology substitution cost. However, that negative impact will gradually weaken over time. After technology replacement, the total added value of 20 industries increased from 2015 to 2017.

1. Introduction

OPLC (optical fiber composite low-voltage cable) technology is a double innovation of communication and power technology. It is another new type of optical fiber composite low-voltage cable, developed and put into commercial use in 2009 by the State Grid Information and Telecommunication Company after optical fiber composite overhead ground wire (OPGW) and optical fiber composition phase conductor (OPPC). With the gradual maturation of OPLC technology via the combining of optical fiber, copper wires, and copper line transmission, promoting the application of OPLC technology is not only an important part of the implementation of the smart grid work for State Grid Corporation of China but also will in turn lay a solid foundation for the construction of four-network fusion based on power optical fiber. As an infrastructure sharing technology, OPLC technology promotes the sustainable development of China’s economy and environment with its high-cost performance, high scalability, and environmental protection.

The State Council’s Guiding Opinions on actively promoting the Internet Plus action plan (No. 40 Document of State Council, 2015) were explicitly put forward to “improve energy Internet information communication systems.” On 14 May 2017, President Xi Jinping proposed to “seize the new round of energy structure adjustment and energy technology change trend, build a global energy Internet and achieve green and low-carbon development” on the Belt and Road Forum for International Cooperation. As high-speed networks faced huge market demand, the 5G network came into being, which brought an ultrafast data transmission...
speed. The transmission rate of 5G network needs 10 Gbps, while the access rate of OPLC technology in the future will not require less than 1000 Gbps. Therefore, the application of OPLC technology is a prerequisite for every family to enjoy 5G or even the latest generation of communication network.

Most research on OPLC technology focuses on its physical and technological characteristics. Zou et al. [1] showed that OPLC is a typical optical fiber temperature communication network. Mizuno et al. [2] demonstrated that a fiber laser radar system was tested and proved and that the radar system showed no detection effect on the thermal attenuation loss of the fiber. Ding et al. [3] analyzed the general structure, installation, and connection of optical fiber composite medium-voltage and low-voltage cables. Xu et al. [4] set up a simulation model to study the heat resistance of OPLC for light attenuation. Few articles have, however, analyzed the economic impact of OPLC technology; therefore, this paper innovatively analyzes the economic effects of OPLC technology by input-output theory in addition to studying its technical characteristics.

Input-output theory was founded by Leontief, an American economist. It uses mathematical methods to analyze the quantitative dependence of various sectors of the national system on input and output. Structural decomposition analysis is used for the empirical study of input and output, mainly to study the degree of variation of independent variables’ contribution dependent variables in the national system. The change of total output in the two periods is generally caused by the change of economic and technological coefficients and final demand, the change of economic and technological coefficients is expressed by the change of Leontief inverse matrix, and the change of final demand is expressed by the column vector of final demand change. Solow [5] and Romer [6] analyzed the contribution rate of the change of economic and technological coefficients, and final demand on the change of total output was measured by the decomposition method.

In addition to traditional input-output analysis, Leontief and Strout [7] introduced the gravity model to estimate the transactions in the input-output table, and the authors of [8–23] used to generate the local input-output table. Leontief [8] applied the input-output approach to environmental repercussions and the economic structure. Additional input-output studies have been reported since to extend the input-output mode at different scales. Hendrickson et al. [9] developed the economic input-output model for environmental life-cycle assessment. Pietroforte and Gregori [10] used the input-output approach to analyze the construction sector of highly developed economies. More recent input-output studies include global energy flows [11], the economic transaction [17–28], and economic resilience [11–13]. Recently, Delgado et al. [14] developed an input-output subsystem analysis based on the Ghosh model. Malik et al. [15] provided an overview of the evolution of MRIO databases and the addition of greater sectoral and regional detail, discussing benefits derived from these enhancements in the economic system. Most scholars generally use input-output theory and structural decomposition to study the relationship between industries and the change of total output. Few, however, have analyzed the interindustry linkages caused by technological innovation using the updated input-output table by considering the direct consumption of one sector for another sector because of the application of a technological innovation in the sector.

Based on the LCC theory, this paper analyzes the influence of OPLC technology on economic development by applying the method of multidepartment input-output analysis. In the theoretical sense, this not only expands the input-output method but also enriches the LCC theory. In a practical sense, the application of the multisector input-output analysis method to analyze the impact of the application of OPLC technology on economic development will promote the popularization of OPLC technology and contributes to the rapid development of China’s economy.

The remaining sections are organized as follows. Section 2 explains the methodology. Section 3 shows a cost analysis of OPLC technology application, based on LCC theory. An influence analysis of OPLC technology application on China’s economy, based on the input-output model, is provided in Section 4, and Section 5 summarizes the findings and conclusions.

2. Methodology

2.1. Formulation of Methodology

2.1.1. LCC Theory Formulation. Currently, the LCC theory is the most widely used technology project cost analysis theory. It originated in Sweden and has been applied in economic analysis since 1947. The theory from the perspective of whole life cycle of technology project, comprehensive install the mid in the early stage of the project design, construction, investment, operation, and maintenance cost last scrap costs are considered in the analysis of the cost, such detailed the cost comparison of each kind of technical application method, for the final selection to meet minimum life-cycle cost, economic efficiency, and social benefit maximization principle of optimal scientific scheme provides the theory support.

Generally speaking, the cost model based on LCC theory is as follows:

$$LCC = CI + CM + CF + CD,$$

where CI (cost of investment) represents the cost of prior investment; CM (cost of maintenance) represents the cost of operation and maintenance; CF (cost of fault) represents the fault cost; and CD (cost of disposal) represents the cost of scrap disposal. The CI and CM are estimated directly in the early stage of the project design, construction, investment, operation, and maintenance cost last scrap costs are considered in the analysis of the cost, such detailed the cost comparison of each kind of technical application method, for the final selection to meet minimum life-cycle cost, economic efficiency, and social benefit maximization principle of optimal scientific scheme provides the theory support.

$$CF = a \times B \times T + \lambda \times RC \times MTTR,$$

where $a$ is the value of interruption communication, $B$ is the amount of data of equipment interruption communication, $T$ is the time of fault, and $\lambda$ is the average number of failures.
Mathematical Problems in Engineering

RC and MTTR are the average number of faults and the average repair cost of equipment, respectively.

The CD includes equipment disposal costs and equipment residual value, and it is calculated as follows:

\[
CD = CD^* - CR,
\]

where \(CD^*\) is the cost of disposal of waste equipment and CR is the residual value of equipment.

2.1.2. Input-Output Model Description. This paper applies the value-based input-output model to describe horizontally the distribution of output in different sectors and vertically the consumption of production in different sectors. Horizontal direction is divided into the intermediate and final needs of each sector. Vertical direction includes intermediate and initial input. The direct consumption coefficient represents the direct consumption of a unit product by one sector to another. The definition is as follows:

\[
a_{ij} = \frac{x_{ij}}{x_j}, \quad i, j = 1, 2, \ldots, n,
\]

where \(a_{ij}\) denotes the direct consumption of unit products in sector \(j\) for products in Section \(i\). The direct consumption matrix between sectors is as follows:

\[
A = \begin{pmatrix}
\begin{array}{ccc}
\alpha_{11} & \cdots & \alpha_{1n} \\
\vdots & \ddots & \vdots \\
\alpha_{n1} & \cdots & \alpha_{nn}
\end{array}
\end{pmatrix},
\]

obtained from the definition of the direct consumption coefficient: \(x_{ij} = a_{ij} x_j\).

According to the line balance of the input-output table, there are

\[
\sum_{j=1}^{n} a_{ij} x_j + y_i = x_i, \quad i = 1, 2, 3, \ldots, n,
\]

where \(y_i\) is defined as the end product output of industry \(i\) for increasing fixed assets, household consumption, etc.

Order \(X = [x_1, x_2, \ldots, x_n]^T\), \(Y = [y_1, y_2, \ldots, y_n]^T\), then formula (6) can be expressed in matrix form:

\[
AX + Y = X,
\]

\((E - A)^{-1}\) is invertible, then it can be transformed to:

\[
X = (E - A)^{-1} Y,
\]

where \((E - A)^{-1}\) is called the Leontief inverse matrix, which is recorded as \(\bar{B}\):

\[
\bar{B} = \begin{pmatrix}
\bar{b}_{11} & \cdots & \bar{b}_{1n} \\
\vdots & \ddots & \vdots \\
\bar{b}_{n1} & \cdots & \bar{b}_{nn}
\end{pmatrix}.
\]

The total consumption matrix is

\[
B = \bar{B} - E.
\]

The horizontal direction of the input-output table can reflect the direct distribution coefficient of products in different sectors:

\[
h_{ij} = \frac{x_{ij}}{x_j}, \quad i, j = 1, 2, \ldots, n,
\]

\(h_{ij}\) represents the share of the output of Section \(i\) that can be allocated to Section \(j\). The direct distribution coefficient matrix is

\[
H = \begin{pmatrix}
h_{11} & \cdots & h_{1n} \\
\vdots & \ddots & \vdots \\
h_{n1} & \cdots & h_{nn}
\end{pmatrix}.
\]

The same as above the method of computing Leontief inverse matrix. The Ghosh inverse matrix is \(\bar{G} = (E - H)^{-1}\). The element meaning of \(\bar{G}\) is the increment of the gross output value of Section \(j\) caused by a unit added value of Section \(i\). \(\bar{G}\) is also called the complete induction coefficient matrix:

\[
\bar{G} = \begin{pmatrix}
\bar{g}_{11} & \cdots & \bar{g}_{1n} \\
\vdots & \ddots & \vdots \\
\bar{g}_{n1} & \cdots & \bar{g}_{nn}
\end{pmatrix}.
\]

The complete distribution coefficient includes direct distribution coefficient and indirect distribution coefficient. The complete distribution matrix is \(G = \bar{G} - E\).

The backward connection means the connection between the production sector and the production sector that provides its raw materials, power, etc. The forward connection means the connection between the sector consuming and using its products. \(\sum_{i=1}^{n} b_{ij}\) represents the sum of the pulling effects of the unit final product of Section \(j\) on each sector of the economic system. To compare the pulling effects of each sector on the economic system, the influence coefficient is introduced:

\[
\alpha_j = \frac{(1/n) \sum_{i=1}^{n} b_{ij}}{\left(1/n^2\right) \sum_{j=1}^{n} \sum_{i=1}^{n} b_{ij}}, \quad j = 1, 2, \ldots, n,
\]

where \(\alpha_j\) represents the impact of an additional unit demand in Section \(j\) on its backward sector. When \(\alpha_j = 1\), the pulling effect of sector \(j\) on the national economy is at the average level of each sector. When \(\alpha_j > 1\), it means that the pulling effect of sector \(j\) on the national economy is greater than the average level of each sector. When \(\alpha_j < 1\), it means that the pulling level of sector \(j\) on the national economy is lower than the average level of each sector, and the pulling level is lower.

Similarly, to compare the role of various sectors in promoting the national economy, the induction coefficient is introduced:

\[
\beta_i = \frac{(1/n) \sum_{j=1}^{n} \bar{g}_{ij}}{\left(1/n^2\right) \sum_{j=1}^{n} \sum_{i=1}^{n} \bar{g}_{ij}}, \quad i = 1, 2, \ldots, n,
\]

where \(\beta_i\) represents the impetus to the forward sector of sector \(i\) by adding a unit output. When \(\beta_i = 1\), it means that
the promotion role of sector \( i \) to each sector is at the average level of each sector. When \( \beta_i > 1 \), the promotion level of sector \( i \) is higher than the average level of each sector. When \( \beta_i < 1 \), the promotion level of sector \( i \) is lower than the average level of each sector.

Since the input-output tables for 2012 and 2015 are used in the following sections, we mainly do comparative static analysis. The change of total output in the two periods is generally caused by the change of economic and technological coefficients and final demand. For the change of total output, this paper takes the average value of two polar decompositions. As far as the mathematical expression is concerned, it does not only compare the weights of two independent variables but also proves more intuitive; there is no hard-to-explain interaction term, so it has been widely recognized by the international academic community of scholars.

\[
\Delta X = X_1 - X_0 = \bar{B}_1 Y_1 - \bar{B}_0 Y_0 \\
= \frac{1}{2} \Delta \bar{B} (Y_0 + Y_1) + \frac{1}{2} (\bar{B}_0 + \bar{B}_1) \Delta Y.
\]

Among them, \((1/2)(Y_0 + Y_1)\) is the effect of technology change and \((1/2)(\bar{B}_0 + \bar{B}_1)\) is the effect of demand change.

2.2. Data Source Description. The basic data are from the Jiaxing OPLC project, taking 2015 as the starting year of OPLC technology application. The input-output tables in this paper are derived from the 139 sectors' input-output tables published by the China National Bureau of Statistics in 2015 and the extended 42 sectors' input-output tables published in 2017. Due to the lack of input-output data after 2015, this paper only studies the impact among different sectors after OPLC technology replaced traditional technology in the short term. The targeted 139 sectors and 42 sectors were merged into 22 sectors according to the National Economic Industry Classification (GB/T 4754-2017) standard. Table 1 shows the sector classification and serial number.

Consumption involving the OPLC technology application in the input-output tables of 2015 and 2017 was small and can be ignored here because it had just begun to be applied in 2015 and 2017. Therefore, the original input-output tables of 2015 and 2017 are regarded as the input-output situation under the application scenario of traditional technology. According to the input-output table compilation method, the consumption items of "civil engineering buildings" sectors in the input-output table for 2015 and 2017 for "optical fiber cables, transmission and distribution, and communication equipment" sectors are updated based on the consumption ratio of OPLC technology and traditional technology per household. The consumption items of "optical fiber cable, transmission and distribution, and communication equipment" sectors for "metal products, machinery, and equipment repair services" sectors are also updated in the same way. They are then balanced according to RAS method. Finally, we obtain the updated input-output tables of 2015 and 2017 after OPLC technology replaced traditional technology.

3. Cost Analysis of OPLC Technology Application Based on LCC Theory

3.1. OPLC Project Overview. This paper studies a typical OPLC project in China: the OPLC project in Jiaxing, Zhejiang Province, in 2012. The project includes nine districts in the Xuzhou and Nanhu Districts, respectively: Chunxiaoyuan Phase I P Chunxiaoyuan Phase II P Chunxiaoyuan•Yanyuan, Jinsetianyuan, Huiken Dormitory in Tongle Community, Xiangdu Apartment District, Longxing Apartment District, Changxin Apartment Phase IV A Heyuanxindu Phase II P. The OPLC project covers 385 buildings with a total of 10,067 households.

3.2. Life-Cycle Cost Analysis of OPLC Technology Project Case. Based on the life-cycle theory, the initial investment of the project in the first year is shown in Table 2.

Among them, CI accounts for 93% of the total investment in the first year, which shows that the initial investment cost of the OPLC project was high, as was the investment risk of the project. This is mainly because the information collection of the OPLC project needs to establish a new network channel. The main information collection equipment of OPLC project is reliant on OPLC technology, and the cost of purchasing these materials and equipment is high.

The CM accounts for 5% of LCC, which indicates that the costs of the OPLC project operation and maintenance are low. Because OPLC project operation and maintenance went through the professional team to undertake the project, the team began to evaluate the various aspects of the project from the beginning of the project, the team itself has rich experience for equipment and project operation and maintenance, so the OPLC project operation and maintenance has the source advantage.

The CF accounts for 1% of LCC, which indicates that the fault cost of the OPLC project is low. The stability of the power grid system will directly affect the amount of data, fault time, and fault number of equipment interruption communication, and operation and maintenance will directly affect the time efficiency of fault handling. Because the information collection of the OPLC project relies on the power grid system of the country, and the power grid system of China shows strong stability, the information collection rate of the OPLC project is high, and the amount of data, fault time, and fault number of equipment interruption communication are effectively reduced. The OPLC realizes real-time monitoring of faults, and timely detection of faults improves the time efficiency of handling faults in OPLC projects.

The CD accounts for 1% of LCC, which indicates that the cost of OPLC project disposal is low. On the one hand, OPLC technology ensures the product itself has a long life cycle, and the equipment scrap rate of the OPLC project is low in the first year. On the other hand, when the equipment...
is scrapped, the original value of it basically completes depreciation.

As far as the LCC cost assessment is concerned, more than 90% of the OPLC project cost is concentrated in the initial investment, while the remaining operational and maintenance costs, fault costs, and disposal costs account for less than 10%. The advantages of the OPLC project lie in the substitution of technology. Increasing the added value of technology in current projects will bring about the increase of initial cost, but the improvement of technology content will also bring about the improvement of other economic as well as social benefits. In the long run, OPLC operation and maintenance costs, fault costs, and disposal costs will continue to decline, which will bring about the increase of benefits.

According to the time value theory of funds, we discount the funds invested in the project with an annual interest rate of 6% and convert them to the base year. We also compare the cost of the pure electric power access network project A and the pure optical fiber access network project B with the cost of the OPLC project. The related information of pure electric power access network project A and pure optical fiber access network project B refers to the relevant research of Li [16]. Based on the data, the cost information of 10,067 users is converted according to the proportion. The cost comparison is shown in Figure 1.

The cost of the OPLC project is relatively high in the initial stage, but as the project progresses, the later cost gradually shows advantages. In terms of initial investment, the cost of the OPLC project is nearly three times that of the traditional A+B project. On the one hand, the main information acquisition equipment of the OPLC project is OPLC and EPON, which have high technology added value and high costs to purchase these materials and equipment. On the other hand, special installation requirements lead to increased labor costs. But from the second year on, the cost of OPLC projects show a year-by-year decrease, so their cost is lower than that of traditional projects. Because of the high added value of equipment technology, power and information can be transmitted synchronously, monitored automatically, and detected and diagnosed automatically through the OPLC project. The fault can be monitored automatically and in real time, and the time of cross-specialty coordination is short, which improves the time efficiency and speed of fault treatment. Fiber optic cable has a strong anti-interference ability, a self-healing ability, and a professional team for maintenance, as well as low operation and maintenance costs. Even though the cost of the traditional project remains higher than that of the OPLC project from the second year and beyond, the total cost of the OPLC project is still lower than that of the OPLC project, until the tenth year, because the initial investment cost of the OPLC project is significantly higher than that of the traditional project.

While the thermal life of cable used in the traditional project is generally 20 years when the environment is good, the thermal life of cable used in the OPLC project is generally 40 years. So, we calculate the long-term cost of traditional projects and OPLC projects within 40 years of OPLC’s general life. For safety reasons, ordinary cables need to be re-laid in the 20th year, and ordinary optical cables need to be

| Sector classification name | Serial number |
|----------------------------|---------------|
| (i) Optical fiber cable, transmission and distribution, and communication equipment | S01 |
| (ii) Metal products, machinery and equipment repair services | S02 |
| (iii) Civil engineering buildings | S03 |
| (iv) Agriculture, forestry, husbandry, and fishery | S04 |
| (v) Mining | S05 |
| (vi) Other manufacturing industry | S06 |
| (vii) Electricity, thermal, gas, and water production and supply industry | S07 |
| (viii) Other construction industry | S08 |
| (ix) Wholesale and retail | S09 |
| (x) Transportation, warehousing, and postal service | S10 |
| (xi) Accommodation and catering | S11 |
| (xii) Information transmission, software and information technology services | S12 |
| (xiii) Finance | S13 |
| (xiv) Real estate | S14 |
| (xv) Leasing and business services | S15 |
| (xvi) Scientific research and technology services | S16 |
| (xvii) Water conservancy, environment and public facilities management industry | S17 |
| (xviii) Resident services, repair and other services | S18 |
| (xix) Education industry | S19 |
| (xx) Health and social work | S20 |
| (xxi) Culture, sports and entertainment | S21 |
| (xxii) Public administration, social security and social organizations | S22 |

Table 2: Initial investment in the first year of the OPLC project.

| Cost item | OPLC project (ten thousand-yuan) |
|-----------|----------------------------------|
| CI        | 2050                             |
| CM        | 118                              |
| CF        | 18                               |
| CD        | 14                               |
| LCC       | 2200                             |

Mathematical Problems in Engineering
4. Influence Analysis of OPLC Technology Application on China Economy Based on INPUT-OUTPUT Model

4.1. Scenario Construction. This chapter analyzes the interaction between the intermediate departments by comparing the output in the traditional technology application scenario with that in the OPLC technology application scenario. First, we take the original input-output tables of 2012 and 2015 as the input-output situation under the traditional technology application scenario. Then, according to the “National Economy Industry Classification,” the overhead laying of optical fiber cable projects belongs to “civil engineering construction.” In accordance with the input-output table compilation method, the consumption ratio of unit household between OPLC technology and traditional technology is taken as the basic condition. Updated the consumption items of “Civil Engineering and Construction” for “Fiber Optic Cable, Transmission and Distribution, and Communication Equipment” and “Fiber Optic Cable, Transmission and Distribution, and Communication Equipment” for “Metal Products, Machinery, and Equipment Repair Service” in the input-output tables for 2012 and 2015. Then, we balance the input-output table according to the RAS method. Finally, the new input-output tables for 2012 and 2015 are obtained after the OPLC technology replaced the traditional technology.

The input-output situation under the scenario of traditional technology application in 2015 is referred to as scenario 1, the input-output situation under the scenario of traditional technology application in 2017 is referred to as scenario 2, the input-output situation after the replacement of traditional technology by OPLC technology in 2015 is referred to as scenario 3, and the input-output situation after the replacement of traditional technology by OPLC technology in 2017 is referred to as scenario 4.

4.2. Industrial Correlation Effect Analysis of OPLC Technology Application. OPLC technology substitution directly affects the consumption of other industries in three industries, namely “civil engineering buildings,” “optical fiber cable, transmission and distribution, and communication equipment,” and “metal products, machinery, and equipment repair services.” The impacts of the three sectors on their forward and backward sectors are analyzed as follows.

4.2.1. Industrial Correlation Analysis of “Civil Engineering Buildings” Sectors. Table 4 shows that under the application of traditional technology in 2015, the average direct consumption coefficient and average direct distribution coefficient of the civil engineering building sectors are lower than those of the civil engineering building sectors under the application of OPLC technology. The average direct consumption coefficient and average direct distribution coefficient of the civil engineering buildings sectors show that the civil engineering building sectors play a stronger role in driving and promoting the upstream and downstream industries on average after technology substitution.

It can be seen from Table 5 that under the application of traditional technology in 2015, the average full demand coefficient of the civil engineering buildings sectors is smaller than that of the civil engineering buildings sectors under the application of OPLC technology. This shows that the average full pulling effect (the sum of direct and indirect effects) of the civil engineering buildings sectors on the...
### Table 3: Comparison of the cumulative cost of traditional projects and OPLC projects.

| Progress (year) | A + B project (ten thousand-yuan) | OPLC project (ten thousand-yuan) |
|----------------|-----------------------------------|----------------------------------|
| 1              | 796                               | 2200                             |
| 10             | 1968                              | 2894                             |
| 20             | 3694                              | 3588                             |
| 30             | 5107                              | 4281                             |
| 40             | 6279                              | 4975                             |

### Table 4: Comparison of backward industrial direct linkage effects for "civil engineering buildings".

| Direct consumption coefficient of civil engineering buildings | Scenario 1 | Scenario 3 |
|-------------------------------------------------------------|------------|------------|
| Optical fiber cable, transmission and distribution, and communication equipment | 0.01078    | 0.02922    |
| Metal products, machinery, and equipment repair services    | 0.00036    | 0.00035    |
| Civil engineering buildings                                | 0.00000    | 0.00000    |
| Agriculture, forestry, husbandry, and fishery              | 0.00462    | 0.00455    |
| Mining                                                      | 0.01020    | 0.01002    |
| Other manufacturing industry                               | 0.48700    | 0.47791    |
| Electricity, thermal, gas, and water production and supply industry | 0.01001    | 0.00983    |
| Other construction industry                               | 0.03885    | 0.03812    |
| Wholesale and retail                                       | 0.01729    | 0.01697    |
| Transportation, warehousing, and postal service            | 0.04766    | 0.04678    |
| Accommodation and catering                                 | 0.00472    | 0.00463    |
| Information transmission, software, and information technology services | 0.00104    | 0.00102    |
| Finance                                                    | 0.03845    | 0.03774    |
| Real estate                                                 | 0.00010    | 0.00010    |
| Leasing and business services                              | 0.00729    | 0.00715    |
| Scientific research and technology services                | 0.07390    | 0.07251    |
| Water conservancy, environment, and public facilities management industry | 0.00005    | 0.00005    |
| Resident services, repair, and other services              | 0.00627    | 0.00615    |
| Education industry                                         | 0.00037    | 0.00036    |
| Health and social work                                     | 0.00000    | 0.00000    |
| Culture, sports, and entertainment                         | 0.00118    | 0.00115    |
| Public administration, social security, and social organizations | 0.00020    | 0.00020    |

### Table 5: Comparison of backward industrial direct correlation effects for "optical fiber cable, transmission and distribution, and communication equipment".

| Direct consumption coefficient of optical fiber cable, transmission and distribution, and communication equipment | Scenario 2 | Scenario 4 |
|------------------------------------------------------------------------------------------------------------------|------------|------------|
| Optical fiber cable, transmission and distribution, and communication equipment                                 | 0.10294    | 0.10327    |
| Metal products, machinery and equipment repair services                                                          | 0.00056    | 0.00047    |
| Civil engineering buildings                                                                                      | 0.00033    | 0.00059    |
| Agriculture, forestry, husbandry, and fishery                                                                    | 0.00002    | 0.00002    |
| Mining                                                                                                           | 0.00146    | 0.00147    |
| Other manufacturing industry                                                                                      | 0.56985    | 0.57540    |
| Electricity, thermal, gas, and water production and supply industry                                              | 0.00879    | 0.00890    |
| Other construction industry                                                                                      | 0.00111    | 0.00113    |
| Wholesale and retail                                                                                             | 0.03902    | 0.03941    |
| Transportation, warehousing, and postal service                                                                  | 0.02255    | 0.02282    |
| Accommodation and catering                                                                                       | 0.00546    | 0.00553    |
| Information transmission, software and information technology services                                           | 0.00386    | 0.00391    |
| Finance                                                                                                          | 0.02067    | 0.02095    |
| Real estate                                                                                                      | 0.00098    | 0.00100    |
| Leasing and business services                                                                                     | 0.01929    | 0.01953    |
| Scientific research and technology services                                                                      | 0.00986    | 0.00998    |
| Water conservancy, environment and public facilities management industry                                          | 0.00036    | 0.00037    |
| Resident services, repair and other services                                                                      | 0.00369    | 0.00374    |
| Education industry                                                                                                | 0.00026    | 0.00026    |
| Health and social work                                                                                            | 0.00050    | 0.00051    |
| Culture, sports and entertainment                                                                                  | 0.00153    | 0.00155    |
| Public administration, social security and social organizations                                                  | 0.00122    | 0.00123    |
upstream industries was enhanced after the technology substitution. Among them, the direct correlation effect is different: under the application of OPLC technology, the pulling effect of “civil engineering buildings” sectors on “optical fiber cable, transmission and distribution, and communication equipment,” “metal products, machinery, and equipment repair services,” “civil engineering buildings,” “agriculture, forestry, husbandry, and fishery,” “mining,” “other manufacturing industry,” “electricity, thermal, gas, and water production and supply industry,” “wholesale and retail,” “real estate,” “leasing and business services,” “water conservancy, environment, and public facilities management industry,” “culture, sports, and entertainment,” and “public administration, social security, and social organizations” are higher than those of traditional technology application scenarios.

4.2.2. Industrial Correlation Analysis of “Optical Fiber Cable, Transmission and Distribution, and Communication Equipment” Sectors. As shown in Table 6, under traditional technology in 2015, the average direct consumption coefficient (ADCC) of the sectors including “fiber optic cable, transmission and distribution, and communication equipment” is 0.037, while the ADCC of the sector under OPLC technology is 0.038. This shows that the average direct pulling role of the sectors including “fiber optic cable, transmission and distribution, and communication equipment” for the upstream industries has been enhanced after the technology substitution. The new type of “optical fiber cable, transmission and distribution, and communication equipment” needs high-tech and value-added raw materials, compared with the traditional “optical fiber cable, transmission and distribution, and communication equipment,” it may need the support of the manufacturing industry. The higher energy consumption of equipment manufacturing means the greater demand for “mining”; the greater demand for parts and components means a larger demand for “wholesale and retail”; and the need for every unit of output value added improving the requirement of raw materials transportation and preservation means greater demand for the “transportation, warehousing, and postal industry.” Developing new types of “optical fiber cable, transmission and distribution, and communication equipment” requires high-tech personnel, and scientific research needs the close exchange of academic achievements, which will potentially stimulate the “accommodation and catering”; the application of OPLC technology needs high-quality information transmission services, software development services, and information technology services. The new type of “optical fiber cable, transmission and distribution, and communication equipment” has increased the demand for “information transmission, software and information technology services”; the new type of “optical fiber cable, transmission and distribution, and communication equipment” promotes the development of 5G, four networks integration, and energy Internet. All of these are based on “scientific research”; therefore, the new type of “optical fiber cable, transmission and distribution, and communication equipment” has applied to “scientific research and technology.” In summary, the direct pulling role of the “fiber optic cable, power transmission and distribution, and communication equipment” sectors for the upstream industries was enhanced after technology substitution.

As shown in Table 6, under traditional technology in 2017, the average direct consumption coefficient of the sectors of “fiber optic cable, transmission and distribution, and communication equipment” was 0.037 and that of the sectors of “fiber optic cable, transmission and distribution, and communication equipment” under OPLC technology was 0.0373. This shows that the average direct pulling effect of “optical fiber cable, transmission and distribution, and communication equipment” sectors on upstream industries is enhanced after technology substitution. OPLC technology has been applied for three years in scenario 4, and the pulling effect of the “optical fiber cable, transmission and distribution, and communication equipment” sectors relative to the upstream industries has been weakened, mainly due to the weakening demand of the “optical fiber cable, transmission and distribution, and communication equipment” sectors for “metal products, machinery, and equipment repair services.” Compared with traditional optical fibers and cables, OPLC achieves synchronous transmission of information and energy: the fault can be monitored in real time and the maintenance team is professional, so the fault handling time is short. The operation mechanism of optical fiber cable under new and old technologies proved different, the fault rate of equipment under OPLC technology was low and the life cycle long, and the demand of “metal products, machinery, and equipment repair services” for “optical fiber cable, transmission and distribution, and communication equipment” sectors has weakened. However, the direct consumption of “fiber optic cables, power transmission and distribution, and communication equipment” sectors for other sectors has increased. In summary, the pulling role of “optical fiber cable, transmission and distribution, and communication equipment” sectors for the upstream industries has been enhanced after technology substitution.

As shown in Table 7, under traditional technology in 2017, the average full demand coefficient of “optical fiber cable, transmission and distribution, and communication equipment” sectors was 0.1753 and that of “optical fiber cable, transmission and distribution, and communication equipment” sectors under OPLC technology was 0.1767. This demonstrates shows that the indirect influence of “optical fiber cable, transmission and distribution, and communication equipment” sectors on the upstream industries is great and that of the average full pulling effect was enhanced completely after technology substitution.

Under traditional technology in 2017, the average direct distribution coefficient of the sectors of “optical fiber cable, transmission and distribution, and communication equipment” was 0.031, while under OPLC technology, it was 0.032. This shows that the average direct pushing effect of the sectors of “optical fiber cable, transmission and distribution, and communication equipment” to the downstream industry was enhanced after the technology substitution. Under the traditional technology in 2015, the average full
induction coefficient of the sectors of "optical fiber cable, transmission and distribution, and communication equipment" was 0.145, and under OPLC technology, it was 0.143. This shows that the average full pushing effect of the sectors of "optical fiber cable, transmission and distribution, and communication equipment" to the downstream industry was weakened after the technology substitution. "Optical fiber cable, transmission and distribution, and communication equipment" in scenario 2 is traditional, and "optical fiber cable, transmission and distribution, and communication equipment" in scenario 4 is new technology. Because of its fast transmission speed, high reliability, strong energy

Table 6: Comparison of backward industrial direct correlation effects for "optical fiber cable, transmission and distribution, and communication equipment".

| Direct consumption coefficient of optical fiber cable, transmission and distribution, and communication equipment | Scenario 2 | Scenario 4 |
|---------------------------------------------------------------|------------|------------|
| Optical fiber cable, transmission and distribution, and communication equipment | 0.10294 | 0.10327 |
| Metal products, machinery, and equipment repair services | 0.00056 | 0.00047 |
| Civil engineering buildings | 0.00033 | 0.00059 |
| Agriculture, forestry, husbandry, and fishery | 0.00002 | 0.00002 |
| Mining | 0.00146 | 0.00147 |
| Other manufacturing industry | 0.56985 | 0.57540 |
| Electricity, thermal, gas, and water production and supply industry | 0.00879 | 0.00890 |
| Other construction industry | 0.00111 | 0.00113 |
| Wholesale and retail | 0.03902 | 0.03941 |
| Transportation, warehousing, and postal service | 0.02255 | 0.02282 |
| Accommodation and catering | 0.00546 | 0.00553 |
| Information transmission, software, and information technology services | 0.00386 | 0.00391 |
| Finance | 0.02067 | 0.02095 |
| Real estate | 0.00098 | 0.00100 |
| Leasing and business services | 0.01929 | 0.01953 |
| Scientific research and technology services | 0.00986 | 0.00998 |
| Water conservancy, environment, and public facilities management industry | 0.00036 | 0.00037 |
| Resident services, repair, and other services | 0.00369 | 0.00374 |
| Education industry | 0.00026 | 0.00026 |
| Health and social work | 0.00050 | 0.00051 |
| Culture, sports, and entertainment | 0.00153 | 0.00155 |
| Public administration, social security, and social organizations | 0.00122 | 0.00123 |

Table 7: Comparison of forward-related industrial direct effects for "optical fiber cable, transmission and distribution, and communication equipment".

| Direct distribution coefficient of optical fiber cable, transmission and distribution, and communication equipment | Scenario 1 | Scenario 3 |
|---------------------------------------------------------------|------------|------------|
| Optical fiber cable, transmission and distribution, and communication equipment | 0.14159 | 0.14147 |
| Metal products, machinery, and equipment repair services | 0.00114 | 0.00112 |
| Civil engineering buildings | 0.00875 | 0.02381 |
| Agriculture, forestry, husbandry, and fishery | 0.00004 | 0.00004 |
| Mining | 0.00587 | 0.00575 |
| Other manufacturing industry | 0.15383 | 0.15076 |
| Electricity, thermal, gas, and water production and supply industry | 0.05514 | 0.05406 |
| Other construction industry | 0.12212 | 0.11974 |
| Wholesale and retail | 0.00021 | 0.00021 |
| Transportation, warehousing, and postal service | 0.00104 | 0.00102 |
| Accommodation and catering | 0.00004 | 0.00004 |
| Information transmission, software, and information technology services | 0.05302 | 0.05201 |
| Finance | 0.00000 | 0.00000 |
| Real estate | 0.00095 | 0.00094 |
| Leasing and business services | 0.04078 | 0.03999 |
| Scientific research and technology services | 0.01468 | 0.01439 |
| Water conservancy, environment, and public facilities management industry | 0.00208 | 0.00204 |
| Resident services, repair and other services | 0.00099 | 0.00085 |
| Education industry | 0.00784 | 0.00784 |
| Health and social work | 0.00008 | 0.00008 |
| Culture, sports, and entertainment | 0.00060 | 0.00059 |
| Public administration, social security, and social organizations | 0.00050 | 0.00049 |
acceptance ability, strong anti-interference ability, and good self-healing ability, the supply-end telecom operators show high technology adoption. From the point-of-user side, the new "optical fiber cable, power transmission and distribution, and communication equipment" can be cloud services, big data technology to interconnect transport networks, the Internet of things, and other platforms more in line with consumer preferences. From the user side, the new "optical fiber cable, power transmission and distribution, and communication equipment" can realize information and energy network upgrades to form a new mode of urban network. The government advocates the use of new “optical fiber cable, power transmission and distribution, and communication equipment.” Twenty-two sectors are composed of the supply side, user side, and social layer. The above three aspects illustrate that the direct demand for new types of “optical fiber cables, power transmission and distribution, and communication equipment” under the application of OPLC technology is expanding. The indirect demand is lower than that of traditional technology, possibly because the price advantage of the OPLC technology application has not been fully revealed in the short term.

As shown in Table 8, under traditional technology in 2015, the average direct distribution coefficient of the sectors of “optical fiber cable, transmission and distribution, and communication equipment” was 0.0277, while under OPLC technology it was 0.0279. This shows that the average direct pushing effect of the sectors of “optical fiber cable, transmission and distribution, and communication equipment” to downstream industries has been enhanced after technology substitution. It can be observed that although 2012 was the first year for OPLC technology application, the new market of “optical fiber cable, transmission and distribution, and communication equipment” remains immature, but OPLC technology advantages are prominent, and downstream industries show a strong preference for new technology products.

As shown in Table 9, under the traditional technology in 2015, the average full induction coefficient of the sectors of “optical fiber cable, transmission and distribution, and communication equipment” was 0.1201, while under OPLC technology, it was 0.1205. This shows that the average full pushing effect of the sectors of “optical fiber cable, transmission and distribution, and communication equipment” to the downstream industry was enhanced after the technology substitution. Different from the direct correlation effect, the sectors of “optical fiber cable, transmission and distribution, and communication equipment” under OPLC technology shows a greater full pushing effect on the “agriculture, forestry, husbandry, and fishery” sectors than traditional technology application scenarios.

4.3.1. Industrial Ripple Effect Analysis of OPLC Technology Application

4.3.1.1. Forward Industrial Ripple Effects Analysis under Four Scenarios. As shown in Table 12, after the substitute of OPLC technology for traditional technology in 2015, the influence coefficient only increased for three industries, namely “optical fiber cable, power transmission and distribution, and communication equipment,” “civil engineering buildings,” and “agriculture, forestry, husbandry, and fishery.” The influence coefficients in the nineteenth industries decreased, indicating that technology substitution has weakened the impact of 86% of industries on other backward industries. The sectors of “Optical fiber cable, power transmission and distribution, and communication equipment,” “civil engineering buildings,” and “agriculture, forestry, husbandry, and fishery” were the first three sectors to be inducted into the application of OPLC technology. Due to the full application of OPLC technology in 2015, the production of optical fiber cable, transmission and distribution, and communication equipment in that year was different from that of traditional products. Every new unit of optical fiber cable, transmission, and distribution and communication equipment was added, more “mining,” “other manufacturing industries,” “wholesale and retail,” “transportation, storage and postal service,” “accommodation and catering,” “information transmission, software and information technology services,” “scientific research and technology services” were consumed. Therefore, the impact of “optical fiber cable, power transmission and distribution, and communication equipment” on its backward industries is increasing; every unit of output added in the laying of optical fiber cables in civil engineering buildings consumes more products from other sectors, especially new OPLC
### Table 8: Comparison of complete forward-related industrial direct effects for "metal products, machinery and equipment repair services".

| Direct distribution coefficient of metal products, machinery and equipment repair services | Scenario 2 | Scenario 4 |
|----------------------------------------------------------------------------------------|------------|------------|
| Optical fiber cable, transmission and distribution, and communication equipment          | 0.01940    | 0.01675    |
| Metal products, machinery and equipment repair services                                 | 0.00204    | 0.00200    |
| Civil engineering buildings                                                             | 0.03324    | 0.05077    |
| Agriculture, forestry, husbandry, and fishery                                           | 0.02581    | 0.02592    |
| Mining                                                                                  | 0.03316    | 0.03325    |
| Other manufacturing industry                                                            | 0.70256    | 0.68919    |
| Electricity, thermal, gas, and water production and supply industry                     | 0.11711    | 0.11483    |
| Other construction industry                                                            | 0.21711    | 0.21291    |
| Wholesale and retail                                                                    | 0.02323    | 0.02278    |
| Transportation, warehousing, and postal service                                         | 0.03357    | 0.03293    |
| Accommodation and catering                                                             | 0.01055    | 0.01036    |
| Information transmission, software, and information technology services                 | 0.08100    | 0.07946    |
| Finance                                                                                 | 0.02560    | 0.02510    |
| Real estate                                                                             | 0.01115    | 0.01094    |
| Leasing and business services                                                           | 0.06713    | 0.06583    |
| Scientific research and technology services                                             | 0.03185    | 0.03123    |
| Water conservancy, environment and public facilities management industry               | 0.00567    | 0.00556    |
| Resident services, repair and other services                                            | 0.01470    | 0.01442    |
| Education industry                                                                      | 0.00525    | 0.00515    |
| Health and social work                                                                  | 0.01072    | 0.01052    |
| Culture, sports, and entertainment                                                      | 0.00366    | 0.00359    |
| Public administration, social security, and social organizations                        | 0.01365    | 0.01339    |

### Table 9: Comparison of forward-related industrial direct effects for "metal products, machinery and equipment repair services".

| Full induction coefficient of optical fiber cable, transmission and distribution, and communication equipment | Scenario 1 | Scenario 3 |
|----------------------------------------------------------------------------------------------------------|------------|------------|
| Optical fiber cable, transmission and distribution, and communication equipment                          | 1.19346    | 1.19329    |
| Metal products, machinery and equipment repair services                                                  | 0.00204    | 0.00200    |
| Civil engineering buildings                                                                             | 0.03324    | 0.05077    |
| Agriculture, forestry, husbandry, and fishery                                                           | 0.02581    | 0.02592    |
| Mining                                                                                                   | 0.03316    | 0.03325    |
| Other manufacturing industry                                                                            | 0.70256    | 0.68919    |
| Electricity, thermal, gas, and water production and supply industry                                      | 0.11711    | 0.11483    |
| Other construction industry                                                                            | 0.21711    | 0.21291    |
| Wholesale and retail                                                                                     | 0.02323    | 0.02278    |
| Transportation, warehousing, and postal service                                                         | 0.03357    | 0.03293    |
| Accommodation and catering                                                                              | 0.01055    | 0.01036    |
| Information transmission, software, and information technology services                                  | 0.08100    | 0.07946    |
| Finance                                                                                                | 0.02560    | 0.02510    |
| Real estate                                                                                              | 0.01115    | 0.01094    |
| Leasing and business services                                                                            | 0.06713    | 0.06583    |
| Scientific research and technology services                                                              | 0.03185    | 0.03123    |
| Water conservancy, environment and public facilities management industry                                | 0.00567    | 0.00556    |
| Resident services, repair and other services                                                             | 0.01470    | 0.01442    |
| Education industry                                                                                       | 0.00525    | 0.00515    |
| Health and social work                                                                                   | 0.01072    | 0.01052    |
| Culture, sports, and entertainment                                                                       | 0.00366    | 0.00359    |
| Public administration, social security, and social organizations                                         | 0.01365    | 0.01339    |

### Table 10: Comparison of complete forward-related industrial effects for "metal products, machinery and equipment repair services".

| Full induction coefficient of metal products, machinery, and equipment repair services | Scenario 2 | Scenario 4 |
|--------------------------------------------------------------------------------------|------------|------------|
| Optical fiber cable, transmission and distribution, and communication equipment      | 1.0254     | 1.0405     |
| Metal products, machinery, and equipment repair services                              | 1.00626    | 1.00625    |
| Civil engineering buildings                                                           | 0.07695    | 0.08115    |
| Agriculture, forestry, husbandry, and fishery                                        | 0.08889    | 0.08901    |
| Mining                                                                               | 0.14383    | 0.14401    |
| Other manufacturing industry                                                         | 2.11865    | 2.12112    |
Table 10: Continued.

| Full induction coefficient of metal products, machinery, and equipment repair services | Scenario 2 | Scenario 4 |
|-------------------------------------------------------------------------------------|------------|------------|
| Electricity, thermal, gas, and water production and supply industry                 | 0.33208    | 0.33240    |
| Other construction industry                                                         | 0.25761    | 0.25721    |
| Wholesale and retail                                                                | 0.04916    | 0.04909    |
| Transportation, warehousing, and postal service                                      | 0.16372    | 0.16378    |
| Accommodation and catering                                                          | 0.03134    | 0.03137    |
| Information transmission, software, and information technology services             | 0.03714    | 0.03705    |
| Finance                                                                             | 0.03313    | 0.03309    |
| Real estate                                                                          | 0.02370    | 0.02375    |
| Leasing and business services                                                       | 0.07197    | 0.07188    |
| Scientific research and technology services                                         | 0.03944    | 0.03939    |
| Water conservancy, environment, and public facilities management industry           | 0.01245    | 0.01243    |
| Resident services, repair, and other services                                       | 0.03434    | 0.03435    |
| Education industry                                                                  | 0.01796    | 0.01281    |
| Health and social work                                                              | 0.04088    | 0.04090    |
| Culture, sports, and entertainment                                                  | 0.00921    | 0.00921    |
| Public administration, social security, and social organizations                    | 0.02856    | 0.02850    |

Table 11: Comparison of backward effects of 22 sectors under four scenarios.

| Influence coefficient | Scenario 1 | Scenario 2 | Scenario 3 |
|-----------------------|------------|------------|------------|
|                       |            |            |            |
| Optical fiber cable, transmission and distribution, and communication equipment     | 1.41479    | 1.41734    | 1.38301    | 1.39126    |
| Metal products, machinery, and equipment repair services                           | 1.34003    | 1.33922    | 1.19055    | 1.18781    |
| Civil engineering buildings                                                       | 1.27768    | 1.28629    | 1.29126    | 1.26235    |
| Agriculture, forestry, husbandry, and fishery                                     | 0.81387    | 0.81479    | 0.81747    | 0.81593    |
| Mining                                                                            | 0.92811    | 0.92746    | 1.29126    | 1.28986    |
| Other manufacturing industry                                                      | 1.29069    | 1.28981    | 1.29126    | 1.12033    |
| Electricity, thermal, gas, and water production and supply industry               | 0.92811    | 0.92746    | 1.29126    | 1.28986    |
| Other construction industry                                                       | 1.25533    | 1.25457    | 1.29126    | 1.28986    |
| Wholesale and retail                                                              | 0.66492    | 0.66445    | 0.71576    | 0.71474    |
| Transportation, warehousing, and postal service                                   | 1.06007    | 1.05933    | 1.03407    | 1.03254    |
| Accommodation and catering                                                        | 1.01274    | 1.01209    | 1.02459    | 1.02281    |
| Information transmission, software and information technology services            | 0.94354    | 0.94306    | 0.90859    | 0.90737    |
| Finance                                                                           | 0.75316    | 0.75263    | 0.67843    | 0.67756    |
| Real estate                                                                        | 0.59941    | 0.59898    | 0.61226    | 0.61297    |
| Leasing and business services                                                     | 1.08379    | 1.08309    | 1.08462    | 1.08303    |
| Scientific research and technology services                                       | 0.98736    | 0.98673    | 0.94327    | 0.94255    |
| Water conservancy, environment, and public facilities management industry         | 0.89501    | 0.89442    | 0.86768    | 0.86639    |
| Resident services, repair, and other services                                     | 0.64046    | 0.64000    | 0.58298    | 0.58206    |
| Education industry                                                                 | 1.04535    | 1.04462    | 1.04611    | 1.04426    |
| Health and social work                                                             | 0.90480    | 0.90417    | 0.89709    | 0.89578    |
| Culture, sports, and entertainment                                                 | 0.79214    | 0.79159    | 0.77094    | 0.77005    |
| Public administration, social security, and social organizations                  | 1.08379    | 1.08309    | 1.08462    | 1.08303    |

Table 12: Comparison of backward effects of 22 sectors under four scenarios.

| Influence coefficient | Scenario 1 | Scenario 2 | Scenario 3 |
|-----------------------|------------|------------|------------|
|                       |            |            |            |
| Optical fiber cable, transmission and distribution, and communication equipment     | 1.41479    | 1.41734    | 1.38301    | 1.39126    |
| Metal products, machinery, and equipment repair services                           | 1.34003    | 1.33922    | 1.19055    | 1.18781    |
| Civil engineering buildings                                                       | 1.27768    | 1.28629    | 1.29126    | 1.26235    |
| Agriculture, forestry, husbandry, and fishery                                     | 0.81387    | 0.81479    | 0.81747    | 0.81593    |
| Mining                                                                            | 0.92811    | 0.92746    | 1.29126    | 1.28986    |
| Other manufacturing industry                                                      | 1.29069    | 1.28981    | 1.29126    | 1.12033    |
| Electricity, thermal, gas, and water production and supply industry               | 1.17007    | 1.16935    | 1.26235    | 1.26055    |
| Other construction industry                                                       | 1.25533    | 1.25457    | 1.29126    | 1.28986    |
| Wholesale and retail                                                              | 0.66492    | 0.66445    | 0.71576    | 0.71474    |
As shown in Table 13, after OPLC technology replaced traditional technology in 2015, the induction coefficient increased by only two industries, but decreased by 20 industries, indicating that technology substitution made 90% of the industries less inductive and the demand of their forward industries. In 2017, three years after OPLC technology replaced traditional technology, the sectors with increased induction coefficients increased to 11 industries, while the sectors with decreased induction coefficients represented 11 industries, indicating that technology substitution still weakened the demand induction degree of 50% of industries to their forward industries. Therefore, technology substitution does not enhance the forward demand induction degree of industries in the short term, but has a negative effect, which gradually weakens over time. The weakening of this negative effect is manifested in the following aspects: in 2015, technology substitution increased the induction degree of 10% of industries to their forward sectors demand; in 2017, technology substitution increased the induction degree of 50% of industries to their forward sectors demand; in the past four years, the induction degree of industries increased by 40%, respectively, “agriculture, forestry, husbandry, and fishery,” “other manufacturing industries,” “wholesale and retail,” “transportation, storage, and postal service,” “finance,” “leasing and business services,” “resident services, repair, and other services,” “education industry,” and “culture, sports, and entertainment.” Among them, the primary industry accounts for 11%, the secondary industry accounts for 33%, and the tertiary industry accounts for 56%. In contrast, the tertiary industry is more inductive to its forward sectors. The development of OPLC technology will provide a physical carrier for multinetowork convergence, help to reduce the cost of access to the third market, encourage more market participants to enter, drive the growth of investment in the tertiary industry, and further optimize the allocation of resources in the tertiary industry.

4.4. Structural Decomposition Analysis

4.4.1. Analysis of Total Output Change under Four Scenarios. We can obtain the contribution rate of the change of economic and technological coefficient and final demand to the change of total output from 2015 to 2017 from formula (16). Detailed information can be found in Tables 14 and 15. Twenty sectors show higher value-added of total output from 2015 to 2017 after technology substitution, while only two sectors show lower value-added, namely “accommodation and catering” and “health and social work.” This indicates that the replacement of OPLC technology is beneficial to the increase of the total output of most sectors. Total output changes more or less in scenarios 3 to 4 than that in scenarios 1 to 2, which is caused by the substitution of OPLC technology. Technology substitution has a negative effect on the total output change of two industries; this may be because the research cycle of this paper is only four years. The application of OPLC technology in these two industries

| Sector | Scenario 1 | Scenario 3 | Scenario 2 | Scenario 4 |
|--------|------------|------------|------------|------------|
| Transportation, warehousing, and postal service | 1.06007 | 1.05933 | 1.03407 | 1.03254 |
| Accommodation and catering | 1.01274 | 1.01209 | 1.02459 | 1.02281 |
| Information transmission, software, and information technology services | 0.94354 | 0.94306 | 0.90859 | 0.90737 |
| Finance | 0.75316 | 0.75263 | 0.67843 | 0.67756 |
| Real estate | 0.59941 | 0.59898 | 0.61226 | 0.61297 |
| Leasing and business services | 1.08379 | 1.08309 | 1.08462 | 1.08303 |
| Scientific research and technology services | 0.98736 | 0.98673 | 0.94327 | 0.94255 |
| Water conservancy, environment, and public facilities management industry | 0.89501 | 0.89442 | 0.86768 | 0.86639 |
| Resident services, repair, and other services | 0.64046 | 0.64000 | 0.58298 | 0.58206 |
| Education industry | 1.04535 | 1.04462 | 1.04611 | 1.04426 |
| Health and social work | 0.90480 | 0.90417 | 0.89709 | 0.89578 |
| Culture, sports, and entertainment | 0.79214 | 0.79159 | 0.77094 | 0.77005 |
| Public administration, social security, and social organizations | 1.08379 | 1.08309 | 1.08462 | 1.08303 |
### Table 13: Comparison of the forward effects of 22 sectors under four scenarios.

| Scenario | Total output change | Effect of economic coefficient change | Proportion of effect of economic coefficient change | Final demand effect change | Proportion of final demand effect change |
|----------|---------------------|---------------------------------------|-------------------------------------------------|---------------------------|----------------------------------------|
| Scenario 1 | Optical fiber cable, transmission and distribution, and communication equipment | 0.98518 | 0.98027 | 0.98027 | 0.98518 |
| Scenario 2 | Metal products, machinery and equipment repair services | 1.71682 | 1.71528 | 1.71528 | 1.71682 |
| Scenario 3 | Civil engineering buildings | 0.37014 | 0.39299 | 0.39299 | 0.37014 |
| Scenario 4 | Agriculture, forestry, husbandry, and fishery | 1.25475 | 1.25335 | 1.25335 | 1.25475 |
| Scenario 5 | Mining | 2.38230 | 2.38015 | 2.38015 | 2.38230 |
| Scenario 6 | Other manufacturing industry | 1.24283 | 1.24174 | 1.24174 | 0.64008 |
| Scenario 7 | Electricity, thermal, gas, and water production and supply industry | 1.62694 | 1.62537 | 1.62537 | 1.64008 |
| Scenario 8 | Other construction industry | 0.43135 | 0.43104 | 0.43104 | 0.38952 |
| Scenario 9 | Wholesale and retail | 1.03720 | 1.03609 | 1.03609 | 0.62229 |
| Scenario 10 | Transportation, warehousing, and postal service | 1.26361 | 1.26276 | 1.26276 | 1.26229 |
| Scenario 11 | Accommodation and catering | 0.92610 | 0.92522 | 0.92522 | 0.73822 |
| Scenario 12 | Information transmission, software and information technology services | 0.75684 | 0.75594 | 0.75594 | 0.76241 |
| Scenario 13 | Finance | 1.29767 | 1.29668 | 1.29668 | 1.26072 |
| Scenario 14 | Real estate | 0.66106 | 0.66027 | 0.66027 | 0.69938 |
| Scenario 15 | Leasing and business services | 1.39674 | 1.39532 | 1.39532 | 1.35773 |
| Scenario 16 | Scientific research and technology services | 1.03280 | 1.03391 | 1.03391 | 1.00501 |
| Scenario 17 | Water conservancy, environment and public facilities management industry | 0.86760 | 0.86587 | 0.86587 | 0.69328 |
| Scenario 18 | Resident services, repair and other services | 0.88559 | 0.88486 | 0.88486 | 0.91068 |
| Scenario 19 | Education industry | 0.42292 | 0.42236 | 0.42236 | 0.40396 |
| Scenario 20 | Health and social work | 0.38897 | 0.38842 | 0.38842 | 0.38573 |
| Scenario 21 | Culture, sports and entertainment | 0.82490 | 0.82407 | 0.82407 | 0.89390 |
| Scenario 22 | Public administration, social security and social organizations | 0.40858 | 0.40801 | 0.40801 | 0.42838 |

### Table 14: Decomposition analysis and proportion of sectors in scenario 1 to scenario 2.

| Scenario 3 to scenario 2 | Total output change (ten thousand-yuan) | Effect of economic coefficient change (ten thousand-yuan) | Proportion of effect of economic coefficient change | Final demand effect change (ten thousand-yuan) | Proportion of final demand effect change |
|--------------------------|-----------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------|----------------------------------------|
| S01                      | 172826480                               | 65228937                                       | 0.38                                            | 107597543                                 | 0.62                                  |
| S02                      | 6092585                                 | 3108094                                        | 0.51                                            | 2984491                                   | 0.49                                  |
| S03                      | 129421596                               | 27580845                                       | 0.21                                            | 10180472                                  | 0.79                                  |
| S04                      | 230564288                               | 115247120                                      | 0.50                                            | 115317168                                 | 0.50                                  |
| S05                      | −128245930                              | −310311993                                     | 2.42                                            | 182060663                                 | −1.42                                 |
| S06                      | 2206826545                              | 172977447                                      | 0.08                                            | 2033849007                                | 0.92                                  |
| S07                      | 203293146                               | 41022330                                       | 0.20                                            | 162270815                                 | 0.80                                  |
| S08                      | 45197368                               | −17775655                                     | −0.04                                          | 432973923                                 | 1.04                                  |
| S09                      | 355533052                               | 112979364                                      | 0.32                                            | 242535387                                 | 0.68                                  |
| S10                      | 265551333                               | 106374926                                      | 0.40                                            | 159176406                                 | 0.60                                  |
| S11                      | 99757954                                | 50101036                                       | 0.50                                            | 49656918                                  | 0.50                                  |
| S12                      | 151289837                               | 38625399                                       | 0.26                                            | 112664437                                 | 0.74                                  |
| S13                      | 344857606                               | 124522606                                      | 0.36                                            | 220335000                                 | 0.64                                  |
| S14                      | 201737450                               | 53761775                                       | 0.27                                            | 147975674                                 | 0.73                                  |
| S15                      | 307746138                               | 167092924                                      | 0.54                                            | 140653214                                 | 0.46                                  |
| S16                      | 90946093                                | 23628898                                       | 0.26                                            | 67317195                                  | 0.74                                  |
| S17                      | 31192887                                | 5538506                                        | 0.18                                            | 25654381                                  | 0.82                                  |
| S18                      | 52622657                                | 13512267                                       | 0.26                                            | 3910389                                  | 0.74                                  |
| S19                      | 96990245                                | 3577098                                        | 0.04                                            | 93413148                                  | 0.96                                  |
| S20                      | 147163025                               | 10012944                                       | 0.07                                            | 13750081                                  | 0.93                                  |
| S21                      | 37969136                                | 13764968                                       | 0.36                                            | 24204169                                  | 0.64                                  |
| S22                      | 109139598                               | 20017021                                       | 0.18                                            | 89122577                                  | 0.82                                  |

### Table 15: Decomposition analysis and proportion of sectors in scenario 3 to scenario 4.

| Scenario 3 to scenario 4 | Total output change (ten thousand-yuan) | Effect of economic coefficient change (ten thousand-yuan) | Proportion of effect of economic coefficient change | Final demand effect change (ten thousand-yuan) | Proportion of final demand effect change |
|--------------------------|-----------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------|----------------------------------------|
| S01                      | 187668666                               | 76692241                                       | 0.41                                            | 110976425                                 | 0.59                                  |
| S02                      | 6120109                                 | 3148007                                        | 0.51                                            | 2972102                                   | 0.49                                  |
| S03                      | 145539039                               | 40564255                                       | 0.28                                            | 104974758                                 | 0.72                                  |
has not been eliminated, or it is hindered in the process of absorption. If we study the change of long-term total output for more than four years, OPLC technology may be better absorbed, thus producing a positive effect.

4.4.2. Analysis of Technical Effect Contribution Change from Sector Perspective under Four Scenarios. As can be seen from Figure 2, 86% of the sectors’ proportion of effect of economic coefficient change is larger than that under traditional technology after technology substitution. On the contrary, the OPLC technology substitution makes 14% of the sectors’ proportion of effect of economic coefficient change smaller than that under traditional technology, and the 14% includes two sectors whose total output change decreased after technology substitution. This shows that OPLC technology substitution not only makes 14% of the industry’s total output decrease but make the increase of total output more

| Scenario 3 to scenario 4 | Total output change (ten thousand-yuan) | Effect of economic coefficient change (ten thousand-yuan) | Proportion of effect of economic coefficient change | Final demand effect change (ten thousand-yuan) | Proportion of final demand effect change |
|--------------------------|---------------------------------------|-------------------------------------------------------|---------------------------------|---------------------------------|----------------------------------------|
| S04                      | 230633502                             | 115177363                                             | 0.50                           | 115456140                       | 0.50                                   |
| S05                      | -128141372                            | -310203265                                           | 2.42                           | 182061893                       | -1.42                                  |
| S06                      | 2207925808                            | 174061154                                             | 0.08                           | 2033864654                      | 0.92                                   |
| S07                      | 203449477                             | 41178563                                              | 0.20                           | 162270914                       | 0.80                                   |
| S08                      | 415240661                             | -17707610                                            | -0.04                          | 432948272                       | 1.04                                   |
| S09                      | 355571035                             | 113011630                                             | 0.32                           | 242559404                       | 0.68                                   |
| S10                      | 265706713                             | 106537221                                            | 0.40                           | 159169491                       | 0.60                                   |
| S11                      | 99720140                              | 50060370                                              | 0.50                           | 49659771                        | 0.50                                   |
| S12                      | 151354510                             | 38677425                                              | 0.26                           | 112677085                       | 0.74                                   |
| S13                      | 345126160                             | 124809225                                             | 0.36                           | 220316935                       | 0.64                                   |
| S14                      | 201841279                             | 53879202                                              | 0.27                           | 147962078                       | 0.73                                   |
| S15                      | 307992447                             | 167370127                                             | 0.54                           | 140622320                       | 0.46                                   |
| S16                      | 91149933                              | 23872196                                              | 0.26                           | 67277738                        | 0.74                                   |
| S17                      | 31331675                              | 5687471                                               | 0.18                           | 25644205                       | 0.82                                   |
| S18                      | 52695660                              | 13586980                                              | 0.26                           | 39108679                        | 0.74                                   |
| S19                      | 97102328                              | 3698234                                               | 0.04                           | 93404094                        | 0.96                                   |
| S20                      | 147104479                             | 9953441                                               | 0.07                           | 137151038                       | 0.93                                   |
| S21                      | 37983117                              | 13773471                                              | 0.36                           | 24209647                        | 0.64                                   |
| S22                      | 109250867                             | 20133448                                              | 0.18                           | 89117419                        | 0.82                                   |

Figure 2: Increase in the proportion of economic coefficient change before and after the substitution of technology.
insensitive to the effect of technological change; on the contrary, it increases the induction to the change of total demand.

For 86% of the sectors, OPLC technology mainly acts on the whole society through the basic grid and communication network technology, and it consolidates the social and technological foundation, radiates various industries from the source, and makes the total output of each sector higher growth.

This paper not only analyzes the direct consumption of cost, but also reveals the indirect consumption hidden behind the direct consumption through input-output analysis. The results are as follows:

1. By comparing the cost of traditional projects to OPLC projects, the result reveal that because of the high initial investment of OPLC projects, the accumulated cost of them is higher than that of a traditional project in the short term. However, over time, the cost of OPLC projects shows a year-by-year decrease, from year two, which is lower than that of traditional projects. In addition, the technical advantages of OPLC projects have gradually become prominent. The long life cycle enables the OPLC project to carry out a new round of renewal, which provides a strong guarantee for innovation and sustainable development. On the contrary, the traditional project only carries on the comprehensive scrap replacement in the technology: the technology elimination falls behind that of the OPLC project. Therefore, from the perspective of promoting sustainable development and technological innovation, the cost advantage of OPLC projects is significantly higher than traditional projects, which can fundamentally guarantee the sustainable development of China’s economic environment.

2. After China’s industrial chain was replaced by OPLC technology in 2015, on the one hand, the average complete pulling effect of the “civil engineering construction” department on the upstream industry was significantly enhanced, while on the other hand, the average complete pulling effect of the “fiber optic cable, transmission and distribution, and communication equipment” department on the downstream industry was also significantly enhanced. Therefore, the OPLC technology substitution not only weakens the influence of 86% of industries on other backward industries; more importantly, however, the substitution weakens the demand response degree of 90% of industries on their forward industries, so that the entire industrial system can achieve stable and long-term sustainable development.

3. In 2017, via a gradual replacement with OPLC technology, the impact on the development of China’s economic industrial chain gradually from forward pull into reverse push: “fiber optic cable, power transmission and distribution, and communication equipment department” for upstream industries average pull function fully, on average, was significantly enhanced, while the downstream industry decreased in completely push forward. The “metalwork, machinery and equipment repair service” sector’s average complete pull on the upstream industry was weakened, while the average complete pull on the downstream industry was significantly enhanced. Technology substitution weakened the spreading effect of 86% of industries on other backward industries. In the short term, technology substitution does not enhance the spreading effect of each industry but produces negative effect. Technology substitution also weakened the demand induction degree of 50% of industries to their forward industries. Therefore, in the short term, technology substitution does not enhance the demand induction degree of each industry but produces negative effects. However, such negative effects gradually weaken over time.

5. Conclusion

This paper takes the application of OPLC technology as the research object, based on the national typical demonstration of the OPLC technology application project, and uses the whole life-cycle cost theory to calculate the comprehensive cost of the project based on OPLC technology. This study then compares that to the traditional technology application of a pure power project and a pure optical fiber project across different time dimensions. Based on the microanalysis of the cost of the OPLC technology application project, with the help of the input-output model, the interaction between the intermediate departments under the implementation scenario of traditional technology and the implementation scenario of OPLC technology, as well as the influencing factors of the change of total output, were compared and analyzed.

After the replacement of technology, the total output value added of 20 industries increased significantly from 2012 to 2015. This shows that the replacement of OPLC technology is beneficial to the development of most industries. As a result, China’s whole industrial chain has achieved a comprehensive basic guarantee in terms of long-term, stable, and sustainable development.

From the perspective of the power grid industry, OPLC technology can realize the acceptance and coordinated control of distributed energy and realize friendly interaction with users, so that users can enjoy the convenience brought by new energy power. At the same time, OPLC technology integrates optical fiber and cable into one, avoiding the secondary wiring and saving ample metal, pipeline, plastic, and other resources. Moreover, it effectively reduces the cost of network construction and has a high cost performance ratio to ensure the long-term, stable, and sustainable development of the power grid industry.

From the perspective of the communication industry, OPLC technology shows strong expansibility, which can simultaneously solve the two services of power supply and information exchange, maximize the integration and sharing
of urban power and communication broadband resources, and promote the “integration of energy flow and information flow” in a smart city. The energy and information revolution will transform every community and every building into a micro-power plant and transform the power grid of each region into an energy sharing network to form an energy Internet. Therefore, as a new economic model, energy and information transformation will bring us into a “post-carbon” era and lead the sustainable development of the communications industry.

Above all, OPLC technology has expanded the industrial scale of new energy and other aspects and promoted the innovation of related new material technology. The progress of new material technology will promote the upgrading of manufacturing industries such as solar power generation equipment, wind power generation equipment, power electronic equipment, wires and cables, transformers, switches, advanced energy storage batteries, and electric vehicles. The development of the energy storage industry will reduce costs, directly affect the cost of solar power generation equipment, wind power generation equipment, energy storage equipment, electric vehicles, and other products, and it will improve competitiveness of the above industries and promote the sustainable development of the new energy industry.

Data Availability

The basic data are from China Statistical Yearbook. The input-output table is from the National Bureau of Statistics. https://data.stats.gov.cn/ifnormal.htm?u=files/html/quickSearch/trcc/trcc01.html&ph=740. The normalized collated data are visible in the attached table.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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References

[1] W. Zou, Z. He, and K. Hotate, “Complete discrimination of strain and temperature using Brillouin frequency shift and birefringence in a polarization-maintaining fiber,” Optics Express, vol. 17, no. 3, pp. 1248–1255, 2009.
[2] Y. Mizuno, W. Zou, and Z. He, “Proposal of Brillouin optical correlation-domain reflectometry (BOCDR),” Optics Express, vol. 16, no. 16, pp. 12148–12153, 2008.
[3] H. Ding, L. Teng, G. Xu et al., “Splicing technology of optical fiber composite low-voltage cable for fiber to the home,” Power System Technology, vol. 35, no. 11, pp. 222–227, 2011.
[4] G. Xu, P. Xie, K. Guo, G. Zhou, and T.-T. Zhang, “OPLC temperature distribution and optical unit transmission loss characteristics analysis,” Study on Optical Communications, vol. 20, no. 5, pp. 40–45, 2018.
[5] R. M. Solow, “Technical change and the aggregate production function,” The Review of Economics and Statistics, vol. 39, no. 3, pp. 312–320, 1957.
[6] P. M. Romer, “Endogenous technological change,” Journal of Political Economy, vol. 98, no. 5, pp. 71–102, 1990.
[7] W. Leontief and A. Strout, “Multiregional input-output analysis,” in Structural Independence and Economic Development, T. Barra, Ed., Palgrave Macmillan, London, UK, pp. 119–149, 1963.
[8] W. Leontief, “Environmental repercussions and the economic structure: an input-output approach,” The Review of Economics and Statistics, vol. 52, no. 3, pp. 262–271, 1970.
[9] C. Hendrickson, A. Horvath, S. Joshi, and L. Lave, “Peer reviewed: economic input–output models for environmental life-cycle assessment,” Environmental science & technology, vol. 32, no. 7, pp. 184–191, 1998.
[10] R. Pietroforte and T. Gregori, “An input–output analysis of the construction sector in highly developed economies,” Construction Management & Economics, vol. 21, no. 3, pp. 319–327, 2003.
[11] B. Chen, J. S. Li, X. F. Wu et al., “Global energy flows embodied in international trade: a combination of environmentally extended input–output analysis and complex network analysis,” Applied Energy, vol. 210, pp. 98–107, 2018.
[12] Q. Shen, H. Wang, S. Liang et al., “A Quasi-input-output model to improve the estimation of emission factors for purchased electricity from interconnected grids,” Applied Energy, vol. 200, pp. 249–259, 2017.
[13] P. Klimek, S. Poledna, and S. Thurman, “Quantifying economic resilience from input–output susceptibility to improve predictions of economic growth and recovery,” Nature Communications, vol. 10, no. 1, 2019.
[14] L. A. Delgado, V. A. Escolano, and E. Padilla Rosa, Transportation and Storage Sector and Greenhouse Gas Emissions: An Input–Output Subsystem Comparison from Supply and Demand Side Perspectives, Department of Applied Economics at Universitat Autonoma of Barcelona, Working Papers wpdea1902, Barcelona, Spain, 2019.
[15] A. Malik, D. McBain, T. O. Wiedmann, M. Lenzen, and J. Murray, “Advancements in input–output models and indicators for consumption-based accounting,” Journal of Industrial Ecology, vol. 23, no. 2, pp. 300–312, 2019.
[16] Z. Li, Research on Project Management of X Power Fiber to the Home, Shandong University China National Bureau of Statistics, Shandong, China, 2016, https://data.stats.gov.cn/.
[17] H. W. Kim, L. Dong, S. Jung et al., “The role of the eco-industrial park (EIP) at the national economy: an input–output analysis on korea,” Sustainability, vol. 10, no. 12, 2018.
[18] H. Gurgul and L. Lach, “Some remarks on a social network approach to identifying key sectors,” Economic Systems Research, vol. 30, no. 1, pp. 120–135, 2018.
[19] K. Kanemoto, T. Hanaka, S. Kagawa et al., “Industrial clusters with substantial carbon-reduction potential,” Economic Systems Research, vol. 31, no. 2, pp. 248–266, 2018.
[20] B. Huang, “An exhaustible resources model in a dynamic input–output framework: a possible reconciliation between Ricardo and Hotelling,” Journal of Economic Structures, vol. 7, no. 1, p. 8, 2018.
[21] X. Yang, W. Zhang, J. Fan et al., “Transfers of embodied PM2.5 emissions from and to the North China region based on a multiregional input–output model,” Environmental Pollution, vol. 235, pp. 381–393, 2018.
[22] S. Qu, H. Wang, S. Liang et al., “A Quasi-input-output model to improve the estimation of emission factors for purchased
electricity from interconnected grids," *Applied Energy*, vol. 200, pp. 249–259, 2017.

[23] A. Druckman and T. Jackson, "The carbon footprint of UK households 1990–2004: a socio-economically disaggregated, quasi-multi-regional input-output model," *Ecological Economics*, vol. 68, no. 7, pp. 2066–2077, 2009.

[24] B. Su, B. W. Ang, and Y. Li, "Input-output and structural decomposition analysis of Singapore’s carbon emissions," *Energy Policy*, vol. 105, pp. 484–492, 2017.

[25] L. Zhe, G. Yong, P. Hungsuck et al., "An energy-based hybrid method for assessing industrial symbiosis of an industrial park," *Journal of Cleaner Production*, vol. 114, pp. 132–140, 2016.

[26] R. E. Lusas, "Macroeconomic priorities," *The American Economic Review*, vol. 93, no. 1, pp. 1–14, 2003.

[27] S. Zhang, "Evaluating the method of total factor productivity growth and analysis of its influencing factors during the economic transitional period in China," *Journal of Cleaner Production*, vol. 107, pp. 438–444, 2015.

[28] B. Lin, Y. Chen, and G. Zhang, "Technological progress and rebound effect in China’s nonferrous metals industry: an empirical study," *Energy Policy*, vol. 109, pp. 520–529, 2017.