The Steel Industry in Transition: Changing Influencing Factors and Trend Forecasts

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Abstract. With the implementation of the "double carbon" policy and the change in national industrial structure, China's steel industry is undergoing a difficult transition. In this paper, rolling iterative regression is used to investigate the main influencing factors of steel production and the changes in these factors in China during the transition; furthermore, a lagged model is used to forecast the trend of steel production. The results find that: firstly, gross construction output is the most important influencing factor for steel production; secondly, crude steel production, coke production, and social fixed investment were all once important influencing factors, but have shown insignificant effects in recent years; thirdly, the trend of steel production is expected to maintain steady growth.

Keywords: Iron and steel industry; Influencing factors; OLS; Distributed-lag model; Trend forecast.

1. Introduction

The iron and steel industry is an important basic industry of the national economy. Since China established the "double carbon" target, as the manufacturing industry with the highest carbon emissions, the steel industry is facing enormous pressure to reduce emissions. With the introduction of a series of national energy-saving emission reduction and capacity adjustment policies, large steel enterprises face capacity structure optimization, and small and medium-sized steel enterprises face mergers and elimination. This series of measures will inevitably have an impact on steel production. And, with the rapid development of China's economy, from 2019 China's output value, the current industrial structure of China is already a "service industry, secondary industry, primary industry" pattern. The change in industrial structure and market-reducing attention will affect steel production. Steel is the lifeblood of the secondary industry of raw materials. While meeting the two major pressures, the factors affecting the steel industry are bound to change. Exploring these changes and forecasting the trend of steel production will help the steel industry chain to adjust the focus of production and the production strategy to maintain the original trend of production.

The Chinese government has always been highly concerned about climate change issues and adheres to the concept of green, recycling, and low-carbon development. As one of the high-emission industries, the issue of how to save energy and reduce emissions in the production process of the steel industry has received wide attention from scholars. Different scholars have proposed different solutions, which have had some influence on the industry and thus led to the change of the main influencing factors of steel production to some extent. Lee & Lee (2019) analyzed the implementation path of low-carbon transition in China's steel industry from three aspects: demand reduction, energy efficiency improvement, and innovative processes. They suggested that carbon emissions differed significantly for different steel production processes. They pointed out that compared with the long process of blast furnace-converter with iron ore as the source, the short process of all-scrap electric furnace can save 1.3t iron ore, reduce energy consumption by 350kg standard coal, 1.4t CO2, and 600kg scrap. Sun & Zhang (2018) showed that the carbon intensity can be reduced by increasing the scrap ratio of converter steel without changing the process. The carbon emission intensity can also be reduced. Wang et al. (2020) discussed the green steel metallurgical technology from the perspective of low carbon emission reduction and suggested that the blast furnace-converter process should focus on the development of low carbon blast furnace iron-making technology represented by hydrogen instead of coke, while the special steel system should focus on the development of hydrogen-rich gas-based shaft furnace direct reduction technology. These studies provide theoretical and technical support for the development of low-carbon transformation of the Chinese steel industry and are important references for achieving the goal of carbon peaking. It also provides a theoretical basis for the iterative optimization of the steel industry. The main factors affecting steel production change during the process improvement.

The steel industry is a necessary support for industrial development, and the forecast of steel production is of great importance for industrial development. Different scholars have different views on the trend forecast of steel production; Zhao (2021) argues that the current development of China's industrialization process is a growing demand for steel and the development of the steel industry is in a period of rapid growth. However, Lee & Lee (2019) argue that in the medium to long term, as China transforms its economic development mode and adjusts its industrial structure, the proportion of tertiary industry will continue to rise, and the proportion of secondary industry will decline. The pulling effect of investment on economic growth will weaken. As consumption will continue to drive economic growth, the intensity of steel consumption will be on a downward trend. This paper forecasts the trend of steel production, which will help judge the actual trend of steel production output.

2. Typical facts about the transformation and development of China's steel industry

On September 22, 2020, Chinese President Xi Jinping made a solemn commitment to the world at the 75th United Nations General Assembly that China will achieve carbon peaking by 2030 and carbon neutrality by 2060. As a typical resource- and energy-intensive industry, the steel industry is a key area for achieving green and low-carbon development (Zhang, Shen & Xu, 2021). China's crude steel production is perennially ranked first in the world, with a global share of over 50%. As shown in Figure 1, China's crude steel production accounts for 56.7% of the world's total crude steel production in 2020 (Zhao et al., 2020). This means that China shares more than half of the world's CO2 emissions in the production of steel. In addition, with the new iterations of cutting-edge technologies such as 5G, AI, big data, and cloud computing in China, and in the context of China's policies to encourage the upgrading of traditional industries, the steel industry is also taking steps towards digital transformation, green production, smart manufacturing, and lean manufacturing.

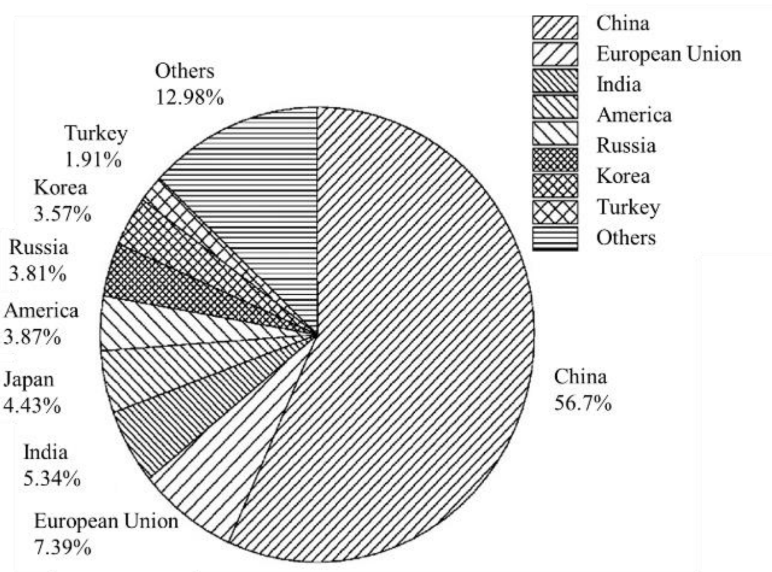
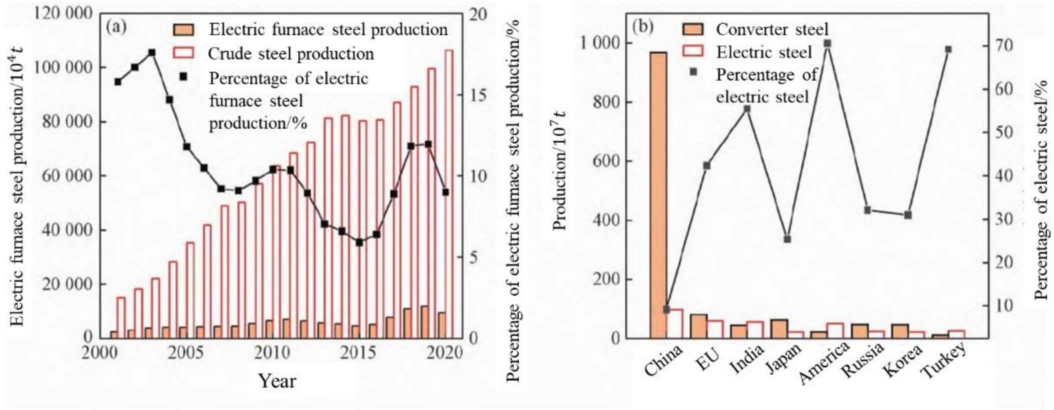


Figure 1. Summary of crude steel production of countries in the world in 2020

The steel production process is mainly based on sintering, coking, iron making, steel making, hot rolling, and cold rolling. The steel-making process includes converter steel making where the power source is coal, and electric furnace smelting, which uses electricity as the power source and has the advantages of low pollution, high thermal efficiency, and high smelting quality (Zhao et al., 2022). From Figure 2 (b), it can be seen that although China has the largest steel production among the major steel-producing countries, it has the lowest percentage of electric furnace steel production. To build a green society and achieve energy saving and emission reduction in the production process, it is necessary to continuously optimize the production structure and increase the proportion of electric furnace steel production. From Figure 2 (a), it can be seen that China is constantly increasing steel production while making efforts to adjust the proportion of electric furnace steel production to reduce the pollution and consumption in the production process and transform it into low-carbon green production.



(a) The production of Chinese electric furnace steel, crude steel and the percentage of electric furnace steel during 2000-2020

(b) The production of converter steel, electric steel and the percentage of electric furnace steel of the leading steel producers during 2000-2020

Figure 2. Summary of output and proportion for converter steel and electric furnace steel

The raw material large-scale steel manufacturing industry is a process-oriented manufacturing industry, which is characterized by complex processes, continuous production processes, strict process control, high-reliability requirements, high production energy consumption, and high pollution. The process of green and low-carbon transformation is also accompanied by digital transformation. The transformation focuses on building a new system of intelligent production, applying big data to help the industry reduce costs and improve quality and efficiency, and gradually building a new system of intelligent production (Wang et al., 2020). Huang (2021) suggests that the digital transformation of steel enterprises often faces the typical characteristics of the steel industry, such as heavy assets, long processes, and wide areas, as well as challenges such as insufficient core technology capabilities, lack of authoritative data standards, high logistics costs, difficulty in coordinating multiple levels of the industrial chain, and contradictions between personalized demand and large-scale production. Made in China 2025 proposes that the steel industry implement intelligent control and optimal coordination of production, logistics, etc., and focus on developing new information technology and intelligent technology based on big data and cloud computing to realize deep information perception, intelligent optimization decision making and accurate coordination and control of enterprises. China's steel industry is also continuing to merge and combine to increase industry concentration and further digital transformation. From 2005 to 2010, the number of enterprises with more than 10 million tons expanded from 8 to 13, and the proportion of crude steel production of the top 10 domestic steel enterprises increased to 48.6% of the national total (Yuan et al., 2020). In the future, the Chinese steel industry will actively face challenges in the process of digital transformation to build an intelligent production system and improve production efficiency.

3. Empirical analysis of the factors influencing the output and trend characteristics of the steel industry

3.1 Variable design and data description

Using economic knowledge analysis and available literature support (Guo 2016; Shi et al. 2019), this paper assumes that total steel production is mainly affected by coke production, crude steel production, pig iron production, GDP, power generation, social fixed asset investment, gross construction output, and railroad transportation. Therefore, the model will build a multiple linear regression model with total steel production as the explained variable and the above eight variables as explanatory variables.

The data source for each indicator is the official website of the National Bureau of Statistics. Table 1 shows the variables and their definitions in this paper. The descriptive statistics of the variables are shown in Table 2.

Table 1. Variable Design

Variable	Definition	Unit	Supporting Literature
Y	Steel production per year	Million tons	
CONS	Gross construction output per year	Billion yuan	Shi et al. (2019)
CT	Coke production per year	Million tons	
FEC2	Pig iron production per year	Million tons	
FIX	Fixed asset investment per year	Billion yuan	
GDP	Gross domestic product per year	Billion yuan	
FEC	Crude steel production per year	Million tons	Guo (2016)
POW	Power generation per year	Billion KWH	
TRA	Railroad transportation per year	Million tons	

Table 2. Descriptive Stats (2001-2020)

	Mean	Median	Maximum	Minimum	Std. Dev.
Y	76341.95	84448.08	132489.2	16067.61	37209.33
CONS	118262.9	106247.2	263947.4	15361.6	84094.01
CT	35879.51	40900.19	48179.38	13130.7	11831.15
FEC	54917.24	61892.11	88897.61	15554.25	22296.65
FEC2	61647.02	66125.65	106476.7	15163.44	27972.34
FIX	254862.3	228808	527270	37214	173882.8
GDP	487034.6	450029.8	1015986	110863.1	303133.6
POW	44606.19	44600.9	77790.6	14808.02	20212.06
TRA	333374.8	334574.5	455236	193189	75339.25

3.2 Linear model estimation

To explore the influencing factors of China's steel production and the changing trend of the influencing factors, rolling iterative regressions were conducted by selecting different ending years in this paper. The regression results of the OLS model are presented in Table 3. Model (1)-(5) are the regression results for the selected years 01 to 15 increasing year by year to 01 to 19, and model (6) is the regression results for the overall data. From the information embedded in the model, we can get the following three regular facts: first, there are four significant variables in the first three years, which are gross construction output, annual coke production, annual crude steel production, and social fixed asset investment. And one significant variable in the last three years and one significant variable in the full sample, indicating that there is indeed a change in the main influencing factors of steel production; second, total construction output is always a significant influencing factor. The Chinese government has invested a lot of money in infrastructure projects in the last two decades, which is one of the reasons why the steel demand in the construction industry sector is very strong. the steel demand in the construction industry accounted for 55.2% of the total steel demand in China in 2019. It can be seen that steel demand from the construction industry is a significant factor affecting steel production in both a statistical and economic sense; thirdly, coke production is only significant in the first two models, and social fixed asset investment is only significant in model (1) and crude steel production is only significant in model (2). Possible reasons are the continuous changes in the structure and production process of the steel industry, as well as changes in the prices of production raw materials and technological upgrading, which lead to the significance of different factors in different periods.

Table 3. OLS

	(1)	(2)	(3)	(4)	(5)	(6)
Coefficient	2001-2015	2001-2016	2001-2017	2001-2018	2001-2019	2001-2020
β_{CONS}	0.677***	0.674***	0.616*	0.653*	0.679**	0.497**
β_{CT}	-1.910*	-1.879*	0.154	-0.110	-0.212	0.493
β_{FEC}	0.880	0.780	1.309	1.496	1.640	1.090
β_{FEC2}	1.170	1.292*	-0.116	-0.207	-0.332	-0.028
β_{FIX}	-2.02*	-0.198	0.021	-0.011	-0.011	0.037
β_{GDP}	-0.105	-0.105	-0.109	-0.112	-0.129	-0.066
β_{POW}	1.114	0.978	-0.783	-0.493	-0.266	-1.131
β_{TRA}	0.007	0.012	0.048	0.041	0.036	0.045
R^2	0.999	0.999	0.997	0.997	0.998	0.998
$S.E.$	1097.140	1046.27	2132.067	2088.824	2004.932	2016.160

Notes: ***p < 0.001, **p < 0.01, *p < 0.05

3.3 Distributed-lag model estimation

In this paper, a distributed-lag model is used to forecast the trend of steel production. For the lag model with a finite horizon, new variables are defined by Almon transformation to reduce the number of explanatory variables, and then the parameters are estimated by the OLS method.

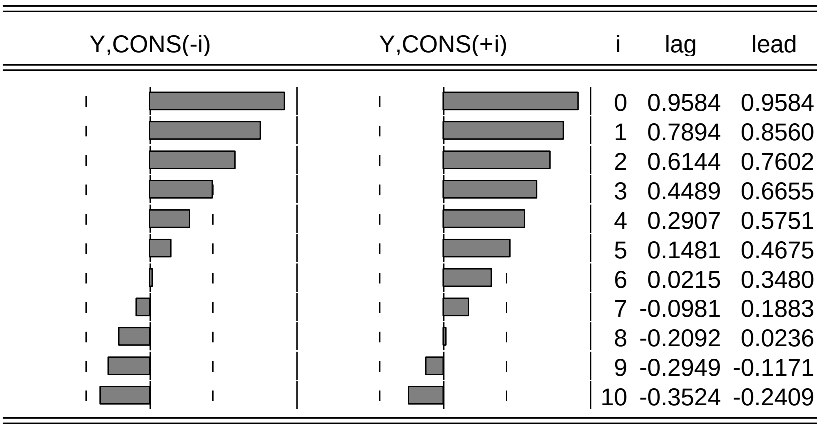


Figure 3. Histogram of correlation coefficients for each lag of Y and CONS

Firstly, the correlation between Y and CONS for each lag period is analyzed. From the first column in Figure 3, the histogram of the correlation coefficients between Y and CONS for each lag period, it can be seen that the steel production is correlated with the construction output for the current year and the previous three years, so it can be set:

$$Y = C + aCT + b_0 CONS_t + b_1 CONS_{t-1} + b_2 CONS_{t-2} + b_3 CONS_{t-3}$$

The model is estimated using the Almon method, assuming that b_i is approximated in three cases, (1) by a primary polynomial; (2) by a quadratic polynomial; (3) by a cubic polynomial.

The parameters of the PDL term are set as follows: PDL(CONS,2,1), PDL(CONS,3,2), PDL(CONS,4,2), PDL(CONS,5,2), PDL(CONS,4,3), PDL(CONS,5,3), and PDL(CONS,5,3) respectively, and the adjusted coefficients, SC, and AIC values are shown in the table:

Table 4. Lag period selection table

Parameters type	$\bar{R}^2$	AIC	SC
PDL(CONS,1,1)	0.99245	19.08191	19.28074
PDL(CONS,2,1)	0.99379	18.76590	18.96376
PDL(CONS,3,2)	0.99163	18.95316	19.19822
PDL(CONS,4,2)	0.98954	19.01583	19.25727
PDL(CONS,5,2)	0.98973	18.79956	19.03557
PDL(CONS,4,3)	0.98850	19.14065	19.43038
PDL(CONS,5,3)	0.98860	18.93165	19.21487

From Table 4, the adjustment decidability factor is maximum at a lag of 2, and AIC and SC are minimum at a lag of 2. Therefore, it is reasonable to set the lag to 2.

The estimation result after the Almon change is:

$$Y = -10447.49 + 1.579CT + 0.069Z_{0t} - 0.329Z_{it}$$
$$(8.5498) \quad (12.722) \quad (-3.3499)$$
$$R^2 = 0.9949 \quad \bar{R}^2 = 0.9938 \quad DW = 1.7121$$

The lag model of the distribution after reduction is:

$$Y = -10447.49 + 1.579CT + 0.398CONS_t + 0.0690CONS_{t-1} - 0.260CONS_{t-2}$$
$$(8.5498) \quad (3.9807) \quad (12.722) \quad (-2.6885)$$
$$R^2 = 0.9949 \quad \bar{R}^2 = 0.9938 \quad DW = 1.7121$$

Next, different values are selected for CT and CONS and their different lags for steel production trend analysis. The specific results are shown in Table 5:

Table 5. Steel Production trend analysis

$(CONS, CONS_{t-1}, CONS_{t}$- / CT	(225816.86,248443.27 ,263947.39)	(230000,250000,270000)	(240000,250000,260000)	(25000,26000,27000)
47116.12	102340	102538	109119	111189
48000	103736	103935	110515	112584
49000	105315	105514	112094	114164
50000	106894	107093	113673	115743

It can be seen that with different substantial changes in coke production and total construction output each year, steel production is in stable growth but the increase becomes smaller. The possible reason is that the upward rhythm of steel demand still depends on the improvement in real estate, infrastructure, and other areas. At present, due to COVID-19, real estate development investment and new construction areas are still falling; infrastructure investment, manufacturing investment, and automobile production and sales have also declined. Lower demand has led to a certain reduction in the increase in steel production. Moreover, under the national policies of double control of production capacity, double control of pollutant emission, double control of energy consumption, and double control of carbon emission, many steel enterprises have started to line up and develop a low-carbon development roadmap to explore the new green and clean production methods. In the new development pattern, steel enterprises achieve the dual goals of carbon emission reduction and enterprise development, the realization process is bound to cause an impact on steel production.

4. Conclusions and recommendations

The steel industry is an important basic industry of the national economy. Since China proposed green and low-carbon development, the steel industry, as a major carbon emitter in the industrial sector, has received high attention from the market. With the continuous optimization of steel production processes and mergers and acquisitions of steel enterprises, the factors affecting steel production have changed. The forecast of future steel production will be of some guidance. In this paper, the data on steel and its various influencing factors from 2001-2020 are used as samples and analyzed by iterative regression with a lagged model, and the following conclusions are obtained.

First, the gross construction output is always the main factor influencing steel production. The Chinese government attaches great importance to infrastructure development and invests a lot of money every year. The construction industry has also become the most important source of steel demand, which significantly influences steel production. Secondly, coke production, crude steel production, and total social fixed assets output were once the main factors influencing steel production, but they have ceased to be significant in recent years due to improvements in steel production processes, raw material prices, and changes in market demand. Finally, it is expected that steel production will still grow steadily in the future, but the increase will decrease. This is related to the decline in real estate development investment and manufacturing investment in China due to the new crown epidemic and other reasons.

In the future, to meet the demand for green and low-carbon development in the steel industry, the steel industry needs to continuously improve the utilization rate of raw materials, explore low-carbon production processes and needs to establish a carbon emission calculation method adapted to the actual situation of the steel industry and the corresponding carbon emission reduction evaluation standard system. For the digitalization and low-carbon transformation of the steel industry, at the government level, it is recommended to strengthen policy support and guidance, organize pilot demonstration projects for digital enterprises and low-carbon production, and create a favorable environment for the digital transformation and low-carbon production transformation of enterprises; at the industry level, the advantages of resources and capabilities of large enterprises should be integrated, sub-industries and subtypes to sort out excellent case libraries, summarize and promote industry model paths, hold experience learning exchanges, and carry out special training and organize consulting service docking; at the enterprise level, we should continue to optimize the manufacturing process, gradually promote the intelligent upgrade of the system platform and strengthen green production.

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