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Predicting the Productivity of China's Building Sector and the Elements that Affect it Using the DEA-Tobit Framework

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ABSTRACT: *The total output value of the construction industry, a pillar industry of China, is continuously growing with the expansion of the production and operation scale of Chinese construction enterprises. The extensive high-input mode has promoted the economic growth of the construction industry. Despite the fruitful and outstanding results, production inefficiency has become especially prominent. Though developing rapidly, China's construction industry possesses fewer ecological investments, accompanied by low environmental awareness and little importance to environmental protection, constantly failing to eliminate high energy consumption, high investments, and high emissions. In addition, the contradiction between the economic growth of the construction industry and the ecological environment remains evident. In this paper, the production efficiency of China's construction industry was transversely and longitudinally measured using the DEA-Malmquist index method, followed by a further analysis of the factors influencing the production efficiency of China's construction industry based on the Tobit regression model. The results show that the average production efficiency of China's construction industry is the highest in the East, moderate in the West, and lowest in the centre. The number of construction enterprises, per capita capital, industrial structure, the proportion of state-owned capitals, and GDP are significant at 1%, 10%, 1%, 1%, and 1%, respectively. The research results can provide theoretical reference for reasonably establishing an ecological efficiency evaluation system for the construction industry to analyze the differences in environmental efficiency among different provinces and regions, further find out the key factors influencing ecological efficiency, propose the corresponding pertinent policy suggestions, and ultimately improve the ecological efficiency of China's construction industry.*

Subject Categories and Descriptors: [K.6 MANAGEMENT OF COMPUTING AND INFORMATION SYSTEMS]: [J. Computer Applications]; Earth and Atmospheric sciences

General Terms: DEA-Tobit framework, Tobit regression model, Construction

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1. Introduction

The construction industry is a pillar industry of China and a key force in enhancing China's international competitiveness. In recent years, China's construction industry has achieved steady development even after being impacted by COVID-19. As a pillar industry of China's national economy, the construction industry plays a key role in promoting China's economic growth. The rapid development of the construction industry not only drives the rapid flow-in of the mass labor force and plays an irreplaceable role in relieving the difficult employment situation in China but also attracts a large number of funds invested in the production activities of the construction industry, making them be the fixed assets required by people's life, with non-negligible social and economic benefits. Although the economic growth of the construction industry has been promoted by the extensive high-input method and fruitful and amazing results have been achieved, the problem of production inefficiency is very prominent, impeding the future sustainable development of the construction industry. Production efficiency is the essential attribute characterizing the competitiveness of the construction industry. The decreasing growth rate of fixed assets investment, the rising raw material prices, and the increasing labor costs in China are directly related to the survival and development of the construction industry in the fierce market competition environment.

With the development of economic transformation and new urbanization in China, the significance of the construction industry in building a resource-saving and environment-friendly society is increasingly enhanced. The construction industry is the pillar industry in China, and the total output value and the house construction area of the construction industry are continuously growing with the expansion of the output value and operation scale of Chinese construction enterprises. Specifically, the total output value of the construction industry increased from 11,646.332 billion yuan in 2011 to 31,197.984 billion yuan in 2022, with an average annual growth rate of 15.26%. Meanwhile, the house construction area also increased from 851,828,120 square meters in 2011 to 1564,518.19 square meters in 2022, with an average annual growth rate of 7.61%. Influenced by resource restraints, however, it isn't easy to sustain the past extensive development model of the construction industry. Therefore, it is urgently needed to transform the economic growth mode of the construction industry to realize green development, energy conservation, and emission reduction while improving production efficiency. The development level of the construction industry has an important influence on economic development and the rational allocation of resource elements. However, China's construction industry has maintained an extensive development mode for a long time, accompanied by weak innovation, excess reliance on the production process upon energy input, and a high local transformation rate of resources. Thus, it is impossible to judge whether China's construction industry has prospered in a real sense from two angles: the total output value and production scale of the construction industry. In the meantime, the important symbol-production efficiency should be combined to investigate China's construction industry's internal mechanism and dynamic laws. China's economic construction continues to develop, the transformation of old and new kinetic energy has entered a critical period, and the pressure on resources and the environment continues to intensify. It isn't easy to meet the needs for the rational allocation of resources under the conditions of an open economy through the economic development mode excessively relying on traditional factors. High-quality economic development takes technological innovation as an important premise. Hence, it is very significant to scientifically locate the weak links in the development of China's construction industry, elevate the level of technological innovation, and improve the energy consumption structure in enhancing production efficiency and promoting the sustainable development of the construction industry.

2. Literature Review

Developed countries in Europe and America started the research on the production efficiency of the construction industry very early, mostly from the perspective of the whole industry and the local perspective of enterprises. The DEA model or model combination has often been used to study the production efficiency of a certain country's construction industry or the production efficiency of selected construction enterprises. For the research on the production efficiency of the construction industry, Hu & Liu (2018) proposed a relational two-stage data envelopment analysis (DEA) method and found that the construction industry in eastern China performs best in overall performance, efficiency, and benefit and the regional gap is mainly reflected in the difference of pure technical efficiency. Through a questionnaire survey, Prabhu & Ambika (2013) found out the influencing factors of the behavior efficiency of construction workers and determined their influencing level on project performance. Xue et al. (2015) used the input-oriented model to measure the changes in energy consumption and productivity of the construction industry in 26 provinces of China during 2004-2009. Then, an energy-saving gap was observed between the northeastern and western regions and China's central and eastern regions. Horta et al. (2013) analyzed the performance trend of the global construction industry and considered it necessary to strengthen the production efficiency analysis of the construction industry. Carson & Abbott (2012) combed the research literature on the productivity and efficiency level of New Zealand's construction industry and analyzed the applicability of various measurement methods to the construction industry in New Zealand. Zhang et al. (2018) used the panel data of 30 provinces and cities in China during 2011-2015 to measure the impact of environmental regulation on the technical efficiency of the regional construction industry by using a three-stage DEA model. The results show that environmental regulation significantly impacts the efficiency of the construction industry in China. Du et al. (2022) estimated the carbon emission efficiency of the construction industry in 30 provinces of China based on the data from 2005 to 2016. The results show that the carbon emission efficiency of the construction industry in China presents the unbalanced regional distribution charactertheir results. Huo et al.

istics of high in the east and low in the west, with a significant spatial spillover effect. You & Zi (2007) pointed out that the efficiency index of Korean construction companies decreased significantly during the sample period, and there was a big difference before and after the economic crisis. Nazarko & Chodakowska (2017) analyzed the differences in technical efficiency measurement between stochastic frontier analysis (SFA) and data envelopment analysis (DEA) in the construction industry and compared their results. Huo et al. (2020) measured the total factor energy efficiency (TFEE) of the construction industry in 30 provinces of China during 2006-2015. The results show that the energy efficiency of the construction industry in most provinces and regions of China is low during the study period. Beijing, Hainan, and Zhejiang provinces have the best efficiency, which constitutes the efficiency boundary of China's energy consumption. The results of Hong et al. (2019) reveal that the construction industry in China consumes the most energy and water during the construction process and faces great challenges in improving energy intensity. Tang et al. (2006) analyzed the correlation between total quality management (TQM) and project performance in China's construction industry. Zhang et al. (2021) found that the optimization of the energy structure, the number of labor forces, the total power of construction equipment, and the construction intensity exert significant positive impacts on the development level of the construction industry. Nazarko & Chodakowska (2015) used DEA and Tobit regression to analyze the productivity of the European construction industry. The results show huge differences in the productivity of the European construction industry. Chen et al. (2016) used a three-stage data envelopment analysis (DEA) model to analyze energy efficiency and its changing trend in 30 provinces of China from 2003 to 2011. The results show that after eliminating the influence of environmental factors and random errors, the energy efficiency value of the construction industry in most provinces has improved, reflecting the relatively mature level of energy management and utilization in the construction industry. Chancellor & Lu (2016) highlighted that the DEA method, an effective means of exploring industry efficiency from different angles, can formulate evidence-based policies to improve building productivity in specific regions or provinces. Kapelko et al. (2015) estimated a specific input Luenberger productivity growth index, and the results show that the productivity changes of labor and capital of Spanish and Portuguese construction companies are negative, and the productivity of Spanish construction companies' capital and Portuguese labor declines more seriously. Jarkas (2015) discussed the relative importance of the key factors affecting the labor productivity of Bahrain's construction industry. They ranked them, which filled the knowledge gap about the factors affecting the labor productivity of the construction industry and helped industry practitioners to understand the factors affecting the efficiency of workers more widely and deeply. Hu & Liu (2016) proposed a two-stage data envelopment analysis (DEA) method to analyze the production efficiency of the Australian construction industry. The results show that from 1991 to 2012, the profitability and efficiency indexes of the Australian construction industry performed poorly, with a slight imbalance, while the benefit indexes performed well. Developed countries in Europe and America started the research on the production efficiency of the construction industry very early, mostly from the perspective of the whole industry and the local perspective of enterprises. The DEA model or model combination has often been used to study the production efficiency of a certain country's construction industry or the production efficiency of selected construction enterprises. For the research literature on the production efficiency of the construction industry from the regional angle, however, the production efficiency of the construction industry has been measured mostly through the input-output method, lacking further influencing factor analysis, the conclusions are not practical, and the research methods remain to be improved. Therefore, China's construction industry was chosen as the research object. Its production efficiency was transversely and longitudinally measured using the DEA-Malmquist index method by reference to previous research results, aiming to solve some problems of the existing relevant literature. Moreover, the influencing factors were further analyzed through the Tobit regression model according to the relevant measurement results. Thus, the factors influencing the production efficiency of China's construction industry were found. Finally, some referable ideas and method suggestions for the future sustainable development of China's construction industry. Knowledge gap about the factors affecting the labor productivity of the construction industry and helped industry practitioners to understand the factors affecting the efficiency of workers more widely and deeply. Hu & Liu (2016) proposed a two-stage data envelopment analysis (DEA) method to analyze the production efficiency of the Australian construction industry. The results show that from 1991 to 2012, the profitability and efficiency indexes of the Australian construction industry performed poorly, with a slight imbalance, while the benefit indexes performed well. 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model according to the relevant measurement results. Thus, the factors influencing the production efficiency of China's construction industry were found. Finally, some referable ideas and method suggestions for the future sustainable development of China's construction industry.

3. Model Introduction and Index System

3.1 Model introduction

In 1978, famous American operations researchers Charnes et al. (1978) first proposed the Data Envelopment Analysis (DEA), which is a nonparametric analysis model for evaluating the relative efficiency of similar decision-making units (DMU) by applying the principle of mathematical programming. The CCR model established by Charnes and the BCC model by Banker et al. is based on the assumption of constant returns to scale. The DEA model constructs a non-parametric envelope frontier; above the production frontier are effective product units and below are ineffective production units. According to the research angle, methods are divided into input-oriented and out-oriented types. The model assumes n decision units, and each unit has s types of "inputs" and t types of "outputs". x_j, y_j, and θ represent the input variable, output variable, and efficiency value of the j^{th} unit, the efficiency value of the j^{th} decision unit can be converted into a linear programming problem, and the corresponding CCR and BCC models are expressed as follows:

$$\min\theta \quad s.t.\begin{cases}\sum_{j\in n}\lambda_j x_j \le \theta x_0\\ \sum_{j\in n}\lambda_j y_j \ge y_0\\ \lambda_j \ge 0,\ j\in n\end{cases} \tag{1}$$

$$s.t.\begin{cases}\min\theta\\ \sum_{j\in n}\lambda_j x_j \le \theta x_0\\ \sum_{j\in n}\lambda_j y_j \ge y_0\\ \lambda_j \ge 0,\ j\in n\end{cases} \tag{2}$$

The θ The value calculated by the CCR model is the corresponding decision unit's comprehensive efficiency value (CRSTE). If the constraint $\sum\lambda_j = 1$ is further introduced into the CCR model, which then evolved into a BCC model, and the θ value obtained by this model is the pure technical efficiency of the corresponding decision unit (VRSTE). The product between pure technical and scale efficiency (SCALE) is the comprehensive efficiency value, i.e., VRSTE × SCALE = CRSTE.

To analyze the production efficiency of China's construction industry, the Malmquist index defined by Färe et al. (1992) was chosen as follows:

$$M\left(X^{t+1},Y^{t+1},X^t,Y^t\right)=\left[\frac{D^{t+1}(X^{t+1},Y^{t+1}|CRS)}{D^{t+1}(X^t,Y^t|CRS)}\times\frac{D^t(X^{t+1},Y^{t+1}|CRS)}{D^t(X^t,Y^t|CRS)}\right]^{\frac{1}{2}} \tag{3}$$

Where $D^t(X^t,Y^t)$ and $D^{t+1}(X^{t+1},Y^{t+1})$ stand for the distance functions under the assumption of constant returns to scale in the same period and $D^{t+1}(X^t,Y^t)$, and $D^t(X^{t+1},Y^{t+1})$ represent the distance functions in different periods, $M(X^{t+1},Y^{t+1},X^t,Y^t)>1$, indicating the efficiency progress of an evaluation unit, or otherwise, it represents efficiency retrogress. The Malmquist index can be decomposed as follows:

$$M(X^{t+1},Y^{t+1},X^t,Y^t)=\frac{D^{t+1}(X^{t+1},Y^{t+1}|CRS)}{D^t(X^t,Y^t|CRS)}\times\left[\frac{D^t(X^{t+1},Y^{t+1}|CRS)}{D^{t+1}(X^{t+1},Y^{t+1}|CRS)}\times\frac{D^t(X^t,Y^t|CRS)}{D^{t+1}(X^t,Y^t|CRS)}\right]^{\frac{1}{2}} \tag{4}$$

Where $EC=\frac{D^{t+1}(X^{t+1},Y^{t+1}|CRS)}{D^t(X^t,Y^t|CRS)}$ is referred to as technical efficiency index, reflecting the closeness of an evaluation unit to the production frontier. EC>1 means that the evaluation unit is close to the production frontier, and the relative technical efficiency is improved.

$TC=\left[\frac{D^t(X^{t+1},Y^{t+1}|CRS)}{D^{t+1}(X^{t+1},Y^{t+1}|CRS)}\times\frac{D^t(X^t,Y^t|CRS)}{D^{t+1}(X^t,Y^t|CRS)}\right]^{\frac{1}{2}}$ denotes the technical progress index, representing the movement of the production frontier itself, and TC>1 indicates the progress of production technology. Assuming that the returns to scale are variable, EC can be further decomposed as follows:

$$EC=\frac{D^{t+1}(X^{t+1},Y^{t+1}|VRS)}{D^t(X^t,Y^t|VRS)}\times\left[\frac{D^{t+1}(X^{t+1},Y^{t+1}|CRS)}{D^{t+1}(X^{t+1},Y^{t+1}|VRS)}\times\frac{D^t(X^t,Y^t|VRS)}{D^t(X^t,Y^t|CRS)}\right] \tag{5}$$

$PE=\frac{D^{t+1}(X^{t+1},Y^{t+1}|VRS)}{D^t(X^t,Y^t|VRS)}$ is the pure technical efficiency index, reflecting the change in the management level of an evaluation unit, and PE>1 indicates the improved management level of the evaluation unit, the improved factor and resource allocation and their utilization level, and the efficiency progress of the construction industry, or otherwise, the management level deteriorates and the efficiency declines. $SE=\left[\frac{D^{t+1}(X^{t+1},Y^{t+1}|CRS)}{D^{t+1}(X^{t+1},Y^{t+1}|VRS)}\times\frac{D^t(X^t,Y^t|VRS)}{D^t(X^t,Y^t|CRS)}\right]$ SE stands for scale efficiency, and SE>1 manifests that the evaluation unit is closer to the optimal production scale or is distant from it.

Meanwhile, to test the factors influencing the production efficiency of the construction industry, bias and inconsistency may be generated if the least square method is adopted. Therefore, regression analysis was performed using the panel Tobit model in this study. As a regression model with restricted dependent variables, the Tobit regression model can solve the modeling problem with restricted or truncated dependent variables, and it can be rewritten as:

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$$Y=\begin{cases} Y^{*}=\alpha+\beta X+\varepsilon, Y^{*}>0 \\ 0, Y^{*}\leq 0 \end{cases} \tag{6}$$

Where: Y is the truncated dependent variable, X denotes the independent variable, α is an intercept term, β represents a regression parameter and ε is a disturbing term, $\varepsilon \sim N\left(0,\sigma^{2}\right)$.

3.2. Index System

The production efficiency of the construction industry should be measured by following the principle of index measurement, and efforts should be made to avoid the correlation between influencing factors.

According to the practice of the existing research literature, the input indexes were chosen from three angles: labor input, capital input, and technical input, and output indexes were selected from two angles: economic benefit and actual benefit. The measurement index system for the production efficiency of the construction industry is listed (Table 1).

To explore the factors influencing the construction industry's production efficiency, the industry's production efficiency was taken as the explained variable and correlation variables as the explanatory variables (Table 2).

Considering the accuracy and availability of data, 30 provinces in China (except Tibet, Hong Kong, Macao, and Taiwan) were taken as the study objects, and the research period was from 2013 to 2021. The original data for each index came from the China Statistical Yearbook, China Statistical Yearbook on Construction Industry, China

Index type	Index name	Unit
Input variable	Number of practitioners in the construction industry	Ten thousand people
	Total assets of construction enterprises	One hundred million yuan/ RMB
	Year-end total number of construction machinery equipment self-owned by enterprises	Set
Output variable	Added value of the construction industry	One hundred million yuan
	Total construction area	Ten thousand square meters

Table 1. Measurement index system for the production efficiency of the construction industry

Explanatory variable	Unit	Concrete meaning
Unit number of construction enterprises	Ea	Unit number of construction enterprises
Per capita capital	Yuan (RMB)/person	Total assets of the construction industry/number of practitioners in the construction industry
Labor productivity of construction enterprises	Yuan (RMB)/person	Per capita output value of the construction industry
Industrial structure	%	Total output value of the construction industry/GDP
Proportion of state-owned capitals	%	Assets of state-owned construction enterprises/total output value of the construction industry
GDP	One hundred million yuan (RMB)	Gross regional domestic product

Table 2. Internal and external factors influencing the production efficiency of the construction industry

Statistical Yearbook on Science and Technology, statistical yearbooks for various provinces, and the official website of the National Bureau of Statistics. According to the actual situation, some missing data were completed using mean or extension methods.

4. Research Results

4.1. Descriptive statistics

The descriptive analysis results (Table 3) show that the input and output index data in each province of China's construction industry fluctuated greatly, fully reflecting the regional unbalance in its development.

Name	Min	Max	Mean	Standard deviation	Median
Total assets of construction enterprises (One hundred million yuan, RMB)	71.25	38244.49	7046.24	6799.82	5413.76
Number of practitioners in the construction industry (Ten thousand people)	1.50	450.20	82.84	83.31	50.20
Year-end total number of construction machinery equipment self-owned by enterprises (Set)	3710.00	2456549.00	330517.23	400034.94	186032.00
Added value of the construction industry (One hundred million yuan, RMB)	178.90	7000.00	1890.94	1481.04	1436.80
Total construction area (Ten thousand square meters)	201.57	273428.00	43457.99	52242.28	28937.13

Table 3. Descriptive analysis of input and output index of China's construction industry

4.2. Efficiency Analysis

Using DEA-Solver Pro.5.0 software, the productivity values of the construction industry in 30 provinces of China during 2013-2021 were calculated from a static point of view (Table 4).

Province	2013-2014	2014 2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021
Shanghai	1.5099	0.7248	1.1257	1.2703	0.9496	0.6753	1.1490	1.6970
Yunnan	1.1657	1.0018	1.1226	1.2435	1.3460	1.5275	1.1670	1.1095
Inner Mongolia	1.1466	1.2547	1.0350	1.0895	1.1245	1.2247	1.0754	1.1659
Beijing	1.7121	0.8539	1.3282	1.8371	0.9262	0.5990	1.0529	1.8578
Jilin	1.0338	1.4113	0.8173	1.0636	0.9952	1.6658	0.9466	0.8518
Sichuan	1.3609	1.0453	1.0965	1.0841	1.0410	1.3632	1.0446	1.3183
Tianjin	0.9097	1.1079	1.0945	1.0010	1.1264	0.9591	1.1110	1.0526
Ningxia	0.5789	1.7621	0.7655	0.8595	1.2031	1.1052	0.9807	1.0236
Anhui	1.1518	1.0983	1.0521	1.1002	1.0355	1.1365	1.0954	1.2823
Shandong	1.5977	1.3720	1.1514	1.3752	1.3437	1.3295	1.0787	1.5818
Shanxi	1.2444	0.9245	1.0742	1.1682	0.7765	0.8179	1.0234	1.4673
Guangdong	1.3507	0.9172	1.0319	1.3259	0.8982	1.0276	1.1759	1.4670
Guangxi	1.1838	0.8014	1.0270	0.9584	1.0374	0.8504	1.1909	1.1495
Xinjiang	0.8110	1.5014	0.8003	1.0984	1.2569	1.3082	1.0815	1.0698
Jiangsu	1.0254	1.0144	0.9865	1.0564	1.0474	1.1045	1.2541	1.2325
Jiangxi	1.1095	0.8038	0.9887	0.9551	0.9745	0.8401	1.0371	1.2160
Hebei	0.9681	1.1146	0.9370	1.6066	0.9682	1.1503	1.0382	1.0698
Henan	1.0748	1.0033	1.0355	1.3102	1.2281	1.0955	0.9705	1.0320
Zhejiang	0.9845	0.9895	1.0807	0.9252	1.0727	1.4398	1.2245	1.0482

Hainan	1.3342	1.2981	1.0685	1.1698	1.0887	0.9803	1.1607	1.0472
Hubei	1.4912	0.7315	1.1518	1.0280	1.0954	0.8705	1.2049	1.3021
Hunan	1.1970	0.8165	1.0629	1.1011	0.9501	0.9047	1.0201	1.2839
Gansu	0.9195	1.1271	0.8134	1.1797	0.9975	0.9428	0.9098	1.0513
Fujian	1.4427	0.9950	1.1748	1.3902	1.2658	1.1236	1.1120	1.6308
Tibet	1.3080	0.8678	1.2321	1.1255	1.4158	0.6262	1.2830	1.2385
Guizhou	1.1302	0.8081	1.0994	1.0140	1.2064	1.2267	1.0101	1.4619
Liaoning	0.6910	2.8795	0.5864	1.1032	1.1796	1.6986	0.8714	0.9377
Chongqing	1.1617	1.0810	1.1052	1.2926	1.2539	1.2991	1.0824	1.4196
Shaanxi	1.2399	1.0403	1.1798	1.2941	1.0884	1.0014	1.0833	1.3034
Qinghai	0.8531	1.1182	0.8824	1.0498	0.9354	1.1015	1.0189	1.1152
Heilongjiang	0.6799	1.9285	0.7008	0.8276	1.3506	1.4981	0.9796	0.7439

Table 4. Productivity values of China's construction industry

It could be found that the average production efficiency of China's construction industry was the highest in the eastern region, followed by the western region and the central region (Table 4). The average change trend of construction efficiency in the eastern region was basically similar to that throughout China, but the fluctuation range was small, indicating that the regional production efficiency of the construction industry in China was relatively high, and the existing resources could be used relatively effectively to engage in the construction industry production. In addition, the extensive development model that only focused on scale while neglecting efficiency was initially implemented. The production efficiency in the western region also showed a U-shaped variation trend, which was quite different from that of China. This phenomenon was ascribed to the high level of economic extroversion in the eastern and central regions of China, the low level of extroversion in the western region, the lack of sensitivity to changes in the external economic situation, and the lagging impact of the financial crisis on the western region. The average change trend of construction efficiency in the central region was the same as that in China, which might be attributed to the large scale of the construction industry in the central region and abundant input resources. Still, the original land, funds, and personnel cannot be well utilized in the extensive development model, resulting in low efficiency. There was a significant difference in production efficiency among provinces in China's construction industry. This is because the development of the construction industry in different provinces and cities is uneven, and the gap in development speed is widening, which leads to overall low pure technical efficiency and high scale efficiency in most regions. This manifests that the construction industry in most provinces and cities is still based on traditional manual work, and it is developing towards industrial production of buildings using high technologies. Still, the industrial production speed of buildings remains very slow. It is very necessary to accelerate the pace of building industrialization, to achieve low-energy and high-efficiency development truly. Meanwhile, because most provinces and cities are on an increasing scale, a small production scale is the main factor that hinders the development of the construction industry in most provinces and cities. The underlying reason is that the technical efficiency of the construction industry in most provinces and cities has not changed much, not to mention the transformation of extensive management to refined management.

4.3. Tobit results

Model	-Twofold logarithmic likelihood value	Chi-square value	df	*p*	AIC value	BIC value
Intercept only	-276.555					
Final model	-397.031	120.476	6	0.000	-383.031	-358.666

Table 5. Likelihood-ratio test of Tobit regression model

It could be known that the p-value in the likelihood-ratio test of the Tobit regression model was smaller than 0.05, thus rejecting the original assumption, i.e., the explanatory variables introduced into the model were effective, and the model process was meaningful (Table 5).

Item	Regression coefficient	Standard error	z value	P value	95%	CI
C	0.817	0.457	1.787	0.074	-0.079	~1.714
Unit number of construction enterprises	-0.186	0.023	-8.272	0.000	-0.231	~-0.142
Per capita capital	-0.023	0.014	-1.673	0.094	-0.049	~0.004
Labor productivity of construction enterprises	0.026	0.041	0.649	0.516	-0.053	~0.106
Industrial structure	0.174	0.02	8.638	0.000	0.135	~0.214
Proportion of state-owned capitals	-0.054	0.012	-4.667	0.000	-0.077	~-0.032
GDP	0.142	0.021	6.714	0.000	0.101	~0.184
log(Sigma)	-2.246	0.046	-49.209	0.000	-2.336	~-2.157

Table 6. Results of Tobit regression

The following could be acquired (Table 6):

(1) The regression coefficient of the unit number of construction enterprises was -0.186, and it was significant at the level of 0.01 (z=-8.272, p=0.000<0.01), meaning that the unit number of construction enterprises has a significant negative impact on the production efficiency of the construction industry. The main reason is that the scale of enterprises has an obvious negative impact on the production efficiency of the construction industry; that is, the larger the scale of enterprises, the more unfavourable it is to the improvement of the production efficiency of the construction industry. This may be because the long-term, extensive-scale expansion of the construction industry has produced a marginal diminishing effect, which leads to the decline of the production efficiency of the construction industry. Therefore, the development of construction enterprises should not simply pursue the expansion scale but should combine the current development situation to promote the efficient transformation of construction resources and scientific and technological innovation.

(2) The regression coefficient of per capita capital was -0.023, and it was significant at the level of 0.10 (z=-1.673, p=0.094<0.10), reflecting an influencing relation between per capita capital and the production efficiency of the construction industry. The per capita capital hurt the production efficiency of the construction industry, and such an influence was statistically significant, manifesting that the resource allocation efficiency of Chinese construction enterprises is not high, and the degree of automation and mechanization of the construction industry remains to be further improved.

(3) The regression coefficient value of labor productivity of construction enterprises was 0.026. Still, it was not significant (z=0.649, p=0.516>0.05), meaning there is no influencing relationship between labor productivity of construction enterprises and construction production efficiency. The technical equipment rate of enterprises had no significant influence on the production efficiency of the construction industry, so it could not be used to explain the problems existing in reality, which might be mainly attributed to the large base of employees in the construction industry. Still, the overall quality was low, manifested primarily on: the low overall cultural level, fewer professional and technical personnel, and not comprehensive solid ability of managers, which will also lead to low production efficiency in the construction industry.

(4) The regression coefficient value of the industrial structure was 0.174, and it was significant at the level of 0.01 (z=8.638, p=0.000<0.01), manifesting that the industrial structure can significantly positively affect the production efficiency of the construction industry. It fully shows that China promotes the continuous improvement of the technical level and technical efficiency through the deepening reform of the machinery management system of construction enterprises and the continuous promotion of key core machinery technology research. And the proportion of construction industry in GDP is gradually increasing, which

is more conducive to increasing the investment of construction enterprises in machinery technology and can reversely promote improving the management level of construction enterprises and the rational allocation of resources.

(5) The regression coefficient of the proportion of state-owned capital was -0.054, and it was significant at the level of 0.01 (z=-4.667, p=0.000<0.01), meaning that there is a significant negative influence between the proportion of state-owned capital and the production efficiency of the construction industry. The increase in the proportion of state-owned capital will reduce the production efficiency of the construction industry, mainly because the management mechanism and property rights of state-owned enterprises have lowered the economic benefits and production efficiency of construction enterprises; on the contrary, non-state-owned enterprises with a higher degree of marketization have more advantages in technology optimization and benefit improvement.

(6) The regression coefficient of GDP was 0.142, and it was significant at the level of 0.01 (z=6.714, p=0.000<0.01), reflecting that GDP can significantly positively affect the production efficiency of the construction industry. The regions with sound economic development and developed construction industries can fuse and utilize outstanding local technologies and advanced management experience faster to realize efficient resource allocation so as to improve the production benefits of the construction industry.

5. Conclusions

Compared with other industries, construction noise, dust, air pollution, and solid waste pollution generated in the production process of the construction industry usually occur in densely populated urban areas, which is more harmful to the human body. The rapid development of the construction industry has caused great adverse effects on the ecological environment. The extensive development of the construction industry is an important starting point for accelerating China's economic transformation. Considering the problems of “high input, high energy consumption, and high emission” faced by the construction industry, it is essential to realize the sustainable development of the construction industry in harmony with economic growth, resource conservation, and environmental protection. In this study, the DEA-Malmquist index method was used to measure the production efficiency of the construction industry in China, and the Tobit regression model was adopted further to analyze the factors influencing construction efficiency in China. The results show that the average production efficiency of China’s construction industry is the highest in the East, followed by that in the West and the Middle, and the regional imbalance of production efficiency in China’s construction industry is obvious. The number of construction enterprises, per capita capital, industrial structure, the proportion of state-owned capital, and GDP are significant at 1%, 10%, 1%, 1%, and 1%, respectively. It is suggested that in the future, further research can be carried out to perfect the construction industry's ecological efficiency evaluation index system and select influencing factors from more angles in an all-around way.

Declarations of interest

None

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