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Evaluation of the Supply-Side Efficiency of China's Real Estate Market: A Data Envelopment Analysis

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Abstract: With the gradual slowdown of economic growth in China, the Chinese government proposed the task of supply-side reform. As a vital part of China's economy, supply-side reform in the real estate market is particularly important. Using 29 provinces (divided into seven regions) in China as examples, this paper empirically studies the supply-side efficiency of China's real estate market using data envelopment analysis (DEA) for the period of 2012–2016. The results showed that (1) the main problem of low supply-side efficiency in the Chinese real estate market is the low land-use efficiency, with a redundancy rate of 60.59% in China's land space pending development; and (2) China's southeastern coastal region, with the highest supply-side efficiency in the real estate market, reached a level of decreasing returns, and it is no longer appropriate to increase the supply-side efficiency by expanding the market scale. However, the southwestern region and the Yangtze River's middle region, which both have lower supply-side efficiency, can improve the land utilization ratio and technology investment to change the current situations. The study results suggest (1) improving the construction land development efficiency by adjusting the input and output of the market according to the specific conditions of each city, and (2) promoting the supply-side reform of China's real estate market and sustainable urbanization.

Keywords: real estate market; supply-side reform; supply-side efficiency evaluation; land supply; data envelopment analysis; sustainable urbanization

1. Introduction

With the declining demographic dividend, the accumulation of the "middle-income trap", and the constantly changing international economic structure, China's economy experienced slower growth in recent years. These changes are particularly noticeable for 2015, when China's economic growth fell below 7% for the first time, the lowest value in 24 years [1]. At this stage, China's economy is facing several problems, including overcapacity, large real estate inventories, a significant decline in corporate profits, and a high level of debt and leverage ratios. In this context, the Chinese leader Xi Jinping first proposed "supply-side reform" in November 2015 and emphasized that there are five vital tasks in the reform—reducing costs, decreasing inventory, solving overcapacity, improving weak parts, and deleveraging—all in the hopes of improving the weak economic growth situation in China [2].

As a crucial component of China's economy, the supply-side reform in the real estate industry is worthy of our attention. A large amount of real estate inventory is a concrete manifestation of resource waste in the real estate market, which is a formidable challenge in China's supply-side reform. As shown in Figure 1, as of September 2017, the total inventory area of China's real estate market amounted to 6.51 billion square meters, and the inventory cycle was 46.42 months, which was reduced by 26.39 months compared with the end of the previous year. However, this inventory cycle is still much higher than the 18-month standard, which is the upper limit of reasonable inventory cycle in China's real estate market [3].

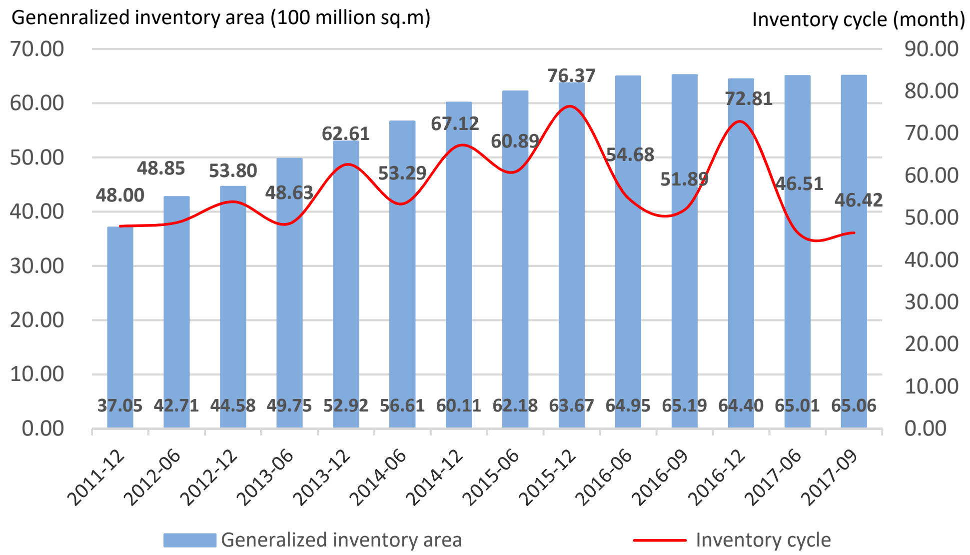

Figure 1. The generalized inventory area and the inventory cycle. The data come from the Market and Price Institute of the Chinese Academy of Macroeconomic Research.

Furthermore, there are still many problems related to supply-side reform in the real estate markets of developing countries, including the supply of land, human resources, capital, and technology. For example, as the housing prices fell, the real estate market in specific regions produced a large number of redundant employees [4]. Due to the imbalanced supply of construction land, a significant supply–demand mismatch in the housing market exists in many big cities [5]. Real estate enterprises in remote areas tend to have lower profit margins on account of insufficient technical input [6].

In summary, under an economic backdrop of intensified supply-side reform in China, a practical issue which needs to be addressed urgently is determining how to assess the current supply situation in the real estate market and adjust the inputs and outputs of various resources to obtain a higher economic return.

The rest of this paper is arranged as follows: Section 2 reviews related studies which discuss efficiency evaluation in the real estate industry. Methodology, including the CCR (the model proposed by Charnes, Cooper, and Rhodes in 1978) and the BCC (the model proposed by Banker, Charnes, and Cooper in 1984) models, is introduced in Section 3. Section 4 includes data sources, variable selection, and research areas. Section 5 describes the process of analysis, including supply-side efficiency comparison, the analysis of redundancy and deficiency values, and the judgment of returns to scale for each region. The final section presents the conclusions of this paper and provides related recommendations.

2. Literature Review

With the prosperity and development of the real estate market, establishing the means of evaluating its efficiency became a research hotspot in the academic world. Such studies can generally be divided into two broad categories according to their analytical methods: methods of index analysis and frontal analysis. Using the relevant indexes of real estate development and financial analysis, the index analysis method evaluates market efficiency. For example, in the real estate securities market of Europe, Lee et al. [7] analyzed the changing efficiency value of the real estate market by studying index futures. Kopczuk and Munroe [8] focused on the transfer taxes in the housing markets of New York and New Jersey; they concluded that a hefty transfer tax on a luxury home will reduce the efficiency of the market. However, there are certain drawbacks to using the index analysis method to analyze real estate efficiency. Yeh [9] pointed out that, due to the randomness involved in the process of index selection, the problem of collinearity and correlation between the indexes cannot be solved, which may lead to erroneous analysis results.

The frontal analysis method was first proposed by Farrell [10] in 1957, and he suggested measuring efficiency by constructing the production–possibility frontier (PPF). This method is made up of two categories: the parametric method and the nonparametric method. Stochastic frontier analysis (SFA) is a widely used parametric approach among papers that examine real estate market efficiency. SFA considers the influence of random factors, such as weather or luck, on the output, making the efficiency value more accurate and authentic. However, when using the SFA model to evaluate efficiency, it is necessary to assume that the inefficient items obey a half-normal distribution, which often introduces a certain degree of error to efficiency evaluation in the actual analysis [11]. Furthermore, obtaining the mathematical expression of the production function is a precondition for the SFA method in efficiency evaluation; however, when faced with China's real estate market, which has multiple inputs and output variables, it is relatively difficult to find its specific function form [12].

Charnes et al. [13] introduced data envelopment analysis (DEA) in 1978, which is the most commonly used nonparametric method to date. Compared with the parametric method, data envelopment analysis does not need to consider the specific form of the production frontier or to set up the weight of each index in advance. Furthermore, it is not affected by the dimension of variables. Therefore, in the real estate industry, this method is frequently used for efficiency evaluation. For example, Wang [14] developed a knowledge decision system based on data envelopment analysis for measuring the performance of government real estate investment. This system contains four commonly used DEA models—CCR, BCC, FDH (free disposal hull) and SBM (slack-based model)—and it can help the government evaluate a variety of indexes of real estate investment, including the efficiency value, returns to scale, and input redundancy. An issue that arises in the general DEA model is that the efficiency values of several provinces reach their maximum simultaneously. To manage this, Wei et al. [15] took advantage of the super-efficient DEA to evaluate the efficiency of China's real estate investment, and they concluded that there are significant regional disparities when it comes to the efficiency of real estate investment: China's higher efficiency values occur in the southeastern coastal region and the northwestern region in China. By constructing the DEA-Malmquist model, Ahmed and Mohamad [16] analyzed the situations of Singapore's real estate investment trusts (REITs), including the technical efficiency, and their research showed that the majority of REITs in Singapore experience almost no increase in efficiency, but the performance of REITs can be improved by further improving technical efficiency.

In summary, we can see that the variables which affect the real estate market's efficiency include capital, taxation, land, human resources, technology, and financial markets. Meanwhile, the related research methods in this area are well developed, laying the foundation for studies in this area. However, although supply-side efficiency is a big issue in the supply-side reform process in developing countries, there is little research on its performance in their real estate markets. Therefore, this paper evaluates the current supply-side efficiency of China's real estate market using the DEA model, and improvement measures are proposed to facilitate the sustainable development of the real estate market in developing countries.

3. Methodology

Data envelopment analysis (DEA) is a method for evaluating the relative efficiency of several decision-making units (DMUs) with multiple inputs and outputs. DMUs generally refer to firms or public sector agencies which require the evaluation of their management or program efficiencies [13]. Judging whether each DMU is DEA-efficient is essentially determining whether each DMU is located on the production–possibility frontier [17]. The DEA models mainly used in this study are the CCR and the BCC models, which are discussed in detail in this section.

3.1. The CCR Model

Charnes et al. established the CCR model in 1978, and it is still the most basic and commonly used DEA model. This model analyzes a DMU's efficiency on the premise of constant returns to scale (CRS). The operation of a DMU is inefficient if the technical efficiency value is less than 1, which means that the production value is below the production–possibility frontier; the operation of a DMU is efficient if the technical efficiency value is equal to 1. We can further analyze the inefficient units and propose improvement suggestions by circulating the redundancy and the deficiency value [18].

The objective function is defined as follows:

$$h_j = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{mn} v_i x_{ij}}, j = 1, \ldots, n, \tag{1}$$

where h_j denotes the technical efficiency of DMU j; x_{ij} and y_{rj} represent the values of input i and output r for DMU j, respectively; and v_i and u_r are weight coefficients that measure input i and output r, respectively.

For the CCR model, the goal is to maximize the efficiency value h_j of the above DMU. Taking the efficiency value of DMU j as the target, we use the efficiency value of all DMUs as constraints. The CCR (C^2R) model is constructed as follows:

$$\begin{aligned} &\max h_{j_0} = \frac{\sum_{r=1}^{s} u_r y_{rj_0}}{\sum_{i=1}^{m} v_i x_{ij_0}} \\ &h_j = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1 \\ &u \geq 0, v \geq 0\,; j = 1, \ldots, n;\ r = 1, \ldots, s;\ i = 1, \ldots, m. \end{aligned} \tag{2}$$

The slack variable S^+ and the residual variable S^- are further introduced into the model, which change the inequality constraints into the equality constraints. In 1952, Charnes, Cooper, and Mellon [19] successfully proposed a small "non-Archimedean" quantity, making calculations faster and more convenient, which is why DEA can be widely used in various fields. Similarly, Charnes established a CCR model with the non-Archimedean quantity, shown below.

$$\begin{cases} \min\left[\theta - \varepsilon\left(\sum_{j=1}^{m} s^- + \sum_{j=1}^{r} s^+\right)\right] = v_d(\varepsilon) \\ \sum_{j=1}^{n} x_j \lambda_j + s^- = \theta x_0 \\ \sum_{j=1}^{n} y_j \lambda_j - s^+ = y_0 \\ \lambda_j \geq 0,\ s^+ \geq 0, s^- \geq 0, j = 1, \ldots, n, \end{cases} \tag{3}$$

where θ denotes the radial value or distance from the production–possibility frontier in this equation, and S^+, S^- represent the redundancy value and the deficiency value, respectively.

The judging criteria are as follows (θ^0 represents the optimal solution):

(1) The DMU j is DEA-inefficient when $\theta^0 < 1$;
(2) The DMU j is DEA-efficient when $\theta^0 = 1$ and $s^+ + s^- = 0$;
(3) The DMU j is weakly DEA-inefficient when $\theta^0 = 1$ and $s^+ + s^- > 0$.

3.2. The BCC Model

The work of Charnes et al. was extended by Banker et al. in 1984. They established a BCC model that applies to variable returns to scale (VRS), which include increasing returns to scale (IRS), decreasing returns to scale (DRS), and constant returns to scale (CRS). Unlike the CCR model, this model provides a measure which can simultaneously assess the efficiency of both technology and scale for each DMU [20]. Its original linear programming P(BC^2) is as follows:

$$\begin{cases} \max h_{j_0} = \sum\limits_{r=1}^{s} \mu_r y_{rj_0} + \mu_{j_0} \\ \sum\limits_{i=1}^{m} w_i x_{ij} - \sum\limits_{r=1}^{s} \mu_r y_{rj} \geq 0, \\ \sum\limits_{i=1}^{m} w_i x_{ij_0} = 1 \\ \mu_r \geq 0, w_i \geq 0;\ \mu_{j_0} \text{ has no limitation;} \\ j = 1, \ldots, n;\ i = 1, \ldots, m;\ r = 1, \ldots, s, \end{cases} \tag{4}$$

where μ_r and w_i denote the corresponding weights allocated to output variable r and input variable i. The μ_{j_0} term represents returns to scale; if $\mu_{j_0} > 0$, it has a status of IRS; if $\mu_{j_0} < 0$, it has a status of DRS; if $\mu_{j_0} = 0$, it has a status of CRS.

Similarly, this equation can be transformed into its dual programming version D (BC^2), and, after the introduction of the slack variable s^+ and the residual variable s^-, its DEA model with the non-Archimedes infinitesimal quantity is as follows:

$$\begin{cases} \min \left[\theta - \varepsilon (\sum\limits_{j=1}^{m} s^- + \sum\limits_{j=1}^{r} s^+) \right] = v_d(\varepsilon) \\ \sum\limits_{j=1}^{n} x_j \lambda_j + s^- = \theta x_0 \\ \sum\limits_{j=1}^{n} y_j \lambda_j - s^+ = y_0 \\ \sum\limits_{j=1}^{n} \lambda_j = 1 \\ \lambda_j \geq 0,\ j = 1, \ldots, n \\ s^+ \geq 0, s^- \geq 0,\ \theta \text{ has no limitation.} \end{cases} \tag{5}$$

The judging criteria of the BCC model are the same as those of the CCR model, which was introduced in Section 3.1.

4. Empirical Analysis

4.1. Input and Output Variable Selection

This paper takes 29 provinces of China as decision-making units, which include several variables. As a summary review of the literature, Table 1 lists the commonly used input and output variables of the efficiency evaluation in the real estate industry.

Table 1. A summary of commonly used variables in the real estate efficiency evaluation.

Type	Attribute	Variable
Input	Labor	Number of enterprises; number of employed persons
Input	Land	Land space pending development of enterprises; floor space of buildings started this year; floor space of buildings under construction; land space purchased this year of enterprises
Input	Capital	Investment completed this year of enterprises; total value of land purchased of enterprises
Input	Technology	Expenditure on research and development (R&D) of enterprises; net worth of owned equipment and machinery
Output	Economy	Floor space of commercial buildings sold; total sale of commercial buildings sold of enterprises; revenue from the principal business of enterprises; operating profits of enterprises
Output	Society	The added value of the real estate industry; related taxes on real estate; per capita floor space of urban residents

Note: the enterprises in the table refer to real estate enterprises; the data of the variables can be found in China's National Bureau of Statistics.

It can be seen that the input variables are mainly from the labor force [21,22], land [23–25], capital [26,27], and technology [28,29]. This paper divides the output variables into economic variables [23,26] and social variables [21,28,30] from the perspective of supply-side efficiency in China, rather than the general efficiency in the real estate industry or individual enterprises. The economic variable is used to measure the economic benefits created by the real estate industry through land development, housing transactions, and other business [31,32]; the social variable is a type of index which can determine whether the real estate industry can meet people's residential needs and production activities, and whether it plays a role in withdrawing currency from circulation, adjusting consumption, and increasing state revenue [33].

However, more DMUs are needed if we select too many variables in the research, thus reducing the accuracy of the data envelopment analysis. Therefore, the total number of variables we generally adopt should be less than half of the number of DMUs in the analysis [34]. As shown in Table 2, according to the perspective of the supply-side and the principles of index selection, which include feasibility, high correlation, and quantifiability [35], this study ultimately selected four input variables and two output variables to form the evaluation system.

Table 2. The final variables in the evaluation system.

Type	Variable	Definition	Unit
Input	Average number of persons engaged in the real estate industry (NPRE)	The average number of employees in a real estate-related enterprise in a certain year, which is calculated from monthly data.	persons
Input	Land space pending the development of real estate enterprises (LPRE)	The sum of the land area belonging to the enterprise which owns the obtained land use rights in various ways in the current year and various land resources acquired but not developed in previous years.	10,000 m^2
Input	Investment completed of real estate enterprises (ICRE)	Total investment in land purchase, housing construction, etc. for real estate enterprises in each year.	100 million yuan
Input	The net worth of owned equipment and machinery (NWEM)	The actual value of the company's construction machinery and equipment after use and wear, which is calculated by subtracting the net value after depreciation from the original value.	100 million yuan
Output	Revenue from the principal business of enterprises (RPBE)	The income of the main business, such as sales of goods and provision of labor services.	100 million yuan
Output	The added value of the real estate industry (AVRE)	All the valuable achievements of all real estate-related enterprises in a country during a certain period, which are calculated by the market price.	100 million yuan

Note: the source of the final variables is from China's National Bureau of Statistics.

4.2. Data Resources

Using 29 provinces in China as examples, we constructed a DEA model with data from 2012–2016. The corresponding data, including six input and output variables combined, are from the China Statistical Yearbook (2013–2017). Descriptive statistics of input–output variables from 2012 to 2016 are shown in Table 3. From Table 3, there is a large gap between the mean values of the input–output variables and the maximum values (or the minimum values), which means that there are large differences in the inputs and outputs across Chinese provinces.

Due to the lag effect between input and return in the real estate market, we need to determine the interval period, which is the average construction cycle of China's real estate projects [36]. A group of scholars calculated the time from the start of construction to the date of completion in 10 typical cities in China's five urban clusters; the average time was determined to be 27.93 months [37]. In 2017, one of China's famous real estate development enterprises, Country Garden, announced that its currently used SSGF (the core idea consisting of sci-tech, safe, green, and fast) high-quality construction system could guarantee an average delivery period of 17–21 months, depending on the different formats, layers, and construction conditions involved [38]. Given the availability of data, this work finally adopted 24 months as the interval period between input and output variables.

Table 3. Statistical description of input–output variables from 2012 to 2016.

Year	Statistics	NPRE	LPRE	ICRE	NWEM	RPBE	AVRE
2012	Mean	71,786.79	2503.12	1660.08	13,604.73	1755.68	850.03
	Standard deviation	44,162.24	1668.89	1118.47	11,170.50	1393.17	840.13
	Maximum	189,590.00	6579.70	4299.38	50,720.36	5854.69	3643.87
	Minimum	10,883.00	408.10	254.37	337.56	277.61	87.51
2013	Mean	77,488.90	2605.99	2125.76	15,872.26	2434.08	999.58
	Standard deviation	43,437.19	1764.17	1414.85	13,264.77	2109.86	953.46
	Maximum	201,153.00	7080.44	5567.94	63,085.69	9510.96	4207.46
	Minimum	14,844.00	424.18	336.23	314.72	352.69	104.05
2014	Mean	81,971.31	2608.61	2469.22	19,599.92	2285.79	1056.91
	Standard deviation	44,390.02	1905.41	1606.06	28,224.05	1894.25	1008.90
	Maximum	196,656.00	7575.81	6206.10	155,294.94	7540.12	4486.92
	Minimum	15,944.00	505.83	429.15	344.66	344.09	114.28
2015	Mean	88,994.10	2718.63	2957.11	20,937.86	2415.13	1141.62
	Standard deviation	49,357.93	2061.15	1896.06	23,450.53	2097.97	1113.81
	Maximum	211,205.00	9095.07	7241.45	112,311.07	8238.36	5117.95
	Minimum	17,444.00	750.97	558.97	311.81	291.87	97.05
2016	Mean	94,734.69	2598.59	3264.63	19,474.59	3096.98	1309.73
	Standard deviation	52,134.80	2065.25	2115.44	16,668.65	2865.79	1318.84
	Maximum	224,619.00	9326.77	8240.22	74,648.84	11,204.32	6229.50
	Minimum	18,831.00	733.37	654.80	410.95	368.59	102.57

Note: the units of input–output variables are respectively shown in Table 2; the data are derived from the China Statistical Yearbook (2013–2017).

The Pearson correlation coefficient (PCC) was adopted in this work to check the isotonicity (the notion that, when the input increases, the output must not be reduced) between variables [39]. Table 4 presents the test results, and it can be seen that the correlation coefficient between variables is positive, and all of them pass the two-tail test at the 1% significance level, showing that all selected variables meet the isotropic principle.

Table 4. The results of the Pearson correlation test.

	NPRE	LPRE	ICRE	NWEM
RPBE	0.801 *** (0.000)	0.742 *** (0.000)	0.884 *** (0.000)	0.781 *** (0.000)
AVRE	0.840 *** (0.000)	0.731 *** (0.000)	0.847 *** (0.000)	0.725 *** (0.000)

Note: *** indicates that the significance level reached 1%, and the number in parentheses is the *p*-value in the test; The data were analyzed using SPSS version 22.0 for Windows (SPSS Inc., Chicago, IL, USA).

4.3. Division of Research Areas

Most of the previous papers which studied the efficiency of a specific industry typically divided China into western, central, and eastern regions according to geographical location [40,41]. However, as the reform in China deepens, the gradually increasing difference in the internal efficiency between these three regions became pronounced [42]. Therefore, combined with the practice in China's Development Research Center [43], we chose gross domestic product (GDP), net population inflow (NPI), and area of construction land (ACL) as the main bases for division; thus, we divided China's 29 provinces into seven regions according to actual conditions. This division of the research areas is shown in Table 5 and Figure 2.

Table 5. The research areas and its respective characteristics. GDP—gross domestic product.

Region	Characteristic	Included Provinces
The northeastern region (Region 1)	This region is an old industrial area in China, which has a low level of development in the service industry and the high-tech industry. The population is in a state of continuous outflow.	Liaoning, Jilin, and Heilongjiang
The northern coastal region (Region 2)	The provinces in this region are close to China's capital, with a dense population, convenient transportation, and developed science, education, and culture.	Beijing, Tianjin, Hebei, and Shandong
The southeastern coastal region (Region 3)	This region achieved modernization early and has close economic relations with other countries. It has obvious development advantages with the largest GDP and population inflows among all regions.	Shanghai, Jiangsu, Zhejiang, Fujian, Guangdong, and Hainan.
The Yellow River's middle region (Region 4)	The development level of this region is at the medium stage. It is located inland with little openness to the outside world, and its task of industrial restructuring is arduous.	Inner Mongolia, Shaanxi, Shanxi, and Henan
The Yangtze River's middle region (Region 5)	With excellent agricultural production conditions, a dense population, and a low degree of openness, this region has the largest net outflow of population in China.	Hubei, Hunan, Jiangxi, and Anhui
The northwestern region (Region 6)	As one of the major inhabited areas of ethnic minorities in China, this region has both the lowest level of economic development and construction land area among all regions.	Xinjiang, Gansu, and Ningxia
The southwestern region (Region 7)	Although this region has the largest number of impoverished people in China, after the successful implementation of the develop-the-west strategy, its GDP was at the forefront in the research areas, so its development potential is relatively high.	Sichuan, Chongqing, Guizhou, Yunnan, and Guangxi

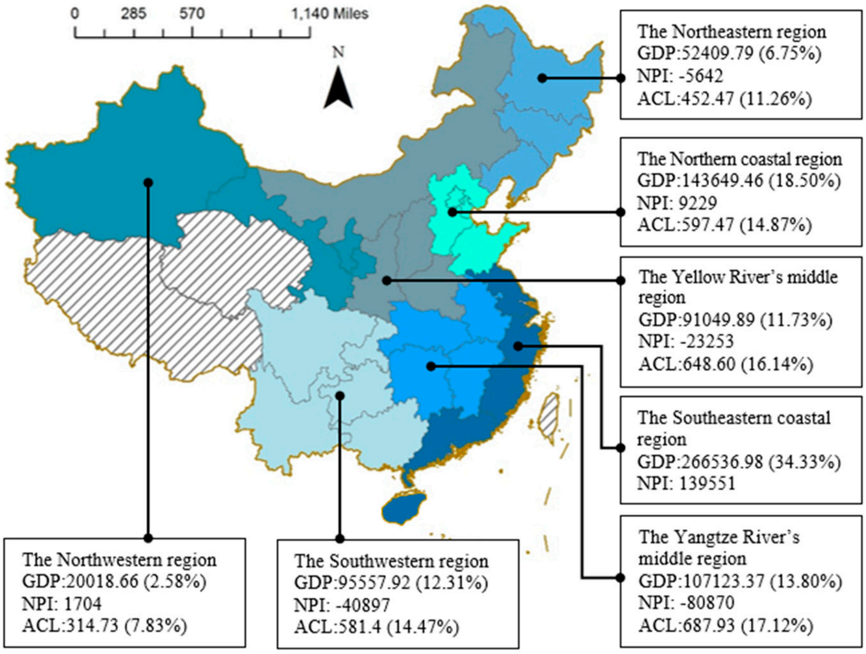

Figure 2. The division of the research areas. The provinces with the slashes on the map are non-research areas for this analysis due to the unrepresentative data; the gross domestic product (GDP) data (100 million yuan) are derived from the China Statistical Yearbook 2016; the net population inflow (NPI) data (person) in 2016 come from China's Migrant Population Serve Center; the area of construction land (ACL) data (10,000 hectares) come from the outline of China's Outline of the overall national land-use plan (2006–2020).

5. Results and Discussion

5.1. Comparison and Trend Analysis

This paper presents the supply-side efficiency in China's real estate market for the period of 2012–2016. The changing trend of the supply-side efficiency is shown in Figure 3. It can be seen that the supply-side efficiency showed an increasing trend at first, and then it gradually declined in 2012–2016. Due to the scarcity of land resources, the land supply market largely determines the direction of China's real estate market [44]; thus, we attempted to analyze the changes of supply-side efficiency from the perspective of land supply in 2012–2016. As shown in Figure 3, the inflection point of the rising supply-side efficiency of the real estate market appears around 2013, which is consistent with the hot real estate market that flourished in China in 2013.

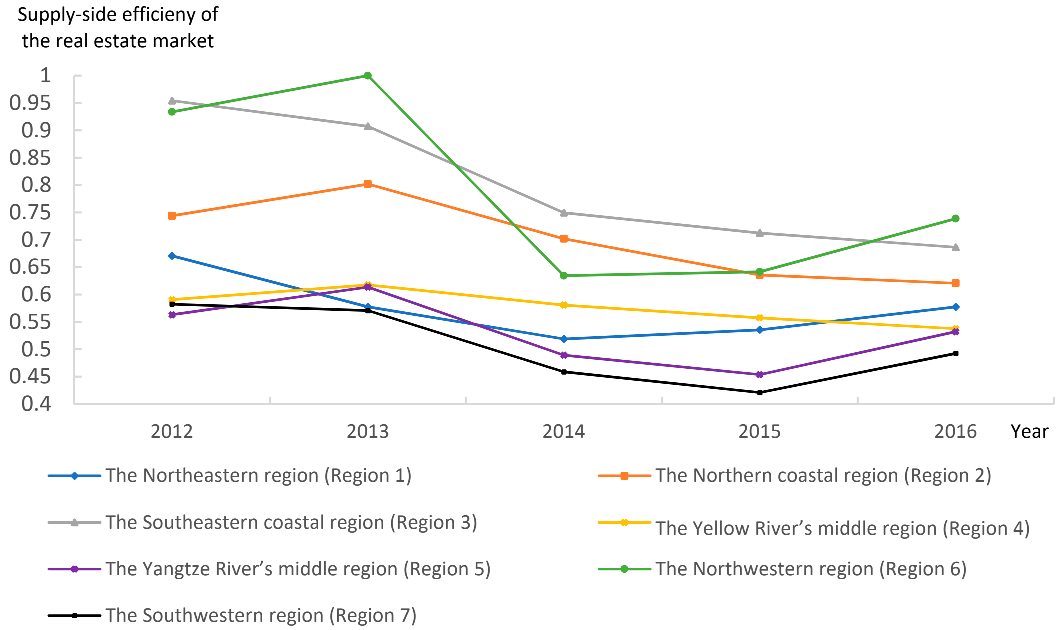

Figure 3. The supply-side efficiency in China's real estate market. The data in Figure 3, and Tables 7 and 8 were analyzed using MaxDEA 6.2 for Windows (Realworld Software Company, Beijing, China).

As shown in Figure 4, the supply of state-owned construction land reached its peak in 2013. At this time, the local government of China relied heavily on land finance, and the added value of the real estate industry was a relatively large proportion of China's GDP, which led to the prosperity of the housing market [45]. The inflection point of the decline appeared around 2015, and China's government and departments proposed a number of land policies related to supply-side reform in this year (shown in Table 6). The core content revolves around optimizing the land supply structure and solving the problem of unbalanced land supply between regions. Meanwhile, the land supply was significantly reduced by China's government that year, which is shown in Figure 4. However, these policies contributed to the improvement in the supply-side efficiency of the real estate market to some extent, since it showed an upward trend in 2016.

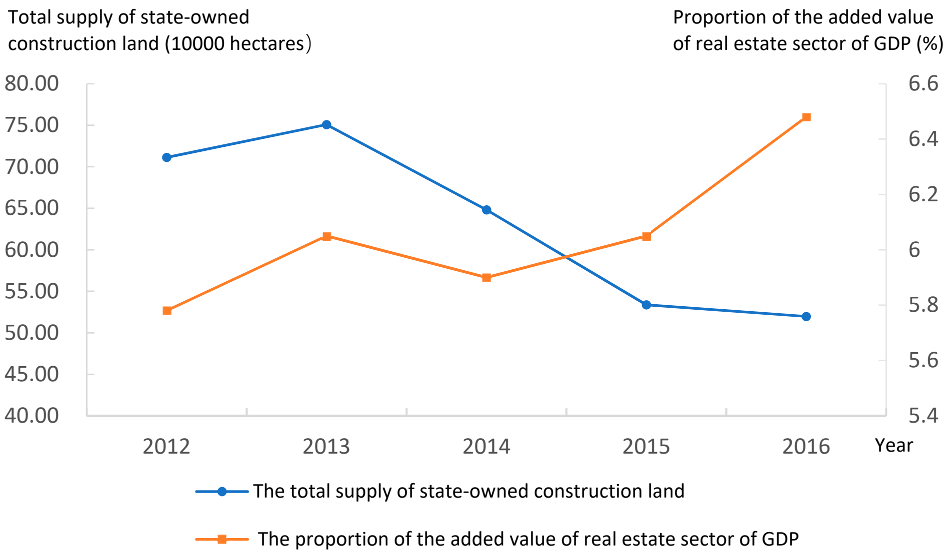

Figure 4. The state-owned construction land supply and the proportion of added value of the real estate industry (AVRE) sector of GDP. The data come from the China Statistical Yearbook (2013–2017).

Table 6. Policies and regulations related to land supply-side reform in 2015.

Date	Policies and Regulations	Content Related to Land Supply-Side Reform
March 2015	Notice on optimizing the housing and land supply structure in 2015 and promoting the sustainable development of the real estate market	Reduce or stop the supply of residential land in cities and counties where housing supply is significantly high; promote the adjustment of land-use structure
April 2015	Notice on standardizing the evaluation of land-saving evaluation of construction projects	Establish an intensive land evaluation and assessment mechanism to improve the land-use efficiency
September 2015	Opinions on land-use policy for supporting new industries and promoting mass innovation	Use a variety of methods to supply new industrial land
November 2015	Guidance on playing a leading role in new consumption and fostering new power of supply-side	Optimize new construction land structure; change the situation of low land use efficiency

Note: policies and regulations are derived from the China State Council and China's Ministry of Natural Resources.

From the comparison of the efficiency between different regions, the top two were the southeastern coastal region and the northwest region. The former is China's most economically developed region, which contributed 35.60% of China's GDP in 2017, while the latter only accounted for 2.67% [46]. It shows that a region's supply-side efficiency of the real estate market does not entirely depend on the stage of local economic development. Furthermore, the two regions with the lowest supply-side efficiency were the Yangtze River's middle region and the southwestern region. It can also be seen that, after seven regions experienced a lower supply-side efficiency in 2015, the Yellow River's middle region and the two regions along the coast (the northern coastal region and the northeastern region) continued showing a downward trend in 2016, while the changing trend in other regions all showed varying degrees of increase.

5.2. Input Redundancy and Output Deficiency Analysis

As shown in Figure 3, in 2016, supply-side efficiency in seven regions' real estate markets remained at a relatively low level compared with previous years. The supply-side efficiency of three regions still showed a downward trend. Therefore, we needed to analyze the output deficiency and input redundancy for each region, then adjust the input and output of labor, land, investment, and other types of variables such that the supply-side efficiency of the real estate market could be improved.

Table 7 describes the redundancy and deficiency conditions of four input variables and two output variables in each region in 2016, including the redundancy value, the deficiency value, and the corresponding rates.

Table 7. The redundancy and deficiency analysis in 2016.

Region	Redundancy Value of NPRE (persons)	Redundancy Value of LPRE (10,000 m^2)	Redundancy Value of ICRE (100 million yuan)	Redundancy Value of NWEM (100 million yuan)	Redundancy Value of RPBE (100 million yuan)	Redundancy Value of AVRE (100 million yuan)
Region 1	71,520.78 (46.56%)	3714.98 (64.62%)	3352.74 (43.79%)	22,860.15 (56.60%)	1826.45 (42.91%)	0.00 (0.00%)
Region 2	222,979.95 (49.08%)	5424.45 (59.34%)	3137.56 (20.52%)	33,378.68 (39.59%)	4575.86 (29.34%)	0.00 (0.00%)
Region 3	163,524.74 (22.51%)	11,438.19 (47.70%)	8482.26 (26.22%)	72,921.13 (38.58%)	2610.96 (6.44%)	0.00 (0.00%)
Region 4	224,298.76 (57.56%)	3512.37 (58.37%)	3136.26 (32.75%)	37,436.22 (53.56%)	3879.82 (54.50%)	0.00 (0.00%)
Region 5	226,897.87 (52.84%)	9773.48 (72.36%)	5810.57 (46.38%)	50,855.86 (53.86%)	1758.16 (16.15%)	0.00 (0.00%)
Region 6	23,630.272 (2.63%)	1834.66 (55.01%)	55.06 (2.30%)	4372.09 (30.40%)	512.68 (27.39%)	0.00 (0.00%)
Region 7	259,990.61 (54.01%)	9958.86 (73.06%)	6126.29 (41.16%)	44,524.70 (61.54%)	2097.40 (21.97%)	0.00 (0.00%)
Rate	43.55%	60.59%	31.79%	47.16%	19.22%	0.00%

Note: the percentage in parentheses represents the rate of input redundancy or output deficiency for a single region, and the rate in the last column represents the rate of input redundancy or the rate of output deficiency for a single variable.

It can be seen that, among the six variables, only the added value of the real estate industry (AVRE) reached the optimum with no deficiency output under the current scale, and the other variables had varying degrees of redundancy. The most prominent one was the land space pending development of real estate enterprises (LPRE), with the highest redundancy rate of (60.59%) among all variables, which means that it became the main factor affecting the supply-side efficiency of China's real estate market. Compared with Figure 4, the total supply of state-owned construction land remained at a low level around 2016. This indicates that there is a problem of low land-use efficiency in China's real estate enterprises, and, meanwhile, some enterprises deliberately hoard land to obtain a higher price for the houses they build [47,48].

Comparing the redundancy of the investment completed of real estate enterprises (ICRE), we can see that there was unbalanced investment redundancy in different regions in 2016, and the higher redundancy rate was presented in the Yangtze River's middle region, the northeastern region, and the southwestern region. It shows that a large portion of real estate investment in these regions did not produce practical benefits. Therefore, in view of the current situation—that the funding source of China's real estate enterprises is mainly through bank loans—supply-side reform in real estate investment should be focused on how to implement differentiated management on development loans and corporate bonds by banks and other financial institutions. Facts proved this in November 2016, when China's National Development and Reform Commission (NDRC) issued *Opinions on Corporate Bond Review and Implementation of Real Estate Control Policies*, which indicated the need to tighten up the development financing of commercial real estate and restrict the issuance of corporate bonds in high-inventory cities and high-asset/liability-ratio companies, which would help reduce the redundancy of real estate investment in some regions and improve the supply-side efficiency of the real estate market [49].

To improve the relatively low supply-side efficiency in some regions, this analysis further compared input redundancy and output deficiency between different regions. As shown in Table 7, the southwestern region (Region 7), which was ranked in last place in the efficiency evaluation, had both the highest redundancy rate in land space pending development of real estate enterprises (LPRE) and the net worth of owned equipment and machinery (NWEM), with values of 73.06% and 61.54%, respectively. The Yangtze River's middle region (Region 5), ranking in second-to-last place, also had a high redundancy for these two variables—72.36% and 53.86%, respectively. Therefore, when we begin solving the problem of low supply-side efficiency in these two regions, we should start by reducing the redundancy of the two variables above. For example, Sichuan province, which is located in the southwestern region, first launched a supply-side system design for land transfer in China, and it was practiced successfully in March 2016 [50], meaning that cities with redundant land could transfer their construction land quota to other cities (in the same province) where land was scarce. This approach contributes greatly to improved land-use efficiency. Moreover, unlike China, India, which is also a big developing country in the world, pays more attention to the scientific planning in the early stage of real estate projects, such as optimizing road design and promoting land-saving techniques—factors that play a bigger role in its reform of the real estate market [4].

Secondly, compared with other regions, the Yellow River's middle region (Region 4) and the northeastern region (Region 1) both had a higher output deficiency value in revenue from the principal business of enterprises (RPBE), in first and second place, respectively, in the rate of output deficiency for this variable. Therefore, it can be judged that raising the income level of real estate enterprises in these two regions is the key to improving their supply-side efficiency of the real estate market.

Furthermore, from the redundancy value of investment completed of real estate enterprises (ICRE), it can be seen that the redundancy value of the northwestern region (Region 6) was at the lowest level among all regions at only 2.30%, which is smaller by two orders of magnitude than that of the other regions. This shows that the amount of funds invested in the real estate market of the northwestern region is relatively small, which explains, to some extent, why China's northwestern region with a relatively backward economy can rank second in the evaluation of the supply-side efficiency of China's real estate market.

5.3. Scale Benefit Analysis

This section further explores the scale benefit in the real estate market, and it can help us judge whether there is a need for each region to expand, shrink, or maintain its market size (land scale) during the process of the supply-side reform in the real estate market. Table 8 shows the results calculated by DEA analysis. The southeastern coastal region, which ranks first in the supply-side efficiency of China's real estate market, faced "decreasing returns to scale (DRS)" since 2014, indicating that the rate of increase for inputs would exceed that of outputs, although we enlarged the market scale and raised the proportion of inputs. Therefore, it can be inferred that the improvement of supply-side efficiency in China's southeastern coastal region cannot depend on the expansion of the market size, but should seek other ways to reduce values of input redundancy and output deficiency. Facts proved this in 2013, when Shanghai, which is located in the Southeastern coastal area, first proposed its aim of "construction land reduction" in China. Through land remediation, such as demolition and reclamation, inefficient construction land (including illegal industrial land and scattered homestead) outside the urban development boundary was restored to agricultural or ecological land [51,52]. This adjustment of the land supply structure in the supply-side reform of the real estate market contributes to limiting the scale of both the land market and the real estate market, and, meanwhile, it is conducive to reversing the decreasing returns to scale in this region.

Table 8. The analysis of returns to scale.

Year	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7
2012	▲	▲	▲	▲	▲	▲	▲
2013	▲	▲	▲	▲	▲	○	▲
2014	▲	▲	▽	▲	▲	▲	▲
2015	▲	▲	▽	▲	▲	▲	▲
2016	▲	▲	▽	▲	▲	▲	▲

Note: the constant returns to scale are indicated by "○"; the increasing and decreasing returns to scale are indicated by "▲" and "▽ ", respectively.

The other six regions experienced "increasing returns to scale (IRS)" in 2012–2016, and this implies that the increase in market size in these regions will promote the supply-side efficiency of real estate market. Therefore, unlike the southeastern region, the construction land quota can be appropriately raised in the other six regions from the viewpoint of the scale benefit in the process of supply-side reform under the requirements of city planning; thus, we can achieve the purpose of expanding the market scale, which will help improve the supply-side efficiency in the real estate market.

6. Conclusions and Policy Recommendations

Based on DEA models, this paper empirically studied the real estate market supply-side efficiency in China's seven regions containing 29 provinces between 2012 and 2016. The results show that low land-use efficiency could be the main reason for the low supply-side efficiency in China's real estate market. There still exists a redundancy rate of 60.59% in land space pending development of real estate enterprises (LPRE) under the circumstance of limited land supply in China. Moreover, China's southeastern coastal region, which ranks first in the real estate market supply-side efficiency, entered a stage of decreasing returns to scale; thus, it is no longer appropriate to continue expanding the market size to further improve supply-side efficiency. However, as low supply-side efficiency regions, the southwestern region and the Yangtze River's middle region can improve real estate market supply-side efficiency by expanding the market size, increasing land utilization, and improving technology investment. On this basis, the policy recommendations proposed in this paper are as follows:

(1) The development efficiency of construction land needs to be increased based on existing land supply. Since China faces a food supply problem for a huge population, there are strict boundaries in China for the division between cultivated land area and construction land area. Therefore, determining how to use existing land resources to improve development efficiency is particularly important. In practice, on the one hand, it is possible to adopt the method of adjusting the market structure, such as revitalizing urban stock land, and encouraging the development and utilization of urban underground space through three-dimensional development [53,54], multiple land use, and circulation utilization [33,55]. At the same time, the redevelopment of urban low-efficiency land should be actively supported, and the transformation of shantytowns, urban villages, and old factories should be accelerated [56,57].

Secondly, it is necessary for the government to build an intensive land-use system in China's real estate market. For example, local governments can regularly conduct investigations and evaluations of the intensive use of construction land by establishing and improving the basic information survey, evaluation, and disclosure mechanism for intensive land use so that real estate development enterprises can operate under the supervision of the public [58]. In this process, the government should improve the construction of a standard control system for the intensive use of construction land, which is used to measure indexes, such as consumption of land, per capita land area, land-use structure, etc. in different urban areas, thereby improving the overall utilization of the land [59].

Furthermore, the government should encourage enterprises to save land resources by applying advanced technology to the total process of real estate development [60]. The enterprises need to learn from domestic and overseas land-saving experience and explore land-saving technology such as underground space utilization [61], wasteland management [62], etc.

(2) The implementation of the policy in the real estate market needs to be combined with specific circumstances and local conditions. From the analysis in this paper, it can be seen that, for different variables and regions, there are different values of input redundancy and output deficiency. Using India as an example, whose real estate market is operating under a new economic situation wherein its tourism industry faced an annual growth rate of 12.7% in 2015, the government adjusted the supply structure of the real estate market by encouraging the development of tourism real estate and changed the weak market environment [63]. Therefore, we need to adjust inputs and outputs according to the respective characteristics of each region so that their supply-side efficiency of the real estate market can be effectively improved.

For example, considering the redundancy of human resources in the real estate market in some regions, the local government should expand employment channels in real estate-related industries and guide the redundant labor force toward these fields for employment [64]. The government is supposed to enhance process management and control to prevent some local real estate companies from deliberately stocking up huge land resources and slowing the speed of construction to pursue a higher return in the future. In addition, related laws should be enacted and imposed strictly to respond to such land-hoarding behavior [48,53]. For regions with redundant technology investment, we should place more emphasis on improving the efficiency of technology commercialization, and the government can provide special funds to support it [65]. If real estate development enterprises face the problem of low levels of income, we can try broadening the depth and breadth of services in the real estate market, such as extending the industrial chain to the design and construction links and providing supporting property services [66], thereby enhancing the profit level of enterprises.

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