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Can China's Market-Oriented Reform Improve the Efficiency of Industrial Land Use? A Panel Data Empirical Analysis at Prefecture Level From 2007–2019

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China is entering rapid industrialization and urbanization since 1990's with the urban land use payment reform. Nevertheless, higher rate of industrial land in construction land driving by local government-led industrial double growth competition fuels China the global biggest manufacturing giant and second largest economy on one hand, waste water, liquid and green house gas emission from industrial development has become more and more serious on the other hand, which has aroused a great concern nationally and globally. So low industrial land use efficiency (ILUE) is a big challenge besieging China at present. Whether the market-oriented reform of industrial land supply (MRIL) launched by the Chinese government can optimize the allocation of industrial land resources and improve the ILUE is urgent to be addressed at present. Basing on panel data of 270 prefecture-level cities in China from 2007 to 2019, we first construct marketization rate of industrial land (MIL) and examine the temporal and spatial change in MIL in each prefecture-level city. Then the impact of MIL on industrial land use efficiency (ILUE) is illuminated by super-efficient slacks-based measure (SBM) model including desirable and undesirable outputs. The results show that: 1) The overall level of the ILUE in China's 270 prefecture-level cities was relatively low, which increase and decrease with the years. 2) China's MRIL plays a positive role in the ILUE, but the impact is low. 3) The effect of MRIL on ILUE varies regionally, namely higher economic development and higher the effect, and the vice versa. We suggest both the central and local governments should target policy reform regarding the land market development and regional economic development. The research will contribute to ongoing market oriented and economic reform both in China and the transitional economies worldwide.

Keywords: industrial land transfer, marketization of industrial land, industrial land use efficiency, SBM model, desirable and undesirable output

1 INTRODUCTION

China is a newly industrialized country (Madelene and Chen, 2006). Since the founding of the People's Republic of China, in order to promote the process of industrialization and continuously narrow the gap with developed countries (Madelene and Chen, 2006; Bai et al., 2014), China has been implementing a catch-up industrialization development strategy. Due to long-term implementation of a planned economic system, China's industrialization process has been advancing for a long time under closed conditions where marketization is backward (Hsieh and Klenow, 2009). After the reform and opening up, China's economy has developed rapidly under the impetus of marketization, the process of industrialization has also accelerated and great achievements have been made (Madelene and Chen, 2006; Bai et al., 2014; Guo et al., 2016). China's industrialization has entered a stage of rapid development and has successfully transformed from a large agricultural country to an industrial one (Choy et al., 2013; Huang, 2013; Wu et al., 2014; Wang et al., 2019). However, with the rapid development of industrialization, the amount of industrial land in China has increased rapidly. In 2016, China's urban industrial land area reached 10,250.60 square kilometers (Huang et al., 2020), an increase of 5,409.06 square kilometers compared with 2000 (Gao et al., 2013). For a long time, China's industrialization process has been driven by a large amount of industrial land investment (Hamblin, 2009; Wu et al., 2014; Zhang et al., 2017). The extensive development model leads to problems such as disorderly utilization, idle waste, and low plot ratio of industrial land (George and Samuel, 2003; Li and Dewan, 2017). As a result, the industrial land use efficiency (ILUE) is low, and the average output value of industrial land still has a large gap with developed countries (Hsieh and Klenow, 2009). Some scholars predict that China will fully realize industrialization in 2030 (Huang et al., 2016), and the level of urbanization will reach 70% (Zou et al., 2014). At that time, the demand for urban industrial land in China will become more tense and the contradictions between people and land will become more prominent (Wang and Scott, 2008; Deng et al., 2010). Therefore, in the context of a large population, scarce land resources, and the rapid development of urbanization and industrialization, how to optimize the use of urban industrial land, and improve the ILUE has become a major problem that the Chinese government needs to solve urgently (Meng et al., 2008; Kropp and Lein, 2012; Liu et al., 2018a; Bao et al., 2019; Huang et al., 2020). In order to solve this problem, and realize the efficient allocation of industrial land resources, Chinese government has formulated a series of land policy reforms (Edmonds, 1986; Ding, 2003; Liu et al., 2014; Li et al., 2017; Tu et al., 2017). It is the market-oriented reform of industrial land (MRIL) that has received widespread attention.

Before 2007, China's industrial land was supplied through transfers or agreement transfers, and this transfer method allowed local governments absolutely monopoly on industrial land prices (Ge et al., 2018). Low price for land transfers without a market competition mechanism became the main means of competition for investment promotion among areas. Local governments compete with each other to lower the land price for investment promotion (Needham et al., 2013; Zhang et al., 2017a), a large number of industrial land is sold at very low prices, resulting in extensive utilization of industrial land (Zhang et al., 2017b; Ge et al., 2018). The excessively low price of industrial land encourages the phenomenon of extensive land use by enterprises, and resulting in low ILUE. In order to change the utilization of industrial land, Chinese government issued the Notice of the State Council on Issues related to Strengthening Land Regulation and Control, which requires that China's industrial land must be sold by bidding, auction and listing (BAL) from 2007 (Friedrich and Nam, 2013; Tu et al., 2014; Liu et al., 2015; Ge et al., 2018). It also stipulates the minimum land transfer price standard, hoping that under the market mechanism, industrial land value will become apparently to improve the ILUE. This policy was put into effect nationwide at the end of 2006, and China's MRIL officially kicked off. So, can the MRIL formulated by the Chinese government really improve China's ILUE (Zhao et al., 2016a; Zhao et al., 2016b).

The existing literature on ILUE is diversified, mainly including ILUE evaluation methods, ILUE regional differences, and factors affecting ILUE (Choy et al., 2013; Xie and Wang, 2015; Arabsheibani et al., 2016; Vandermeer and Halleux, 2017; Ge et al., 2018; Jin et al., 2018; Dong et al., 2020). Early market-related reforms related to land focused on whether the market price mechanism can maximize the rational allocation of land resources (Lopez et al., 1994; Hanink and Cromley, 1998; Messner, 2008), it was not until the research of Haque and Asami (2014) provided empirical evidence for the allocation of land elements that the market price mechanism has gradually become main means of allocating land resources in most countries in the world (Dowall, 1993). Most of the current research on market-oriented reform is its impact on local fiscal revenue and economic development. Researches that combine market-oriented reforms with ILUE are mainly carried out from the following aspects: First, from the perspective of industrial resource allocation, the market-oriented reform is connected with the production efficiency of industrial enterprises. The market-oriented reform changes the resource allocation of land production factors by adjusting industrial land price, that is to use the market and price mechanism to optimize the allocation of capital and labor factors to affect ILUE (Hsieh and Klenow, 2009; Li et al., 2016, Lin and Ben, 2009; Shao et al., 2013; Zhang et al., 2017). The second aspect is in terms of the scale of industrial production. Market-oriented reform affect the ILUE by increasing land prices, restricting the entry of low-efficiency enterprises, promoting the agglomeration of high-efficiency industries, and promoting the scale of production (Adams et al., 1993; Lin and Ben, 2009; Choy et al., 2013; Liu et al., 2015; Liu et al., 2018b; Ustaoglu et al., 2020). The third point from the perspective of upgrading industrial structure. Market-oriented reforms change the input and output of industrial

enterprises through industrial structure optimization, and influence the ILUE through the use of industrial structure adjustment, transformation, and upgrades (Dowall, 1993; Huang et al., 2017; Tu et al., 2017; Yang and Li, 2018; Zhang et al., 2018; Zheng and Shi, 2018; Shu and Xiong, 2019). In addition, government policies related to land marketization reforms, such as land financing, land property rights and new urbanization construction, as well as the government's annual industrial land supply policies all have an impact on the ILUE. (Meng et al., 2008; Choy et al., 2013; Gao et al., 2014; Lei and Gong, 2014; Tu et al., 2014; Guo et al., 2016; Albouy and Ehrlich, 2018; Zhang et al., 2019; Ustaoglu et al., 2020). On this basis, some scholars have studied the regional heterogeneity of the impact of marketization reform on ILUE, this type of research studies the impact of the "land finance" formed by different transfer methods of local governments on the allocation of land resources during market reform, and the difference in ILUE caused by the impact of low land price competition on urban economic growth (Tao et al., 2007; Buera et al., 2011; Xiong and Guo, 2013; Guo and Xiong, 2014; Zou et al., 2014; Zhang and Wu, 2017; Chen et al., 2019; Wang et al., 2019). For example, Zhao et al. (2016) used provincial panels to calculate the impact of market-oriented reform on ILUE without undesired output. The results show that there are regional differences. In summary, the current research on the relationship between the market-oriented reform and the ILUE is very scarce, some have only collected provincial-level research data, and no scholar has used industrial land data covering the national prefecture-level cities to study the impact of MRIL on ILUE, this makes prefecture-level city governments lack a practical theoretical basis in formulating feasible policies. What's more, most of the existing researches on ILUE measurement did not include undesired output, the efficiency measurement results are higher than the actual, and the results are not objective. In order to fill the above gaps and check whether the MRIL formulated by the Chinese government really improve China's ILUE, this paper tests the MIL based on the industrial land transfer data of 270 prefecture-level cities in China from 2007 to 2019, and uses the SBM model with undesired output to measure the ILUE. In this way, we can comprehensively and systematically study the impact of China's MRIL process on ILUE, and obtain effective result. We attempt to examine the specific impact of MRIL on ILUE and provide a reference for other countries in the world that are developing in a transitional period to save land resources and achieve sustainable development.

The structure of this paper is as follows: The second part briefly introduces the background of this paper, the characteristics of China's land marketization, and discusses the impact of MRIL on ILUE. The third part conducts an empirical analysis on the measurement method of MRIL, the measurement model of ILUE, and the measurement model of the impact of MRIL on ILUE. In the fourth part, based on the above-mentioned measurement models, we choose mainland China and its eastern area, central area, and western area as samples and analyze the specific impacts of the MRIL on ILUE. The last part provides the conclusion of the study, and puts forward policy suggestions for the improvement of MRIL and ILUE in the future in China.

2 BACKGROUND AND HYPOTHESES

2.1 Background

2.1.1 Characteristics and Process of Land Marketization in China

At present, China's land market is divided into the primary land markets and secondary markets (Qian and Mou, 2012; Kok et al., 2014; Chen et al., 2015). Among them, the transfer of state-owned land use rights is considered the first allocation of urban land. It is a land use right transaction between the government and land users. It is called the primary market for land use rights. In the primary land market, the Chinese government transfers state-owned land use rights through administrative allocations, agreements, leases, BAL, or other methods. The market for land transaction activities such as leasing of land use rights among land users is considered to be the re-allocation of land after the primary land market, and is called the secondary land market (Qian and Mou, 2012). The biggest feature of the primary land market is the government's complete control land supply. In contrast, the secondary land market is closer to a complete market in economics (Tan et al., 2008). The industrial land market covered in this paper is limited to the primary land market mentioned above. Moreover, this study defines the MRIL as the optimization of industrial land transfer methods in the primary land market (Qian and Mou, 2012). That is, the increase in the proportion of "BAL" transfer methods (Zhao et al., 2016; Zhang et al., 2017).

China's land market appeared relatively late, and its development has not been long enough (Liu et al., 2016). After the reform and opening up in the 1980s, the planned economy was gradually transformed into a market one (Tan et al., 2008; Qian and Mou, 2012). The introduction of market mechanisms was used to optimize the allocation of land resources, and land marketization gradually developed. In 1987, Shenzhen's first transfer of state-owned land use rights by way of bidding and auction marked the formal entry of the Chinese land market into a market-oriented stage.

The MRIL in China has been slow. Before 2004, China's industrial land was basically supplied in the form of allocation or agreement transfer. On 21 October 2004, Chinese government issued the Decision of the State Council on Deepening the Reform and Strict Land Management, which stated the need for gradual implementation of BAL for sale. This is the first time that Chinese government has proposed to implement the BAL policy. On 31 May 2006, Chinese government issued the Specifications for the Use of State-owned Land by BAL (Liu et al., 2015), which required that industrial land with competitive requirements should be sold by BAL and this is a tentative attempt at the BAL policy (Liu et al., 2015). On 31 August 2006, Chinese government issued the Notice on Strengthening Land Regulation and Relevant Issues, which claimed that industrial land with competition requirements should be sold by BAL. The BAL policy was officially promoted. On 23 December 2006, Chinese government issued the National Minimum Standards for the Transfer of Industrial Land, which determined the minimum

control standards for the transfer prices of industrial land use rights in cities and counties (Ge et al., 2018; Zhang et al., 2017). The BAL policy is completely perfect, and MRIL is fully implemented in China In 2009, Chinese government issued the Notice of the Ministry of Supervision on Further Implementing Industrial Land Assignment System (Guo et al., 2016), which requires that the industrial land assignment system be further improved to improve utilization efficiency from a market perspective (Tu et al., 2017).

2.2 Theoretical Framework and Hypothesis

The main body of resource allocation is related to the efficiency and fairness of resource allocation (Zhao et al., 2016). As a provider of industrial land, local governments' actions will affect the status of land circulation and resource allocation (Tu et al., 2017). The driving force for the allocation of market resources comes from the self-interested behavior of enterprises in pursuit of profit maximization. From the perspective of industrial land demand, it comes from land users. According to China's national conditions, we analyze how market-oriented reforms affect the efficiency of China's industrial land use from the two levels of local government and land users.

As shown in **Figure 1** below, during the planned economy period, urban land was also included in the orbit of the planned economy. The administrative allocation system for free use has resulted in low land prices. In China, the main driving force of regional economic growth is investment by local governments. The reform of the tax-sharing system redefines the allocation of financial resources between the central and local governments, and the growth of gross domestic product (GDP) has become the main basis for local government performance evaluation, which has promoted competition among local governments. Under tremendous financial pressure, local governments have adopted various methods to expand public expenditures to promote economic growth. The most direct way is to provide cheap land, labor and various preferential policies, reduce the prices of production factors, attract enterprises to enter, and help capital inflow. Land circulation system before the land market reform provided tools and conditions for this. According to China's current legal system, local government is the only supplier in the land transfer process. In order to promote regional economic development, local governments use low-cost or even free transfer of industrial land to attract investment and set up industrial parks or development zones in remote areas of the city. A large amount of industrial land has been extensively used. The allocation of industrial land resources is seriously unreasonable, and development model of relying on land element input has resulted in low ILUE. On the other hand, in order to obtain maximum land use benefits, industrial land users use a large amount of cheap industrial land to replace advanced production factors such as capital and technology that require high production costs. The low purchase cost leads to a large amount of low-cost industrial land being put into industrial production, while the backward production technology makes the land yield so low. This extensive production mode of high input and low output makes the ILUE low. With the advancement of market-oriented reforms, price mechanisms have been introduced into land transactions. The market-oriented reforms of industrial land stipulate the minimum standard for the transfer price of industrial land use rights. This measure has improved the transparency of local government land transfers and reduced the transfer of low-cost land such as allocation. The local government's reliance on selling land at low prices to attract foreign investment was restricted, and the land finance phenomenon was reduced.

From the perspective of local government, In the process of land marketization, the advanced production technology brought by foreign investment has promoted industrial production technology and management innovation, improved production conditions, and promoted the development of productivity. Advanced production model brought by foreign investment has gradually changed the extensive production model that local governments used to rely on a large amount of land element inputs. The reform of land marketization has changed the development model of "land development" that local governments used to rely on land finance to stimulate the economy, and improved the use of industrial land. On one hand, market-oriented reforms have vigorously promoted the development of local economy. With the development of economy, advanced production technology has driven the free flow of production factors and the adjustment of industrial structure, which is conducive to broadening the scope of spatial flow of factors such as capital and labor, intensifying the diffusion of advanced knowledge and information, and strengthening technology spillovers between industries and improve the ILUE. On another hand, changes in the amount of land brought by advanced technology, and the continuous upgrading of land use structures such as functional conversion and spatial reconstruction will further improve the ILUE. From the perspective of industrial enterprises, the impact of land marketization reform on ILUE is reflected in the effect of factor reallocation among enterprises and the effect of factor substitution within enterprises (Zhao et al., 2016). On one hand, the scarcity of land resources will be further highlighted in the process of land marketization reform, and the limited land resources can only be sold to enterprises with more efficient production at high prices, some traditional enterprises with extensive land use and low added value have been squeezed out of the local market. The surrounding areas interact with the local market by undertaking locally transferred industries. This process allows the land with better location advantages to be allocated to enterprises with higher marginal output, factors of production gradually flow from marginally low-efficiency sectors to marginally high-productivity sectors, and industries with weak competitive are gradually replaced, the surrounding areas will be affected by the spillover of local knowledge and technology, which will accelerate the adjustment of industrial structure. The trend of rationalization of industrial structure is becoming more and more obvious,

which is helpful for the intensive use of industrial land and improving the ILUE. On the other hand, the production factors of industrial enterprises include land, capital, labor and technology. Changes in each factor of production will cause changes in other factors. With the increase of land prices, in order to save production costs, industrial enterprises replace the original land input by increasing the input of non-land elements. Enterprises adjust the ratio of factor input, increase capital, manpower, technology and other factors to replace industrial land investment, reduce dependence on industrial land, and produce factor substitution effects. Production factors such as land and labor are gradually replaced by advanced technology and capital, industrial enterprises have improved the ILUE while keeping output unchanged. In addition, a series of measures taken by industrial enterprises to reduce land production costs, including optimizing land use structure, increasing labor capital concentration and infrastructure investment, promoting industrial scale upgrading and structural transformation. These measures will also promote the intensive use of industrial land and raise ILUE. The above changes in production methods optimize resource allocation, increase industrial land output while reducing industrial land input and improve ILUE. Based on the above analysis, this article proposes hypothesis 1:

Hypothesis 1. In the process of China's market-oriented reform, local governments and land users changed the ILUE by changing development method and land use method.

China has a vast territory, and there are obvious differences between developed and underdeveloped regions in terms of resource endowment, social and economic conditions, industrial structure, and factors of industrial production. The land marketization reform is constrained by various factors such as economic factors, social factors, natural environment factors, political, legal environment factors, cultural environment factors, social psychological environment factors and other factors in different regions, resulting in a regional "Matthew effect".

As shown in **Figure 2** below, in the process of promoting land marketization reform, developed regions with higher economic development level can provide better public facilities, more efficient financial and information services, and form better location advantages. In particular, the good railway network in developed areas and the improvement of urban rail transit bring value-added utility to the surrounding land, which can further strengthen the element substitution mechanism brought by the land marketization reform, and strengthen the impact of the land marketization reform on ILUE. At the same time, foreign investment brought by the promotion of land marketization will give priority to supply, allocation and inclination to developed regions with large market demand potential, strong industrial foundation and significant scale benefits. The advanced technology and management innovation brought by foreign capital have promoted the efficient production of enterprises, and the desirable output of industrial enterprises has increased. Undesirable outputs (industrial waste water emissions, industrial sulfur dioxide emissions, and industrial smoke and dust emissions) in industrial production processes are correspondingly reduced. In the process of industrial production, desirable output increases and undesirable output decreases, the resources are optimally allocated, and the ILUE can be significantly improved.

In contrast, the situation is reversed in underdeveloped regions. Foreign capital brought by land marketization is less invested in backward areas with poor infrastructure, lower returns and higher risks. Due to the lack of advanced foreign investment and low production technology, industrial production is mostly labor-intensive polluting enterprises. Small enterprises with serious pollution produce more undesirable output and less desirable output in the industrial production process, and there is little room for ILUE to improve. At the same time, the socio-economic conditions, industrial structure, and factors of industrial production in undeveloped area areas are at a disadvantage. Due to the poor external environment, a series of chain effects brought about by the land marketization reform have not been brought into play, and the effect of resource reallocation and factor substitution mechanism has been weakened, making it difficult to convert into advanced productivity. The effect of land marketization reform on ILUE is not as good as in developed areas. Based on the above analysis, this paper proposes a second research hypothesis:

Hypothesis 2. The ILUE in different regions is affected to varying degrees by the MRIL.

3 DATA AND METHODOLOGY

3.1 Research Area and Data

3.1.1 Research Area

Through data matching, after removing missing and singular values, 270 prefecture-level cities covering 30 province-level administrative regions in China were finally selected as the study area. At the same time, in order to study regional differences, eastern, central, and western areas were selected.

3.1.2 Data

The Ministry of Land and Resources of China stipulates that from 1 August 2006, the land administration department of the Chinese city and county government must publish the prior transfer plan for each state-owned land use right, and announcing the results of the transfer of land on the China Land Market Website (http://www.landChina.com/). The calculated data of the industrial land marketization rate in this paper is the data of industrial land transactions in the "Results Disclosure" column of the land transfer of China Land Market Network (Zhao et al., 2016; Zhou L. et al., 2019). The results include fields such as the local government, geographical location, land supply method and corresponding land supply area, transaction value, transfer

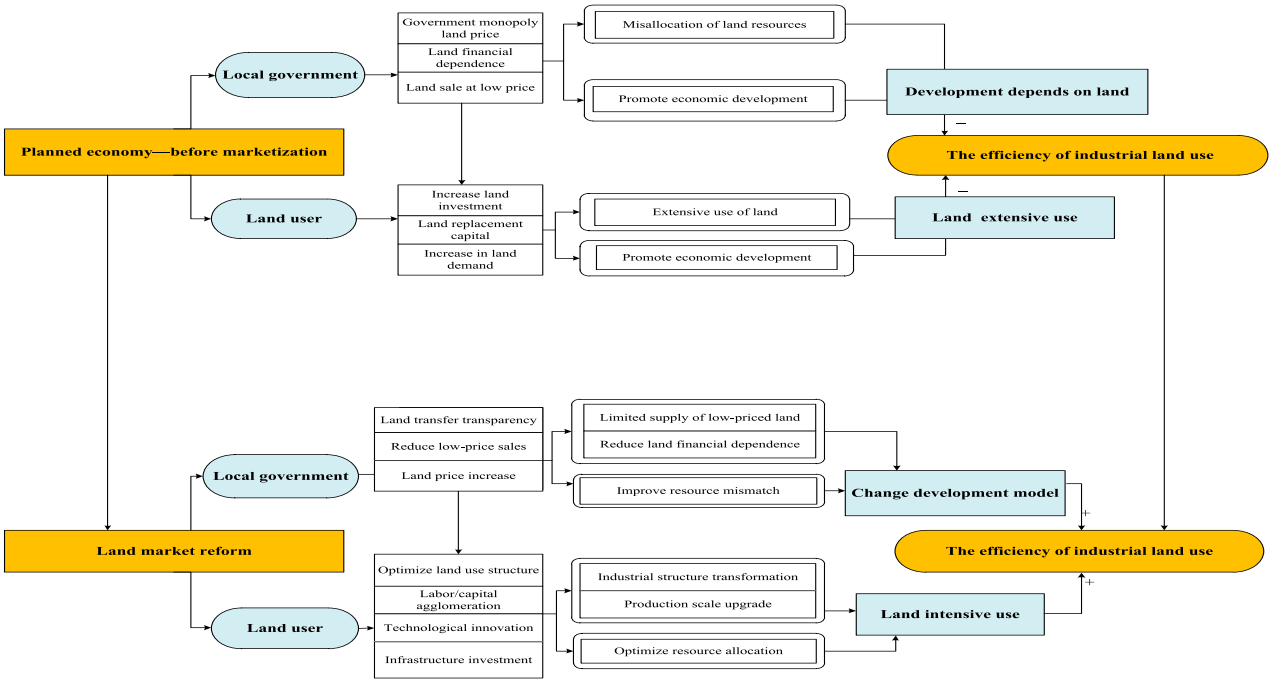

FIGURE 1 | Theoretical framework of impact of marketization process on the ILUE.

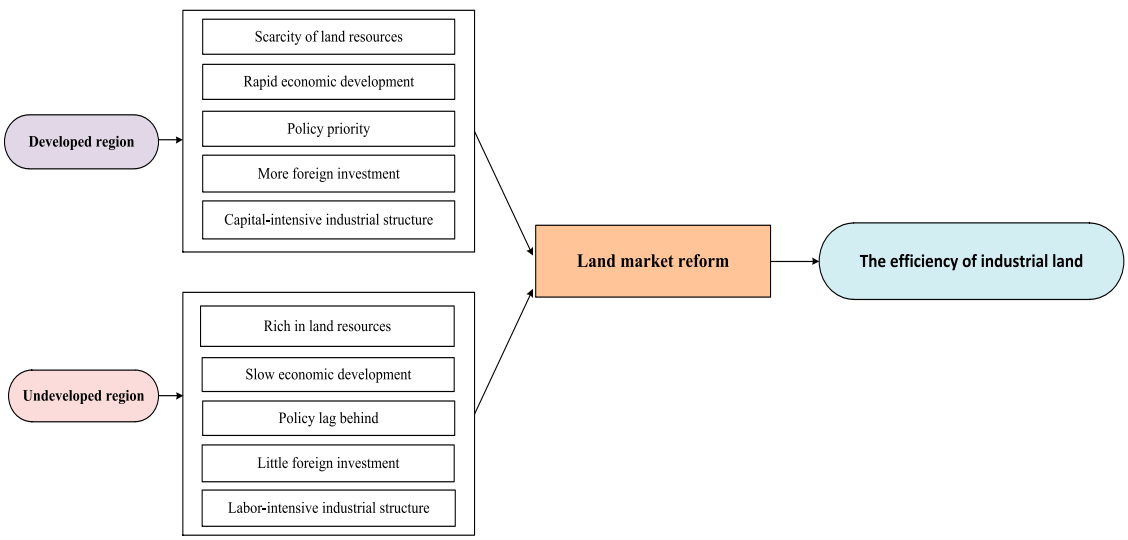

FIGURE 2 | Theoretical framework of MRIL affecting the ILUE in different regions to different degrees.

time and estimated completion time for each land. The data covers industrial land transfers in 288 prefecture-level cities in China. After excluding duplicate and obviously wrong entries, the data totaled 627,000. The industrial land efficiency measurement data and regression equation panel data used in the research are from China Land Market Network and China Urban Statistical Yearbook (Ge et al., 2018; Zhao et al., 2018).

3.2 Methodology

3.2.1 Market-Oriented Reform of Industrial Land Supply Measurement Method

China's current industrial land transfer includes bidding, auction, listing, allocation, agreement and other methods. According to the market-oriented reform of industrial land, the three methods of bidding, auction and listing (BAL) are based on the market-oriented reform of industrial land and

FIGURE 3 | China's industrial land transfer and MIL change. Unit (hectare).

conducted according to the market mechanism. However, several methods such as allocation and agreement are not carried out according to the market mechanism. According to this feature, scholars have constructed a method for measuring MRIL. Those study defines the MRIL as the optimization of land transfer methods in the primary land market (Qian and Mou, 2012). That is, the increase in the proportion of "BAL" transfer methods (Zhao et al., 2016; Zhang et al., 2017)This paper refers to previous research and uses the MIL to indicate the degree of MRIL. Based on the analysis of China's land market structure, the static market structure is used to determine the level of marketization of urban land (Zhao et al., 2012; Zhang et al., 2017). The area proportion measurement method is adopted. The "market area for BAL divided by total area for sale" is used as the measurement standard for the degree of MIL. Refer to the calculation formula of Zhang et al. (2017):

$$MIL = \frac{GTB_a + GTAU_a + GTL_a}{AL_a + GTAG_a + GTB_a + GTAU_a + GTL_a + LE_a + OLSW_a}$$

In the formula, MIL is the marketization rate of industrial land; a is the area; *GTB* is the bid transfer; *GTAU i*s the auction transfer; *GTL* is the listed transfer; *AL* is the transfer; *GTAG* is the transfer of the agreement; *LE* is the lease; OLSW is another way of supplying land, That is, the numerator is the sum of the transferred area of industrial land for BAL, and the denominator is the total area of industrial land transferred (Wu and Qu, 2007; Zhang et al., 2017).

3.2.2 Calculation Method of Industrial Land use Efficiency: Slacks-Based Measure Model Based on Data Envelopment Analysis

The traditional Data Envelopment Analysis (DEA)method directly evaluates the efficiency of the decision-making unit because it does not take into account the slack variables of the input elements of the decision-making unit (Zhao et al., 2014). The measurement results are likely to be biased. To solve this problem, Tone (2001) designed non-radial and non-angle SBM models (Slack-Based Measure, SBM) based on slack variable measures. Putting variables into the objective function solves the above problems well. As a non-parametric method, SBM does not need to set the optimal behavior target of the producer, it does not need to make assumptions on the overall parameters and special assumptions on the form of the production function. The result is better stability. Base on the above analysis, this paper selects the SBM model containing undesired output built on the basis of tone by Zhao et al. (2014), the formula is as follows:

$$\rho = \min \frac{1 - \frac{1}{N}\sum_{n=1}^{N} \frac{s_n^x}{x_{k'n}^{t'}}}{1 + \frac{1}{M+I}\left(\sum_{m=1}^{M} \frac{s_m^y}{y_{k'm}^{t'}} + \sum_{i=1}^{I} \frac{s_i^b}{b_{k'i}^{t'}}\right)}$$

$$\begin{cases} \sum_{t=1}^{T}\sum_{k=1}^{K} z_k^t x_{kn}^t + s_n^x = x_{k'n}^{t'}, n = 1, \ldots, N, \sum_{t=1}^{T}\sum_{k=1}^{K} z_k^t y_{km}^t - s_m^y = y_{k'm}^{t'}, m = 1, \ldots, M \\ \sum_{t=1}^{T}\sum_{k=1}^{K} z_k^t b_{ki}^t + s_i^b = b_{k'i}^{t'}, i = 1, \ldots, I \\ z_k^t \geq 0, s_n^x \geq 0, s_m^y \geq 0, s_i^b \geq 0, k = 1, \ldots, K \end{cases}$$

In the formula, ρ is the efficiency value to be calculated, and N, M, I is the number of inputs, desired outputs, and undesired outputs. $(\boldsymbol{s_n^x}, \boldsymbol{s_m^y}, \boldsymbol{s_i^b})$ represents the input-output relaxation vector, $(x_{k'n}^t, y_{k'm}^t, b_{k'i}^t)$ Is the input-output value of the k' production unit in the t' period. z'_k represents the weight of the decision unit. Objective function ρ strictly decreases with respect to s_n^x, s_m^y, s_i^b.

3.2.3 Panel Data Measurement Model for the Impact of MRIL on the Industrial Land use Efficiency

$$Y_{st} = \alpha_0 + \alpha_1 MIL_{st} + \sum \beta C_{st} + \mu_{st}$$

In the formula, Y_{st} represents the ILUE in period t in region s, and MIL_{st} represents the MIL in period t in region s. In addition, other control variables C_{st} that affect the ILUE in this paper introduced, and μ_{st} represents a random error term. α and β are the parameters to be estimated (Zhao et al., 2016).

3.3 Variable Selection

3.3.1 Input-Output Indicators for the Industrial Land use Efficiency Evaluation

Based on previous studies (Zhang et al., 2009; Yang et al., 2014; Zhang et al., 2017; Ge et al., 2018; Huang et al., 2020), this paper selects the input-output indicators for the ILUE measurement as follows:

Input: the area of industrial land (IL), the number of employees in the secondary industry (ESI), and investment in industrial fixed assets (IFA).

Output: The output includes desired output value and undesired output value. The desired output value is the total industrial output value of the city (IOV), and the undesired output value is three waste emissions from the industrial land use in the city, which are industrial wastewater discharge (IWD), industrial sulfur dioxide discharge (ISD), and industrial smoke and dust emissions (ISDE).

3.3.2 Measurement Index of Marketization Rate of Industrial Land

Referring to the study of Zhang et al. (2017), we use the data of each industrial land transfer in the city as the measurement index of MIL. The data including bidding, auction and listing, agreement and other transfer methods The transfer time is selected from 1 January 2007 to 31 December 2019.

3.3.3 Control Variables

This paper selects five control variables: per capita GDP(PCG), secondary industry structure ratio (SIS), foreign direct investment (FDI), the population density (TPD) and number of industrial enterprises (NIE) (Feinberg and Majumdar, 2001; Cheung and Ping, 2004; Zhao et al., 2016; Ge et al., 2018; Huang et al., 2020). PCG represents the level of economic development in a region (Wang et al., 2007). Regions with relatively higher levels of economic development will pay more attention to the quality of industrial economic development, and high-quality industrial economic development usually requires higher land use efficiency. The change in the ratio of the secondary industry to GDP(SIS) represents the government's adjustment of the industrial structure. We use it to represent the role of local governments in ILUE changes, and the number of industrial enterprises represents the behavior of industrial enterprises (Wang et al., 2007). After FDI enters the Chinese industrial market, it may stimulate the vitality of the local market, and then promote the transformation of the industrial industry's development mode and improve the ILUE. Changes in population density will also have an impact on ILUE. PCG variable have been processed with logarithm. All variables are described in **Table 1** below.

3.3.4 Variable description

4 RESULTS

4.1 Marketization Rate of Industrial Land Change

Based on data calculations, MIL in the 270 prefecture-level cities in this study is shown in the following figure. As shown in the **Figure 3** the total area of new industrial land transfer in China from 2007 to 2019 was a N-shape, The same is true for the changes of the area of industrial land sold through "bid, auction and listing". From 2007 to 2011, the total area of new industrial land increased year by year, after 2012, the total area of new industrial land transfer began to decrease year by year. The MIL was 0.397 in 2007 and 0.959 in 2019, and the overall trend increase and decrease with the years. From 2012 to 2019, there is a U-shaped change.

At the regional level, as shown in the **Figure 4** below, the MIL in the eastern, central, and western areas were 0.30, 0.38, 0.50 in 2007, 0.99, 0.94, and 0.94 in 2019, respectively. The level of MIL was stable after 2017. It does not change much with the year.

4.2 Industrial Land use Efficiency Change

According to the SBM model calculation, as shown in **Figure 5** below, the overall level of the ILUE in China's 270 prefecture-level cities from 2007 to 2019 was relatively low. The ILUE in 2007 was 0.49 and 2019 was 0.39, which is increase and decrease with the years. Among them, the highest ILUE use was 2013, which was only 0.64, and there is still a certain gap with the level of developed countries. In addition, there is a large gap in ILUE in different regions. The ILUE in developed areas is significantly higher than in undeveloped areas. The ILUE in developed cities such as Beijing is estimated to be 1, while the efficiency in remote and backward urban areas is as low as 0.043.

At the regional level, China's ILUE is significantly different, this is consistent with the findings of Zhao et al. (2016). In 2007, the ILUE in the eastern, central and western areas was 0.55, 0.46, and 0.44, respectively. The eastern area was higher than the national average, and the central and western areas were low. To the national average. In 2019, the ILUE in the eastern, central and western areas was 0.46, 0.40, and 0.31, respectively. From 2007 to 2019, the highest and lowest values of ILUE were 0.69 in 2013 in the western area and 0.44 in 2007 in the western area, it shows that at the regional level, the ILUE in the western area has the largest change. The maximum ILUE in three areas all appeared in 2013. It can be seen that the ILUE at the regional level has increased and decreased with time, and the overall improvement in the ILUE has been small.

4.3 Regression Results for the Impacts of MRIL on the Industrial Land use Efficiency

According to the panel model test results, there is no multicollinearity among independent variables. The Hausman test results rejected the random effects model, this paper chooses a fixed effect model for model estimation. That is, models 1, 3, 5, and 7 are the test results of this paper (Zhao et al., 2016; Zhang et al., 2019).

As shown in **Table 2** above, at the national level, the MIL in China has a significant impact on ILUE. The result is positively correlated, indicating that the degree of MIL has a positive effect on improving the ILUE, that means MRIL by Chinese government can improve ILUE. This is consistent with our hypothesis 1. However, it can be seen from the regression coefficients that the MIL has little effect on ILUE, which indicates that China's industrial land market system is still not perfect, and changes in the resource allocation mechanism brought by the MRIL have not been reasonably translated into

TABLE 1 | Statistical description of the selected variables.

Variable	Obs.	Unit	Max	Min	Mean	Std. dev
IL	3,510	Hectare	4406.356	0.539	418.917	446.234
ESI	3,510	10^4 person/hectare	429.13	0.38	25.44	36.345
IFA	3,510	10^8yuan/hectare	17245.76	0	1210.518	1423.942
IOV	3,510	10^8 yuan	32445.15	5.293	2883.219	4170.763
IWD	3,510	10^4 ton	262,000	0	10028.33	24281.61
ISD	3,510	10^4 ton	315.382	0	8.766	17.928
ISDE	3,510	10^4 ton	595.182	0	4.431	19.86
ILUE	3,510	/	1	0.043	0.512	0.29
MIL	3,510	/	1	0	0.862	0.230
PCG	3,510	10^4/person	640.176	0.01	4.730	11.267
SIS	3,510	%	90.97	10.68	47.783	11.050
TPD	3,510	Person/km^2	2978.11	4.82	525.030	357.534
NIE	3,510	Company	18,792	0	1308.455	1725.903
FDI	3,510	10^8dollar	308.256	0	8.681	20.766

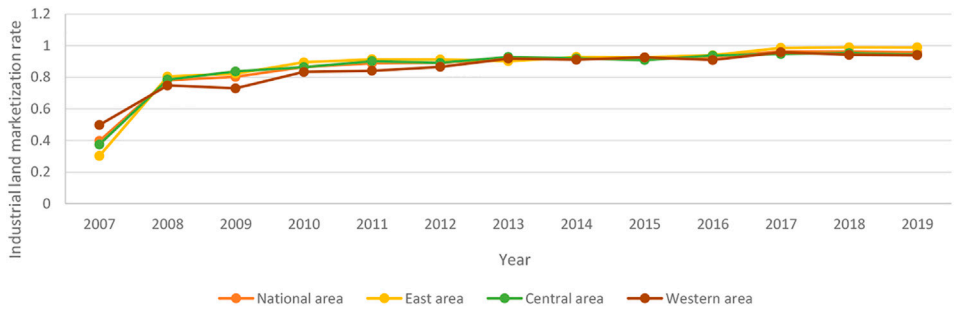

FIGURE 4 | Changes in the MIL in the three major areas of China.

driving force to improve resource utilization efficiency (Zhao et al., 2016). Among the five control variables, SIS, TPD and NIE are significant, indicating that they play a role in the ILUE. The estimated value of the coefficient of three control variables are positive, indicating that they all promote the ILUE. The regression of the SIS to the ILUE is positively correlated, indicating that the larger the SIS, the higher the ILUE. TPD has a positive impact on ILUE, we analyze this because the larger the TPD, the higher the demand for land, which will promote the intensive use of land and increase ILUE. NIE is also a positive effect, because the more NIE, the more intense the competition among industrial enterprises, this will promote the intensive use

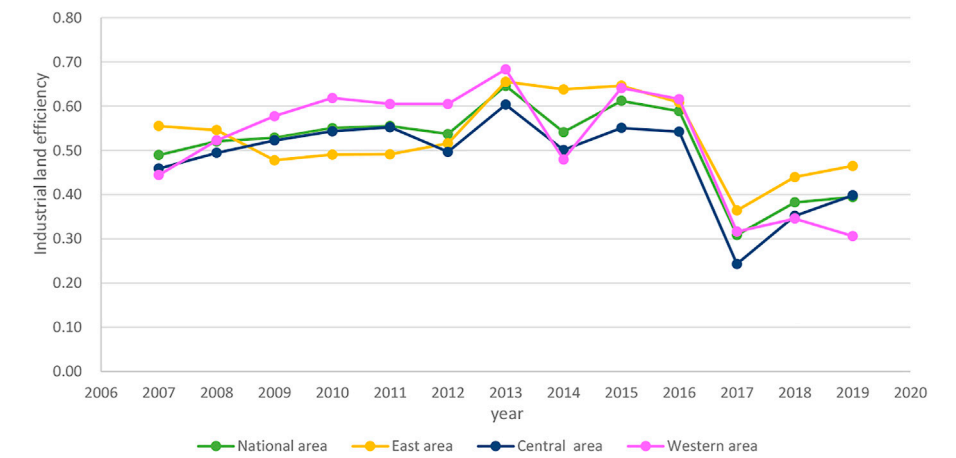

FIGURE 5 | The average change of urban ILUE in China.

TABLE 2 | Impacts of MRIL on the ILUE.

Explained variable: Industrial land use efficiency								
Explanatory variables	**Overall area**		**East area**		**Central area**		**West area**	
—	Model1	Model2	Model3	Model4	Model5	Model6	Model7	Model8
Industrial land marketization rate (MIL)	0.051*** (2.91)	0.030* (1.73)	−0.040 (−1.24)	−0.067** (−2.12)	0.103*** (3.69)	0.091*** (3.29)	0.083** (2.45)	0.069** (2.05)
GDP per capita (PCG)	0.001 (−0.12)	0.001 (−0.23)	0.002 (0.61)	0.001 (0.09)	−0.021*** (−5.05)	−0.016*** (−4.03)	0.001 (0.26)	0.001 (0.11)
The ratio of secondary industry to GDP(SIS)	0.007*** (9.92)	0.007*** (10.84)	−0.002 (−1.11)	0.001 (−0.32)	0.008*** (7.89)	0.007*** (8.13)	0.010*** (7.65)	0.009*** (7.96)
The population density (TPD)	0.001*** (−8.29)	0.001*** (−7.65)	0.001*** (−5.32)	0.001*** (−2.89)	0.001* (−1.65)	0.001*** (−3.94)	0.001*** (−6.03)	0.001*** (−6.38)
Number of industrial enterprises (NIE)	0.001*** (−2.93)	0.001 (−0.96)	0.001 (−0.27)	0.001 (−0.02)	0.001 (1.09)	0.001 (1.09)	0.001 (−1.61)	0.001 (−0.78)
Foreign direct investment (FDI)	0.001 (1.46)	0.001*** (3.51)	0.002*** (3.76)	0.002*** (4.38)	0.001 (1.16)	0.001 (1.31)	−0.002*** (−2.61)	−0.001 (−1.14)
Constant	0.266*** (5.81)	0.260*** (6.70)	0.789*** (7.99)	0.652*** (7.85)	0.117* (1.83)	0.196*** (3.54)	0.114 (1.38)	0.181*** (2.64)
R	0.088	0.020	0.045	0.006	0.123	0.047	0.180	0.065

Note *** p < *0.01*, ** p < *0.05*, * p < *0.1*.

of land and increase ILUE. These are in line with China's current development and prove the reliability of the research results.

At the regional level, the impact of land market-oriented reforms on ILUE varies significantly, which is consistent with our research hypothesis 2. The MIL in the central and western areas has a significant effect on improving the ILUE and has a positive correlationIn the eastern area the result did not pass the significance test and were not statistically significant. We consider that this is due to the unreasonable intervention of the local government in the transfer market. Although the market-oriented reform of industrial land is easy to carry out market-oriented operations from the legal framework, the information asymmetry between the upper and lower governments and lack a relative reward and punishment mechanism. Local governments still have a strong desire to intervene in the transfer of industrial land due to short-term political achievements and competitive investment incentives. Such improper intervention in the land market distorts the market operation mechanism and reduces the efficiency of resource allocation, the effect of re-allocation of factors among departments and the substitution of factors within enterprises will decrease. This will result in a loss of efficiency in the ability of the market mechanism to allocate industrial land resources. The regression coefficient in the central area is greater than that in the western area, it indicating that MIL has a greater impact on ILUE in central area than economically backward western regions, this is for the reason that since the reform and opening up, China's various policies have basically adopted a model of gradual expansion from the coast to the inland, and the same is true of the promotion of land marketization reform. The economically developed regions took the lead in implementing the opening-up and market economy system. At the same time, as analyzed above, Matthew effect formed by the land marketization reform makes the land marketization reform in the developed central regions have a greater impact on ILUE than in the undeveloped western regions. the geographical advantages of developed regions have strengthened the chain effect brought about by the land marketization reform. It is also related to the differences in the reform demands of different regions for land marketization. On the one hand, the central region is relatively more developed than the western region, and the resource endowment of the developed regions is relatively scarcer. The more economically developed regions, the greater the competitive pressure they face. Under the pressure of competition, in order to obtain excess profits, central region relies on marketization process to accelerate the promotion of scientific and technological research, and promote industrial transformation and upgrading. The central region is more motivated to improve resource allocation through land market reform than the western region and the reform will be promoted faster. Those will lead to a higher degree of impact of the market-oriented reform on ILUE.

Among the controlled variables, the results of TPD's impact on the three regions are consistent with the national situation. There are obvious regional differences in the other four control variables. PCG has a negative impact on the central region and will reduce ILUE. The results in the eastern and western regions did not pass the significance test and were not statistically significant. The results of SIS's impact on the central and western regions are consistent with those of the national situation, while NIE's impact on the three regions has not passed the significant test. What's more interesting is FDI. Results are different for each region. The eastern region and the western region are just the opposite, FDI in the eastern region has a positive effect on ILUE, while in the western region has a negative effect. The results for the central region, like the national region, fail the significance test.

5 DISCUSSION

China has experienced a long period of planned economy since the founding of the People's Republic of China. It was not until the advancement of market-oriented reforms after the reform and

opening up that the market economy was gradually established. During the planned economy period, China's industrial economic development was mainly driven by a large number of factor inputs, which consumed a lot of resources. Compared with the planned economy, advanced productivity and technology in the market economy have promoted social development. The intensive mode of low input and high output not only saves production costs, reduces resource consumption, but also reduces pollution emissions and protects the ecological environment. In this study, we tried to construct a theoretical framework to analyze the impact of China's market reforms on the efficiency of industrial land use. We analyzed how local governments and industrial enterprises affect ILUE in the process of marketization, on this basis, we also analyzed the regional differences caused by land market reforms in different regions of China based on the regional characteristics. Our research results can provide some reference for other developing countries that are in a transitional period of economic development like China to save resources and achieve sustainable development. In addition to theoretical innovation, we have also improved in methods. Most of the previous calculations of ILUE did not include undesired output. Our research took this factor into account when measuring the ILUE. The results include industrial undesired output are more objective. However, this paper also has a limitation when measuring the efficiency of industrial land use. Some other industrial undesirable output such as chemical oxygen demand and ammonia nitrogen are not considered, this is mainly due to a lack of data. This can be the direction for future improvement of this research.

6 CONCLUSIONS AND POLICY IMPLICATIONS

6.1 Conclusions

This paper selects 270 prefecture-level cities in China from 2007 to 2019 as the research object, and measures the MIL in each prefecture-level city through MRIL transfer "BAL" policy. We use the SBM model measures the ILUE of each city that contains undesired output, and uses panel data models to conduct an empirical analysis to study whether the MRIL will affect the ILUE. Through calculation, the following conclusions are reached.

The MRIL launched by the Chinese government can optimize the allocation of industrial land resources and improve the ILUE. The MIL was 0.397 in 2007 and 0.959 in 2019, showing an overall upward trend. The level of MIL has been significantly improved and the MRIL has been advanced well.

We can see that the effect of MRIL on ILUE varies regionally, namely higher economic development and higher the effect, and the vice versa. According to the SBM model calculation, the overall level of ILUE in China was relatively low and the regional differences are obvious, the ILUE was 0.49 in 2007 and 0.39 in 2019, which has a lot of room for improvement. There is still a certain gap with the level of developed countries. At present, China's MRIL has played a positive role in promoting ILUE, but the overall effect is relatively weak, it indicates that China's industrial land market system is still not perfect, and the changes in the resource allocation mechanism brought by the MRIL have not been reasonably translated into the driving force to improve resource utilization efficiency (Zhao et al., 2016). We suggest both the central and local governments should target policy reform regarding the land market development and regional economic development.

6.2 Policy Implications

The contradiction between people and land has always been an important limiting factor restricting Chinas economic development (Tan et al., 2008), low land use efficiency is a major problem in China. From 2006 to 2012, the efficiency of building land in most Chinese cities was declining (Chen et al., 2016).

In the context of rapid industrialization, it is of great significance to rationally allocate industrial land resources with a market-oriented mechanism and increase ILUE on limited industrial land resources to achieve the goal of sustainable land resource utilization. Based on the analysis conclusions of the study, this paper proposes the following measures to promote China's MRIL and improve ILUE.

First, Improve the industrial land market system and its operating mechanism to improve the impact of MRIL on ILUE. Because China's land market appeared relatively late and the time for MRIL was relatively short, it took some time to transition from a planned economy to a market economy. According to the research results in this paper, although MIL has a positive correlation with ILUE, the impact is relatively weak. Therefore, the marketization reform of industrial land still needs to be further improved. The government must strictly implement the "BAL" system to reduce the proportion of allocations and transfer agreements. Optimizing the allocation of industrial land resources in an environment of full market competition, reduce idle and waste of industrial land resources, and promote the market-oriented operation of industrial land. In addition, improve the minimum price transfer system for industrial land, determine the price of industrial land through market demand, and promote the efficient use of industrial land.

Second, formulate a differentiated industrial land market mechanism to improve the impact of MRIL on ILUE. This paper finds that the level of MIL in the eastern China is generally higher than the central and western areas. To improve the comprehensive level of land marketization in China, we must increase reform efforts in areas with low land marketization (Qian and Mou, 2012). Based on this, in the process of market-oriented reform of industrial land, Chinese government should formulate a differentiated industrial land market mechanism to allocate industrial land indicators, promote industrial land concentration and optimize industrial structure upgrades. At the same time, increase the implementation of market-oriented reforms in the undeveloped area, and improve supporting measures related to market-oriented reforms.

Third, improve the supervision mechanism of MRIL and improve the ILUE. It is necessary to strengthen the supervision of the local government's industrial land transfer process, improve the "BAL" operating mechanism, and regulate the government's supplier behavior (Zhang et al., 2017). For land use supervision, a dynamic monitoring mechanism should be established to achieve full supervision of industrial land use.

Last but not least, guide enterprise technology innovation and promote industrial energy conservation and environmental protection (Needham et al., 2013). It can be seen from the research that China's reform of land cannot significantly improve China's ILUE. At the same time, Chinese enterprises are accompanied by undesired output from environmental pollution in the production process. Therefore, the Chinese government must continuously improve the industrial production technology and optimize the allocation of production factors to form a sustainable development model.

DATA AVAILABILITY STATEMENT

The data analyzed in this study is subject to the following licenses/restrictions: The data in this article comes from the official public data of China Land Market Network. Since the data will be used for later research, the author declares that this data will not be disclosed in the attachment of the article. Requests to access these datasets should be directed to http://www.landChina.com/.

AUTHOR CONTRIBUTIONS

AZ conceived, designed and wrote this study. WP wrote the paper. All authors have read and agreed to the published version of the manuscript.

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