sustainability

Article

The Economic Effect of the Steel Industry on Sustainable Growth in China—A Focus on Input–Output Analysis

Jungseok Choi [1], Woohyoung Kim [2,*] and Seokkyu Choi [3,*]

[1] Chinese Language and Chinese Studies, Sunmoon University, Asan-si 31460, Korea; ayuwa@hanmail.net
[2] Graduate School of Technology and Management, Kyunghee University, Yongin-si 1732, Korea
[3] Department of Counseling and Industrial Psychology, Summon University, Asan-si 31460, Korea
* Correspondence: kimwh@khu.ac.kr (W.K.); choisk74@hanmail.net (S.C.)

Abstract: The purpose of this study is to analyze the economic ripple effects caused by the supply-side reforms on China's steel industry. To this end, using the 2012 and the 2017 China Input–Output Tables, this study analyzes the economic ripple effect of the Chinese steel industry caused by its supply-side reform. In this study, the influence coefficients (rear-linked effect) and the sensitivity coefficients (forward-linked effect), conceptualized by Leontief, are used as research tools to analyze the ripple effects of the Chinese steel industry. The analysis results are as follows. First, the fact that 2012 ranked high in professional equipment and meter manufacturing shows that the Chinese government's supply-side reforms are effective and creating the required shift from traditional manufacturing to qualitative growth. Second, in terms of the sensitivity coefficient, in 2012, most of the top industries contributed significantly to the development of the Chinese economy. The originality of this study is as follows. The input production analysis used in this paper is a methodology mainly used in the steel, coal, automobile, and petrochemical industries, which clearly distinguishes the front and rear industries. Additionally, this study is a novel attempt at comparative research on the Chinese steel industry between 2012 and 2017.

Keywords: China; input–output analysis; economic effect; steel industry; sustainable growth

check for updates

Citation: Choi, J.; Kim, W.; Choi, S. The Economic Effect of the Steel Industry on Sustainable Growth in China—A Focus on Input–Output Analysis. *Sustainability* **2022**, *14*, 4110. https://doi.org/10.3390/su14074110

Academic Editor: Anna Visvizi

Received: 16 February 2022
Accepted: 24 March 2022
Published: 30 March 2022

1. Introduction

Since China joined the World Trade Organization (WTO) in 2001, its economy has been growing at an average annual rate of six to seven percent, with the steel industry contributing a large share. Furthermore, since 1996, China has globally been considered a major steel producer and consumer, possessing the highest steel-making capacity in the world. In 2020, China accounted for 56.5% of the world's steel production, making it a key player in the development of the global steel industry [1]. Despite the supply-side structural reforms (SSSRs) initiated by the Chinese government, China's crude steel production is globally unrivaled, surpassing 900 million tons in 2018. SSSR seeks to shift the focus from quantitative development based on aggregate demand, toward qualitative development by upgrading the economy and industry through improvements in aggregate supply.

For China, 2020 marks the culmination of the 13th five-year plan (FYP) (2015–2020); after the introduction of intensive supply-side reforms in the steel sector, and given the prospect of a new political and economic era starting in 2021, the Chinese government has stressed that China requires further institutional development. In 2021, China's demand, including both domestic demand and net imports, increased by 2% compared with the previous year, with actual consumption increasing rapidly, and crude steel production increasing relatively gradually. Wang forecasts that production will increase slightly to 1.08 billion tons in 2021, from 1.05 billion tons in 2020 [2]. According to a government report released at China's National People's Congress (NPC) in 2020, China plans to reduce carbon emissions by 2030 to achieve its carbon neutrality target by 2060 and is trying to peak carbon emissions in the steel sector by 2025. However, China's steel demand is expected to rise in 2021. This is despite the government's order to cut steel output due to its investment-oriented economic structure and also despite recent declines in iron ore futures which have raised concerns over steel demand in the world's largest steel-producing country. The influence of COVID-19, which emerged in 2020, negatively affected industries, including the Chinese steel industry, and overall domestic demand. However, it seems that the Chinese government's unique economic policy will overcome the negative impact of COVID-19. In addition, the willingness to successfully complete policies such as supply-side reform and Chinese manufacturing 2025, which are ongoing, seems clear [3]. To achieve its goal of ranking as a superpower by 2050, China plans to transform its economy, from the labor and capital-intensive growth model followed for the past 30 years to an innovative economic growth model employing methods to enhance technology productivity and raise supply-side reforms.

The 12th FYP established an industry-specific development strategy based on a combination of market-led and government-controlled principles and set specific goals for the steel industry, including structural advancement, energy saving, industrial redeployment, technological innovation, and industrial concentration [4]. Furthermore, the Chinese government realized that the economy could not be advanced without dealing with the problems of over-facility and corporate debt in the traditional manufacturing sector. This is because corporate profits decline due to the low-cost competition that is caused by overproduction, and when the excess volume is exported, trade friction is generated. In 2008, the Chinese government proposed a new macro-development strategy to address the high inefficiency of the state-owned sector, the increased risk of state-owned finance, and the sluggish rate of the growth of the private economy and the new growth industries. In other words, structural reforms on the supply side have been considered for the redressal of serious over-facility problems in the state-owned sector and to implement intensive industrial restructuring of traditional industries. It is believed that China's funding and production factors were concentrated in inefficient state-owned traditional industries, which negatively affected the development of private companies and the advancement of manufacturing. Hence, through SSSRs, the Chinese government aims to enhance industrial competitiveness by restructuring the steel and other oversupply industries, while promoting new industries through industrial policies such as "Made in China 2025" [5]. Specifically, the Chinese government announced that it would implement over-facility reduction, new facility expansion, reinforcement of supervision and management, and relocation of employees to restructure the steel industry [6].

China's steel industry is undergoing many structural changes in line with the supply-side reforms. After the Chinese president Xi Jinping announced in 2015 that the old facilities producing 150 million tons would be shut down by 2020, "Ditiaogang" capacities were gradually withdrawn from the market. Ditiaogang refers to the illegal induction furnace steelmaking capacity in which melted ferrous scrap is used to produce steel [7]. The Chinese government achieved 100% of its target by closing all those old steel facilities between 2016 and 2018. Thus, China has significantly reduced its crude steel production capability in line with its goals for the period [8].

The Chinese government's steel-related industrial policies are aimed at achieving sustainable development for the Chinese economy through qualitative growth based on historical data and economic growth based on quantitative growth. Unlike most developed countries, China adopts a special state operating system called the socialist market economy; in this case, government policies are bound to quickly affect the real economy. Therefore, restructuring the steel industry, which has many structural problems, such as low value-added production and overlapping investment in China, can be regarded as a fundamental problem that needs to be solved to ensure China's continued economic development.

As mentioned earlier, although the Chinese government has achieved the desired results in the steel industry through supply-side reforms, the quantitative effects of supply-side reforms on the steel industry have yet to be measured. Therefore, it is necessary to analyze the exact economic ripple effect through empirical analysis, in order to gauge the impact of the supply-side reforms on the steel industry. Thus, the purpose of this study is to analyze the economic ripple effects caused by the supply-side reforms on China's steel industry; this will be accomplished by utilizing the 2012 and 2017 China Input–Output reports and data. The period is set for 2012 and 2017 because the Chinese Input–Output Table is published by the Chinese Bureau of Statistics every five years. As the recently released statistics cover 2017, the data are used for comparison with the previously released 2012. We consider how much of a ripple effect the Chinese government will have through the restructuring of the steel industry for sustainable growth in the future. Therefore, we aspire to compare and analyze statistical data in 2012 and in 2017, after the supply-side reform was implemented.

Therefore, we would like to analyze how the forward and backward linkage effects have changed over the past five years in line with the Chinese government's supply-side reform policy. This is expected to provide useful practical implications for all entities. The results of this study will provide meaningful advice on the path of the Chinese economy by accurately analyzing the economic effects of future supply-side reforms. So far, no research has analyzed the economic ripple effects of China's supply-side reforms on the steel industry. This study will analyze the economic effects and make suggestions for the future direction of the Chinese economy based on proven empirical results. The research questions are as follows: how does the forward-related industry affect China's steel industry? How does the backward-related industry affect China's steel industry? What structural reforms has the Chinese government implemented in the steel industry? How are China's industrial policies related to the real economy?

2. Literature Review

2.1. China's Steel Industry and Supply-Side Structural Reforms

The Chinese government needs to study the background of its SSSRs from both a micro- and a macro-perspective so that the reforms can ensure higher demand, capital investment efficiency, and the sound development of the steel industry, while utilizing innovative production networks and controlling overproduction based on capital circulation. President Xi Jinping initiated China's supply-side reform agenda in 2015 to reduce China's crude steel production, which began to surge in 2012, to reform the oversupply accumulated in key industries such as the steel industry while China emerged as an economic powerhouse. Industries subject to the FYP announced by the United States' Human State Development and Reform Committee in 2016 include steel, coal, cement, and aluminum. These industries have experienced heavy growth but are generating too much pollution and focus only on the export market. China is pushing for reforms to improve the quality of its industrial production, improve the environment, and reduce its dependence on external markets. The supply-side reforms reflect China's plan to shift to a sustainable consumption-led economy, instead of relying on investment in heavy industry. Chinese companies were able to make more profits due to industrial mergers and acquisitions, restructuring, and solid demand. This is because small-scale, low-quality construction steel producers have been restructuring since 2017, and the larger steel mills have been pushing for reforms to restructure unlicensed steel manufacturers due to the high investments necessary to reduce environmental pollution [9].

Song et al. (2020) emphasized combinations at the micro- and macro-levels. The first consideration is that the main components of production and manufacturing, combined with labor, land, natural resources, capital, and human resources, have certain production or service delivery capabilities [10]. In particular, the author emphasized that the supply-side reform of prior research has a long-term existence of competitiveness and viability in addition to labor, land, capital, and human resources, as well as 'scientific and technological innovation-based production innovation'. The study also emphasizes a combination of government industrial policy, technology policy, finance and taxation policies at the micro- and macro-levels based on growth breakthroughs, and core competitiveness as key developments in the "new economy" [11–15].

Over the past few decades, China has focused on the development of secondary manufacturing industries. According to data from China's National Bureau of Statistics, the secondary manufacturing industry sector accounts for about 40% of China's GDP. The steel industry, ranked second among the six major sectors of the economy, has been regarded as a pivotal industry because it provides raw materials. The steel industry is China's root industry, which has played an indispensable and important role in producing materials and finished products that are widely used for multiple purposes. The market share of steel products in China is over 99% and has developed due to the heavy demand for the steel products which have been required for national economic and social development [16].

The World Steel Association's 2017 World Steel Industry report includes criticisms of China for problems in the existing steel industry [17], and the oversupply and low yield indicated by the figure of 81.75% for the actual performance of infrastructure investment are disappointing. Xi pointed out that fighting zombie companies is the biggest challenge and that some zombie companies in the steel industry have shown negative earnings per share for three years consecutively, mainly due to government subsidies and bank loans [17]. The efficiency and stability of the industrial funding chain are at risk. According to the report, "Oversupply and Zombie Companies in China-Status and Countermeasures" [18], the proportion of zombie companies in the steel industry was 51.45% in 2013, ranking the highest in Chinese industry. China is facing the problem of decelerating GDP growth; asset investment growth and the steel industry are directly impacted by the fact that crude output and fixed asset investment per unit of GDP are decreasing. International demand, on the other hand, is growing at a rate that can absorb excess production, but the biggest problem in China today is the decline in domestic steel consumption.

2.2. Recent Research Trends on the Supply-Side Structural Reforms

The Chinese government sees supply-side reform as an indispensable tool for driving economic growth [19,20] and believes that the actual process for manufacturer reform or re-organization will be very difficult. This is because significant expenditure and investments are required for companies to survive and introduce innovative technologies in competitive markets. However, as the reforms are expected to effectively control infrastructure and basic service costs, promote decentralization, and improve corporate management and economic benefits, they have been accepted by businesses in the hope that the changes will further economic development, achieve efficiency, and revamp management strategies.

China's SSSRs have mainly highlighted the need for "cutting overcapacity, destocking, removing inventory, clearing debt, reducing costs, reducing costs, and improving the provisioning areas of knowledge" [20].

Additionally, SSSR emphasizes free flow among competing elements through the effective intervention of deeply and systematically optimized institutional elements. It is also important to actively introduce and develop opportunities for a new technological revolution to form an optimized "upgraded version" of traditional industry based on an "Internet+" strategy to lay a solid foundation for the new economy. The actual percentage of specific industries reflects the government's ability to incentivize investment in Natural Access Capacity (NAC). Because Cyclical Access Capacity (CAC) is affected by business-like demand shocks, macroeconomic regulatory policies for the management of interest rates and other indices play an important role in mitigating fluctuations. In particular, high interest rates negatively impact coal demand, thereby alleviating negative CECs due to rapid economic growth [21].

The main view of the recent research is that the reforms have cleared up the weak economic links of the past and now emphasize the quality and efficiency of the supply system. In contrast to the past, there is now one authoritative voice emphasizing that special attention should be paid to the steel, coal, cement, shipbuilding, and aluminum industries, which are rife with overproduction capacity and zombie companies; this will help with overproduction reduction and supply optimization structures.

3. Research methods and Empirical Analysis

3.1. Research Method

The Input–Output (IO) Tables are comprehensive statistical tables that record all transactions relating to the production and disposal of goods and services in a given economy over a period, in accordance with certain principles and formats. Thus, it is a statistical table that indicates the sectors in which goods and services are produced and what the inputs are per sector. The analysis of China's economy and industry links usually involves various practices and procedures that underlie the IO model (e.g., a table by product and industry) for a period of one year. In an environmental–economic analysis, we believe that it is provided by a physical input–output table comprising the main tools [22–24].

Recent empirical studies using input and output technologies have been conducted considering both the demand and the supply aspects. In particular, there is significant interest in solutions that can solve some of the shortcomings as well as the correlation between the International Input–Output Association (IIOA) disaster impact analysis and the input and output technology. The IIOA focuses on input and output technology, which is attracting attention as a tool to quickly evaluate continuous economic impacts, and observes that the expression of reverse and forward connections allowed by input and output models could contribute to key sector identification, various factors, system sensitivity, and economic comparison [25,26].

Based on industry-related tables, the analysis uses applied mathematics to produce results, as mentioned by [27,28]. It is a methodology that shows that inter-industry interdependent structures are mathematically and quantitatively influenced. The measure of the forward and backward linkage effects (impact and sensitivity analyses) associated with the input–output analysis, which is the semi-finished product of other industries, is to conduct sales drive production activities and the degree of interdependence between each industry. In this study, the influence coefficients (rear-linked effect) and the sensitivity coefficients (forward-linked effect), conceptualized by Leontief [29,30], are used as research tools to analyze the ripple effects of the Chinese steel industry, as follows [31]. First, the coefficient of influence is a coefficient of how final demand rises with production in a particular industry segment. The formula for the coefficient of influence is as follows:

$$F_j = \frac{\sum\limits_{i=1}^{n} \overline{b}_{ij}}{\frac{1}{n}\sum\limits_{i=1}^{n}\sum\limits_{j=1}^{n} \overline{b}_{ij}} \; (j = 1,\, 2,\, 3,\, \ldots\ldots\ldots) \tag{1}$$

In the influence coefficient formula, $\sum_{i=1}^{n} \overline{b}_{ij}$ is the sum of column j of the Leontief inverse matrix formula, and the increase in sector j means the final product of one unit. In addition, $\frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{n} \overline{b}_{ij}$, which is the complete demand for products in each sector of the national economy, means the average value of the sum of the aforementioned matrix.

If the influence coefficient is greater than 1, the additional unit of production in the jth sector is greater than the average impact figure for the extent of the ripple produced in other industrial sectors. A value of 1 equals the average impact figure, and less than 1 indicates less than the average impact figure. Therefore, the higher the coefficient of influence, the higher the influence of the industry sector. Second, the sensitivity factor refers to the impact on a certain industry sector when the final demand for produce for all industrial sectors rises by one unit at a time. In other words, the formula for the sensitivity coefficient as a coefficient of the forward linkage effect is as follows:

$$E_i = \frac{\sum\limits_{j=1}^{n} \overline{b}_{ij}}{\frac{1}{n}\sum\limits_{i=1}^{n}\sum\limits_{j=1}^{n} \overline{b}_{ij}} \; (i = 1,\, 2,\, 3,\, \ldots\ldots\ldots) \quad (2)$$

where n is the sensitivity coefficient formula, $\sum_{i=1}^{n} \overline{b}_{ij}$ is the sum of columns i of the Leontief inverse matrix formula, and the increase in the i-segment is the final product of one unit. In addition, $\frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{n} \overline{b}_{ij}$, which is the complete demand for products in each sector of the national economy, is the average value of the sum of the aforementioned matrix. If the sensitivity factor is greater than 1, it means that the sensitivity received by the ith sector is higher than the average level. A value of one indicates equality with the average level, and less than one indicates a lower-than-average level. Thus, the larger the sensitivity factor, the more the product is used as a raw material within and outside the industry, showing that related industries can be affected.

3.2. Empirical Analysis

3.2.1. Analysis of Influence Coefficients

To derive the influence coefficient of the Chinese steel industry, there is a limit to including all 42 categories of the industry association table in 2017; so, we arbitrarily determined the criteria in the order of high association with the steel industry and summarized them in Table 1. All of the original 42 categories that are part of China's industrial table in 2012 cannot be used to derive the influence factor of its steel industry in this study. Therefore, the total consumption coefficient of 42 segments was selected for 12 segments with values above 0.04. The results were derived using the influence coefficient formula for each of the 12 segments and summarized in descending order of the coefficient values. The influence coefficient derived from Table 1 refers to the backward-linked effect on all sectors when the demand for the Chinese steel industry changes by one unit.

Table 1. The influence factors of China's steel industry in 2012.

	Influence Coefficients
17 Specialized equipment manufacturing industry	3.780887
22 Other manufacturing industries	1.370608
21 Measurement/Measurement Manufacturing	1.340107
20 Manufacturing of telecommunication facilities and other electronic equipment	1.293867
19 Manufacturing of electrical machinery and equipment	1.252527
16 General manufacturing industry	1.236126
24 Metal products, mechanical equipment repair services	1.235980
18 Transportation equipment manufacturing	1.227700
15 Metal production	1.221107
14 Metal smelting and rolled processing	1.176323
10 Manufacturing paper, printing, and cultural and sports equipment	1.126413
28 Building trade	1.123992

Source: Data taken from China's 2012 input report. From 42 complete consumption coefficients, 12 segments of value 0.04 or higher are taken. National Economic History of the Bureau of National Statistics of China (year 2012 Input–Output Table) (year 2015).

Table 1 shows that the range of the highest three coefficients is 1.340107–3.780887. The highest value is found for the specialized equipment manufacturing industry at 3.780887; other manufacturing industries are at 1.370608; and the measurement/measurement manufacturing sector is at 1.340107. This can be analyzed to mean an increase of 1.340107–3.780887 units in each of these sectors. The fact that specialized equipment manufacturing and meter manufacturing are ranked at the top shows that the supply-side reforms by the Chinese government have been effective to some extent and are bringing about a shift from traditional manufacturing to qualitative growth. It can also be surmised that the reforms have affected the IT manufacturing industry, where technology and expertise are employed, and which is affected by government policies for specialized facility manufacturing, other manufacturing, and measuring-instrument manufacturing. In addition to the Chinese government's supply-side reforms, the changes are believed to be related to the Chinese government's "Made in China 2025" policy to upgrade manufacturing [5]. The policy goal of "Made in China 2025" emphasized the will to foster growth of the top ten core industries in the long run; it is a policy that represents China's long-term vision for sustainable growth, focusing on both low-added and high-value manufacturing.

Next, for estimating the 2017 influence factor there is a limit to writing all 149 subcategories of China's industrial-related table. Seventeen of the 149 total consumption factors were therefore selected. The results were derived using the sensitivity coefficient formula for each of the 17 segments and summarized in descending order of the value of the coefficients (see Table 2). Because there is a limit to including all 149 subcategories of China's industry-related table in 2017 to derive the influence coefficient of the Chinese steel industry, the authors arbitrarily determined the criteria in the order of high association with the steel industry and summarized them in Table 2.

Table 2. The influence factors of China's steel industry in 2017.

	Influence Coefficients
69 Material handling equipment	1.23243
79 Rail transportation and urban rail transportation equipment	1.2305
75 Agriculture, wood, and fisheries machinery	1.21958
70 Pumps, valves, compressors, and similar machines	1.19225
73 Mining, metallurgy, and construction special equipment	1.19113
80 Ship-related equipment	1.18801
72 Other common facilities	1.18208
67 Burner and motivation facilities	1.17991
76 Other dedicated facilities	1.17733
74 Special equipment for chemical, wood, and non-metallic machining	1.15824
68 Metal processing machinery	1.15776
66 Metal products	1.11852
102 Civil engineering process architecture	1.10912
101 Domestic architecture	1.09722
62 Steel rolled products	1.01726
63 Steel alloy products	0.9891
61 Steel industry	0.98814

Source: From the total consumption coefficient of 149 sectors in China in 2017, the authors substituted 17 sectors with values of 0.1 or more. National Economic History of the Bureau of National Statistics of China (year 2017 Input–Output Table) (year 2020).

Table 2 shows that, overall, the influence factor of the development of the Chinese steel industry on other industries was insufficient compared to 2012. The highest coefficients ranged from 1.21958–1.23243: 1.23243 for Material handling equipment; 1.2305 for Railway transportation and urban railway transport equipment; and 1.21958 for Agriculture-, wood-, and fisheries-dedicated machinery. This can be analyzed to mean an increase of 1.21958–1.23243 units in these sectors. This indicates that the Chinese government focused on building infrastructure for one-on-one development at the time and supported the machinery used for the development of agriculture, farming, and farmers' livelihoods to solve the problems of this sector. However, the reason the overall influence coefficients in 2017 are smaller than in 2012 is that with the launch of the Xi Jinping administration, projects were launched in earnest, exerting a significant influence on the entire industry.

3.2.2. Analysis of Sensitivity Coefficients

To derive the sensitivity factors of China's steel industry, there is a limit to writing all 42 categories in China's industrial-related table in 2012. The total consumption coefficient of 42 sectors was selected for 14 sectors with values of 0.04 or higher. The results were derived using the sensitivity coefficient formula for each of the 14 segments and arranged in descending order. The sensitivity factor derived in Table 3 refers to the forward-related effect of how demand in China's steel industry was affected by all sectors when one unit changed.

Table 3. The sensitivity factor of China's steel industry in 2012.

	Sensitivity Coefficient
12 Chemical industry	3.451570
14 Metal smelting and rolled processing	2.891365
25 Power, heating production and supply	1.932049
29 Wholesale and retail	1.613322
33 Financial industry	1.596233
30 Transportation and warehouse/mail business	1.529516
11 Oil processing, refining/nuclear fuel processing	1.458722
03 Oil and natural gas mining	1.410033
02 Coal mining	1.232892
35 Leasing and business services	1.099991
16 General manufacturing	1.011091
04 Metal mining	0.969674
13 Non-metal mineral products	0.829476
23 Waste/Disclosure	0.523324

Source: Among the 42 categories of total consumption coefficients in China in 2012, 14 categories with values of 0.04 or more were rewritten. National Economic History of the Bureau of National Statistics of China (year 2012 Input–Output Table) (year 2015).

The sensitivity factors of the Chinese steel industry demonstrated in Table 3 show that they are distributed in the range of 1.932049–3.451570, with the chemical industry at 3.451570, the metal smelting and rolling industries at 2.891365, and the power, heating production, and supply at 1.932049. This can be analyzed to mean an increase in 1.932049–3.451570 units in these sectors.

In particular, it is necessary to analyze the wholesale and retail sector (1.613322), which ranks fourth in the 2012 sensitivity coefficient analysis results. This is because (like the 2012 impact factor analysis), the domestic and retail support policies that were implemented to overcome the crises generated by the supply-side reforms have affected the wholesale and retail sectors, including that of the steel industry. In addition, it is apparent that raw material suppliers, including those suppliers that have contributed to the development of traditional manufacturing (which is the front-line industry of the Chinese steel industry), have not been restructured effectively enough, despite various restructuring policies.

With the 2017 sensitivity coefficient, there is a limit to writing all 149 subcategories of China's industrial-related table. Of the 149 total consumption factors, 18 segments were selected. The results were derived using the sensitivity coefficient formula for each of the 18 segments and summarized in descending order (see Table 4).

Table 4. The coefficients of sensitivity in China's steel industry for 2017.

	Sensitivity Coefficient
98 Electricity, heat production and supply	4.9087
126 Monetary financial and other financial services	4.14273
41 Refined petroleum and nuclear fuel processed goods	3.12797
64 Colored metals and alloys	3.05543
105 Wholesale business	2.84371
106 Retail business	2.74231
07 Oil and natural gas mining refining industry	2.72406
110 Road freight and transportation support activities.	2.56755
06 Coal mining and laundry products.	2.55402
66 Metal products	2.29652
72 Other common facilities	1.64765
08 Black metal mining industry	1.29316
96 Waste resources and waste recycling products	1.03798
73 Mining, metallurgy, and construction special equipment	0.82948
63 Steel alloy goods	0.73733
42 Methane process industry	0.7356
61 Steel industry	0.59613
59 Fire resistance material products	0.54418

Source: The authors rewrote the total consumption coefficient of 149 sectors in China's 2017 input report, replacing them with 18 sectors with values of 0.2 or more. National Economic History of the Bureau of National Statistics of China (year 2017 Input–Output Table) (year 2020).

Reviewing the highest sensitivity factors in Table 4, electricity and thermal production and supply have the highest coefficient at 4.9087, followed by monetary and other financial services at 4.14273, and refined oil and nuclear fuel products at 3.12797, providing the range of 3.12797–4.9087. Compared to 2012, the overall Chinese steel industry is increasingly responsive to the development of the affected forward industries. The affected industries were mainly the raw material industries of chemical, metal smelting and rolling, electricity, and heating production and supply, but in 2017, they were transformed into more concrete and progressive industries from traditional manufacturing. If the effectiveness and influence of the Chinese government's implementation of supply-side reforms was insignificant in 2012, the analysis shows that the effect was gradually becoming visible in 2017.

4. Conclusions

As highlighted, China's steel industry has been ranked first in terms of crude steel production since the beginning of the 2000s; this is especially the case in 2020, as it accounts for 56.5% of the world's crude steel production [1].

As the importance of the Chinese steel industry in the 21st century is emphasized and increasing, this paper analyzed the specific changes using the Chinese input and output tables in 2012 and 2017 to see how the Chinese government's reforms have affected the steel industry. In 2012, 42 industrial classification criteria were used, but the 2017 Chinese input calculation table was highly differentiated in that it used 149 industrial classification criteria to allow for a more detailed analysis than the existing ripple effect analysis methods.

Specifically, the analysis results are as follows. First, the fact that 2012 ranked high in professional equipment and meter manufacturing shows that the Chinese government's supply-side reforms are effective and creating the required shift from traditional manufacturing to qualitative growth. It can also be said that it has affected the IT manufacturing industry, where technology and expertise are used, and is affected by government policies for specialized facility manufacturing, other manufacturing, and measuring-instrument manufacturing. In addition to the Chinese government's supply-side reforms, the changes are also related to the government's "Made in China 2025" policy to upgrade manufacturing [5]. Overall, in 2017, the scope of the influence factor is insignificant compared to 2012. Due to the nature of the Chinese government's policy, intensified policies were implemented in 2017, based on the 2012 policy implementations, which would inevitably lead to fluctuations in the early stages of implementation. As the analysis shows, material handling equipment, railway transportation and urban railway transportation equipment, and machinery dedicated to agriculture, forestry, and fisheries can be seen as evidence that the policies are now being implemented in greater detail than in 2012 However, the reason the overall influence coefficient in 2017 was smaller than in 2012 is that in the beginning of the Xi Jinping administrative term, projects were launched in earnest and influenced the entire industry.

Second, in terms of the sensitivity coefficient, in 2012, most of the top industries contributed significantly to the development of the Chinese economy. These industries can be seen as the main target of the supply-side reforms conducted by the Chinese government. However, it is noteworthy that wholesale and retail, along with traditional manufacturing groups, influenced the growth of the wholesale and retail sectors and further influenced the steel industry through various domestic and external economic support policies. In addition, raw materials, including the raw materials which have contributed to the development of traditional manufacturing, have not been restructured quickly enough despite various restructuring policies.

Contrary to the influence coefficient, 2017 shows that the range of changes in the sensitivity coefficient has increased compared to 2012. While the traditional manufacturing sector was significantly impacted in 2012, 2017's results showed that more specific and processed industries, ranging from the raw material-oriented industries to the financial sectors, such as electricity and heat production, monetary finance, and other financial services, were affected. The analysis shows that if the effectiveness and influence of the Chinese government's implementation of supply-side reforms seemed insignificant in 2012, the effect was gradually becoming visible in 2017. This supports recent research that emphasizes that inter-industry interdependent structures can be connected mathematically and quantitatively [27,28].

Based on these findings, the implications are as follows. As seen in the 2012 and 2017 influence and sensitivity coefficients, the industries that are more influenced by the development of the Chinese steel industry in 2017 than in 2012 show that the policy effects are converting to technological qualitative growth in 2017. Through this, supply-side reforms conducted by the Chinese government are also exposed to problems such as the decline in the supply of steel and a sharp rise in prices, which adversely affected basic infrastructure investment plans and hindered other economic goals. The Chinese government's supply-side reforms have already significantly impacted its steel industry; the government made efforts to adjust its economic policies by improving the quality of supply in contrast to the previous expansion of demand that arose from the 2008 US-led financial crisis. The main challenges include oversupply, the reduction in corporate costs, resolving real estate inventory, and the reduction in financial risk.

Overall, structural reforms, such as the supply-side reforms to the steel industry, which have been actively implemented by the Chinese government since 2015, are expected to serve as a cornerstone for the sustainable development of the Chinese economy in the future. Furthermore, they are expected to restructure not only the steel industry but also the state-led industries in China that have achieved quantitative economic development (e.g., the coal industry) and oversupply. If these national policies succeed, then China will become a true G2 country in line with the fourth industrial era.

In conclusion, it can be seen that in China the structural reform (supply-side reform) of the steel industry had a heavy influence on related industries. These results seem to deliver the following message to developing countries across the world and countries aiming for sustainable growth. Essentially, structural reforms, such as mergers and acquisitions, are first implemented for the production of low value-added products in a nation's leading industries, especially in industries such as steel, coal, and automobiles. Meanwhile, if eco-friendly products can be continuously produced through technology development and the construction of research and development (R&D) centers, it is believed that national development suitable for the high-tech era can be achieved.

The originality and the significance of this study are as follows. The input production analysis used in this paper is a methodology mainly used in the steel, coal, automobile, and petrochemical industries, which clearly distinguishes the front and rear industries. Additionally, this study is a novel attempt at comparative research on the Chinese steel industry between 2012 and 2017. In addition, the 2012 China inputs table utilized 42 industrial classification criteria, but the use of 149 industrial classification criteria in 2017 helped us conduct a more detailed analysis than the existing knock-on effect analysis and therefore contributed to the erstwhile insufficient literature on the subject.

A limitation of this study is that the period of analysis differs from the current period, leading to difficulties in analyzing currently prevailing industrial relations. This is because China's input/output tables are published on an average of two to three years after the data are collected. Due to this problem of publishing statistical data, more specific analysis results would be derived if the impact and sensitivity were analyzed annually from 2012 to 2017, but they remain insufficient. Research on particular periods of time has advantages for policymaking, but as shown in this study, a long-term continuous follow-up study can also effectively reveal the existing development trend. Based on this, it is expected to help establish economic policies around the world if analyzed according to how it affects macroeconomic policies such as supply-side reform, Chinese manufacturing 2025, and the carbon policies emphasized by the Chinese government.

As this model is mainly optimized for analyzing the front–rear association effects of a specific industry, it is suitable for approaching the subject of this paper from diverse perspectives. However, some limitations of the study need to be addressed by future research. First, it is necessary to utilize the characteristics of the production inducement coefficient, derived based on the input coefficient calculated as primary data in the input and output table. Additionally, it is necessary to expand the scope of the research by analyzing policy effects, trade in value-added products, environment, energy, and the local economy in detail. Moreover, the simplicity of the research methodology, pointed out as a limitation of this study, needs to be supplemented by further research.

Author Contributions: All authors have contributed to this paper. J.C. designed the research and wrote the manuscript. W.K. designed the research and helped revise the manuscript. S.C. analyzed the data and wrote the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Date is not publicly available.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Steel Statistical Yearbook. 2021. Available online: https://www.worldsteel.org (accessed on 4 May 2021).
2. Demand-Side Reform to Drive China's Steel in 2021. (Mysteel.net). Available online: https://www.mysteel.net/article/5020386-0504/CONF---Demand-side-reform-to-drive-Chinas-steel-in-2021.html (accessed on 6 May 2021).
3. China's Just-in-Time Logistics Industry Report. 2020. Available online: http://www.iresearchchina.com/content/details8_63004.html. (accessed on 30 May 2021).

4. Li, J.; Wang, X. Energy and climate policy in China's Twelfth Five-Year Plan: A paradigm shift. *Energy Policy* **2012**, *41*, 519–528. [CrossRef]
5. Li, Z.; Li, J.; Chen, J.; Vinig, T. One Belt, One Road—Innovation & Entrepreneurial Practices in China. *Chin. Manag. Stud.* **2020**, *14*, 325–333.
6. National Development and Reform Commission (NDRC). 2016. Available online: http://www.gov.cn/zhengce/content/2016-02/04/content_5039353.htm (accessed on 18 April 2020).
7. OECD. Latest Developments in Steelmaking Capacity, Tomohiro HIJIKATA. 2020. Available online: https://www.oecd.org/industry/ind/latest-developments-in-steelmaking-capacity-2020.pdf (accessed on 15 May 2021).
8. National Development and Reform Commission (NDRC). 2019. Available online: http://www.gov.cn/xinwen/2019-05/09/5390005/files/d5917e1b74194fe189de4b20b4a5300c.pdf (accessed on 18 April 2020).
9. Zhang, J.; Zhou, A.O. China Steel, Refining Capacity Rises as Supply-Side Reforms Come under Pressure. S&P GLOBAL PLATTS. 2019. Available online: https://www.spglobal.com/en/research-insights/articles/china-steel-refining-capacity-rises-as-supply-side-reforms-come-under-pressure (accessed on 5 May 2021).
10. Song, X.H.; Zhao, C.P.; Han, J.J.; Zhang, Q.; Liu, J.P.; Chi, Y.Y. Measurement and Influencing Factors Research of the Energy and Power Efficiency in China: Based on the Supply-Side Structural Reform Perspective. *Sustainability* **2020**, *12*, 3879. [CrossRef]
11. Goulder, L.H.; Stephen, H.S. Induced technological change and the attractiveness of CO_2 abatement policies. *Resour. Energy Econ.* **1999**, *21*, 211–253. [CrossRef]
12. Popp, D. Endogenous technological change in the DICE model of global warming. *J. Environ. Econ. Manage.* **2004**, *48*, 742–768. [CrossRef]
13. Gerlagh, R.A. Climate-change policy induced shift from innovation in carbon-energy production to carbon-energy savings. *Energy Econ.* **2008**, *30*, 425–448. [CrossRef]
14. Acemoglu, D.; Aghion, P.; Bursztyn, L.; Hémous, D. The Environment and Directed Technical Change. *Am. Econ. Rev.* **2012**, *1*, 131–166. [CrossRef] [PubMed]
15. Zhu, H.H.; Sun, Y.Y.; Li, J.B. Study on Enterprise Value and Asset Structure Optimization of the Iron and Steel Industry in China under Carbon Reduction Strategy. *J. Asian Financ. Econ. Bus.* **2022**, *9*, 11–22. Available online: https://www.koreascience.or.kr/article/JAKO202206159759817.pdf (accessed on 10 April 2021).
16. Chen, Y.; Li, Y.Q. Research on the Transformation and Upgrading of Steel Industry under Structural Reform in the Supply End, Price. *Theory Pract.* **2016**, *7*, 81–84. Available online: http://www.ixueshu.com/document/7308babedc2da579318947a18e7f9386.html (accessed on 15 May 2021).
17. Jinping, X. Secure a Decisive Victory in Building a Moderately Prosperous Society in All Respects and Strive for the Great Success of Socialism with Chinese Characteristics for a New Era. Delivered at the 19th National Congress of the Communist Party of China. 2017. Available online: http://www.xinhuanet.com/english/download/Xi_Jinping\T1\textquoterights_report_at_19th_CPC_National_Congress.pdf (accessed on 10 May 2021).
18. Nie, H.H.; Jiang, T.; Zhang, Y.X.; Fang, M.Y. Current Status, Causes and Countermeasures for China Zombie Enterprises. *Macroecon. Princ.* **2016**, *9*, 63–68.
19. Geng, L. Supply-side reforms to promote the development path of traditional finance to Internet finance. *Commer. Econ. Res.* **2017**, *6*, 183–184.
20. Yin, X. Research on Path Selection of Economic Growth Promoted by Supply-side Reform Based on Computer Simulation. *J. Phys. Conf. Ser.* **2020**, *1544*, 012202. [CrossRef]
21. Qing, Y.; Hou, X.; Han, J.; Zhang, L. The drivers of coal overcapacity in China: An empirical study based on the quantitative decomposition, Resources. *Conserv. Recycl.* **2019**, *141*, 123–132.
22. Leontief, W. Environmental repercussions and the economic structure: An input-output approach. *Rev. Econ. Stat.* **1970**, *52*, 262–271. [CrossRef]
23. Hoekstra, J.C.; van den Bergh, J.C. Constructing physical input-output tables for environmental modeling and accounting: Framework and illustrations. *Ecol. Econ.* **2006**, *59*, 375–393. [CrossRef]
24. Dietzenbacher, S.; Giljum, K.; Hubacek, S.S. Physical input-output analysis and disposals to nature. In *Handbook of Input-Output Economics in Industrial Ecology*; Suh, S., Ed.; Springer: Heidelberg, Germany, 2009; pp. 123–137.
25. Miller, R.E.; Blair, P.D. *Input-Output Analysis: Foundation and Extension*, 2nd ed.; Cambridge University Press: Cambridge, UK, 2009.
26. Luca, G. On input-output economic models in disaster impact assessment. *Int. J. Disaster Risk Reduct.* **2018**, *30*, 186–198.
27. Dente, A. Partial Quantum Tensors of Input and Output Connections. *Adv. Pure Math.* **2018**, *8*, 764–769. [CrossRef]
28. Ebiefung, A. A Generalization of the Input-Output Pollution Control Model and Product Selection. *Appl. Math.* **2013**, *4*, 360–362. [CrossRef]
29. Leontief, W. Quantitative Input and Output Relations in the Economic System and the United States. *Rev. Econ. Stat.* **1936**, *3*, 105–125. [CrossRef]
30. Leontief, W. *Input-Output Economics*; Oxford University Press: New York, NY, USA, 1986.
31. Choi, J.S.; Kim, W.H.; Choi, S.K. The Economic Effects of China's Distribution Industry: An Input-Output Analysis. *Sustainability* **2021**, *13*, 3477. [CrossRef]