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Article

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Journal of Applied Economics

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Suggested Citation: Lin, Shiue-Hung (2023) : The measurement of zombie enterprise under information asymmetry: A case of China's iron and steel industry, Journal of Applied Economics, ISSN 1667-6726, Taylor & Francis, Abingdon, Vol. 26, Iss. 1, pp. 1-29, <https://doi.org/10.1080/15140326.2023.2259245>

This Version is available at:

<https://hdl.handle.net/10419/314238>

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To cite this article: Shiue-Hung Lin (2023) The measurement of zombie enterprise under information asymmetry—a case of China's iron and steel industry, *Journal of Applied Economics*, 26:1, 2259245, DOI: [10.1080/15140326.2023.2259245](https://doi.org/10.1080/15140326.2023.2259245)

To link to this article: <https://doi.org/10.1080/15140326.2023.2259245>



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Published online: 21 Sep 2023.



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The measurement of zombie enterprise under information asymmetry—a case of China’s iron and steel industry

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ABSTRACT

The problem of zombie enterprises originated in Japan’s bubble economy around 1990. Afterward, after China’s oversupply problem in 2016, it gained attention and received policy support from the Chinese government in solving related problems. The contribution of this measurement is to integrate the investor’s demand index for listed companies and the company’s actual production and operation performance simultaneously. Based on the panel data of 28 Chinese-listed iron and steel enterprises from 2003 to 2022, the simulation and empirical analysis are carried out. Our research found that the 28 listed steel enterprises in China generally performed poorly from 2007 to 2016, and even some steel enterprises had negative operating profits, but they still survived in the market. In addition, there is a problem of information asymmetry between the actual operation of the enterprise and the capital or financial market in the listed steel industry in China.

ARTICLE HISTORY

Received 10 July 2022

Accepted 11 September 2023

KEYWORDS

Zombie enterprises;
information asymmetry;
technical efficiency; China’s
iron and steel industry

1. Introduction

The word “zombie enterprise” comes from the situation in which the Bank of Japan supported Japanese companies after the bubble economy in Japan around 1990. The target of support is those Japanese companies that have weak operations or are about to break down. Afterward, China’s economic downturn in 2016 caused overcapacity on the supply side. This has led to the phenomenon of zombie companies gradually occurring in many Chinese state-owned enterprises, such as steel, aluminum, and paper industries. In 2018, 13 departments including the National Development and Reform Commission of China jointly issued the “Notice on Further Doing a Good Job in the Debt Disposal of Zombie Enterprises and De-Capacity Enterprises”, which requires that the disposal of related companies must be completed by the end of 2020. The policy implication is that the determination of zombie enterprises needs to be confirmed before the disposal of zombie enterprises. The problem of zombie enterprises has been the focus of research consequently in recent years. The main questions include “Why do the zombie enterprises survive?” and “How do to further measure zombie enterprises?”. For the above second question, our study also attempts to construct a new measurement method

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to explain. According to the past literature, our article collates the common points of zombie enterprises: low profitability (Garcia-Herrero et al., 2009), high debt ratio (Yu & Lu, 2016), and wrong government policies (Jaskowski, 2015). These factors may lead to market investors being exposed to investment damage and risks based on information asymmetry in the actual operations of enterprises.

In addition, the leveraged operations of enterprises cannot be easily observed in relevant financial reporting indicators, which means that “transparency” has always been the top concern of market investors. At the same time, zombie enterprises or potential zombie enterprises will continue to obtain funds through debt or equity finance and continue to survive in the market. However, debt or equity financing issues can lead to the problem of information asymmetry and credit quality, and further increase the risks faced by market investors and the turmoil in financial and capital markets. Therefore, in the case that the enterprise financial reporting indicators cannot fully reflect the problems of enterprises, it is necessary to actively combine the information of the actual production side of the enterprises, which will effectively improve the transparency of the enterprises, and reduce the information asymmetry between the market investors and the actual operations of the enterprises. This will have a significant positive impact on financial or capital markets.

Based on the above reasons, our study is based on Melitz (2003) to construct an extended model and take into account the financial reporting indicators and the technical efficiency of the production side simultaneously. The main reason for using this extended model is that this model can appropriately describe the type of monopolistic competition among heterogeneous firms in China’s iron and steel industry, which is reflected in the slight differences between the same types of commodities in the industry. Accordingly, the novelty of this research lies in the integration of the production efficiency of the enterprise and the demand index of individuals to verify the true operating conditions of the enterprise and to observe the potential information asymmetry. This is significantly different from the research on the measurement method of zombie enterprises in the past related literature. In the past, most measurement methods focused on corporate financial reporting indicators and debt relationships, such as the CHK method (Caballero, Hoshi, and Kashyap; 2008). Accordingly, this study uses the data of China’s listed steel enterprises from 2003 to 2022 for simulation and empirical analysis. The main reasons why this paper takes China’s listed iron and steel enterprises as the research object are as follows: First, the problem of zombie companies is not a new phenomenon. From the financial crisis in 2008 to 2016, the Chinese economy gradually faced the problem of overcapacity. Therefore, there is a background for the Chinese steel industry to become the object of discussion among zombie companies. Secondly, according to the 2016 research report (Nie et al., 2016) of the National Academy of Development and Strategy of Renmin University of China point out that among the top three industries with the highest proportion of zombie enterprises in 2013, the steel industry ranked first (51.43%), followed by the real estate industry (44.53%) and the architectural decoration industry (31.76%). Hence, this article chooses China’s iron and steel industry as the main research object.

The layout of the subsequent sections of this paper is as follows. The second section is the literature review. In the third section, we construct a theoretical framework that includes technical efficiency, demand index, and the zero-cutoff profit condition. The fourth section is more analytical; here, we discuss the results of the simulation and

empirical analysis, followed by robustness analysis and treatment of the endogeneity problems. In the fifth section, we present our conclusions.

2. Literature review

The literature collected in this study discusses the causes and influences of zombie enterprises, the problem of information asymmetry, and the measurement. Firstly, our study attempts to sort out the causes and influences. Second, we collate the discussion and results of past literature on zombie enterprises and information asymmetry and further try to highlight the importance of information asymmetry in this issue. Finally, our article explains and discusses how to measure in the past literature. And further, explain the difference between the measurement method in this study and the measurement methods of past literature.

In the past literature, these articles discuss the causes and influences of zombie enterprises and seem to point to two aspects respectively: One is mostly derived from “evergreen lending”, which presents the difficulties in the operation of zombie enterprises and the embarrassing role of lending banks. On the other hand, the increase in the survival rate of zombie enterprises will lead to the crowded effects of the market, which will hurt the overall industrial productivity and the operation and profitability of healthy enterprises. Moreover, it is also not conducive to the market entry of potential new companies. Our article lists systematically as follows: Peek and Rosengren (2005) and Fukuda and Nakamura (2011) respectively pointed out from the Japanese survey that the misallocation of credit and evergreen lending are important factors leading to zombie enterprises. Similarly, Kobayashi and Inaba (2005) indicated that Japan released a large number of non-performing loans in the early 1990s to maintain non-viable enterprises. But these companies have not become more active and even possess loans from these banks. The study found that banks indirectly undermined the debtor’s integrity, leading to mistrust between enterprises, which in turn destroyed the development of the production chain. Imai (2016) conducted a study by using Japanese SME panel data from 1999 to 2008 and found that 4–13% of SMEs were zombie companies during this period. In addition, this study used the marginal q to measure the profitability of zombie enterprises. The results indicate that the investment growth caused by Evergreen loans was not necessarily productive or profitable.

For the influences of zombie enterprises, Shen and Chen (2017) used firm-level data from China’s manufacturing industry from 2011–2013 to explore the issue of zombie companies and overcapacity. This study found that overcapacity in the heavy chemical industry and the state sector in the central and western regions of China is serious. In addition, they have caused problems with overcapacity by crowding out healthy enterprises. It means that the crowding effect exists between healthy enterprises and zombie enterprises. Recent research mainly focuses on financing constraints, political connections, and financial subsidies. Shao et al. (2022) found that “political connections” plays a key role in the zombification of enterprises through the data of China’s listed manufacturing enterprises from 2007 to 2017. The intermediary role of political connections makes zombie enterprises obtain large credit subsidies and make inefficient over-investment. Deng and Wang (2022) used industrial firm-level data from 1998 to 2007 and identified zombie enterprises through the FN-CHK method. This study finds that financial subsidies

prolong the survival time of zombie firms. This policy not only reduces the possibility of zombie enterprises exiting the market but also reduces the possibility of the resurrection of such companies. Finally, the research of Wu and Pan (2023) pointed out that the constraints of zombie enterprises promote high-quality economic development to some extent. The main reason is that zombie enterprises intensify the financing constraints of non-zombie enterprises, thus accelerating the process of financialization of non-zombie enterprises.

In addition, sort out the relevant research in different countries (regions). Caballero et al. (2008) based on the phenomenon in the 1990s that the Japanese banks often engaged in sham loan restructurings, which explored how the crowded effects created by zombie enterprises hindered the profitability, market-entry, and investment opportunities of healthy enterprises. This implies that the problem of zombies will lead to employment downturns and a decline in productivity. Kwon et al. (2015) used the 1981–2001 Japanese manufacturing plant-level data to measure the total productivity growth. The research found that the wrong lending (zombie lending) by banks to failed companies will avoid a decline in production factor input in these companies, especially labor. Simultaneously, this study found that if there is no zombie lending, the annual total productivity will increase by one percentage point during the 1990s. Adalet McGowan et al. (2018) found that the expansion of zombie enterprises restricts the growth of companies with higher productivity through the observations in OECD countries. Multinational analysis from 2003 to 2013 shows that market congestion caused by these enterprises not only restricts the expansion of healthy incumbent companies but also hinders the entry and growth of new companies. The study by Andrews and Petroulakis (2019) focused on the relationship between zombie enterprises and bank health and the impact of 11 European countries on total productivity. The study found that the links between these enterprises and weaker banks get closer, which limits the growth of more productive enterprises and thus the overall productivity growth. Carreira et al. (2021) used the panel data of Portuguese manufacturing and service firms from 2004 to 2017 to find the widespread existence of zombie enterprises. These enterprises have low productivity, and the probability of transition to recovery or exit is relatively low. In addition, downsizing and debt restructuring are key points for enhancing the recovery of these enterprises. Some of the literature also extends and discusses how the insolvency system affects the restructuring of zombie enterprises, such as McGowan et al. (2017). In the literature of the past two years, Blažková and Dvoutělý (2022) used Czech data from 2003 to 2015 to explore the financial management symptoms and development process of companies before they became zombie enterprises. They found that such enterprises are mainly characterized by small-scale, middle-aged, and located in large cities mostly. Moreover, the negative development of financial performance significantly increases the possibility of becoming a zombie.

In the literature concerning the issues of zombie enterprises, the discussion of information asymmetry is still rare. However, this issue may be a core factor. Hence, our research also hopes to support the problem of information asymmetry which exists between the actual operation of the enterprise and the capital or financial market through empirical analysis. The past literature concerning the issues of zombie enterprises and information asymmetry is presented as follows: Peek and Rosengren (2005) studied the misallocation of credit in Japan and the unnatural incentive faced by banks to provide

additional credit to the weakest firms. It turns out that troubled banks have incentives to allocate credit to underperforming borrowers to avoid the realization of losses on their balance sheets. This also implies the problem of adverse selection in information asymmetry to some extent. Banks in trouble cannot attract reputable borrowers to borrow, which leads to weak enterprises getting the credit. Thereafter, Oh et al. (2009) compared a large sample of guaranteed companies and matching non-guaranteed companies from 2000–2003 to evaluate the effectiveness of the credit guarantee policy. It turns out that credit guarantees significantly affect the companies' ability to maintain their scale and survival rate of companies, but it does not have an influence on the R&D and the investment of enterprises, which in turn affects the growth of their productivity. In addition, the companies with lower productivity are more likely to receive guarantees due to the adverse Selection problems. It means that the problem of information asymmetry exists between both. Moreover, Fukuda and Nakamura (2011) indicate that corporate restructuring without accounting transparency in the effective restructuring of zombies is ineffective. It illustrates the importance of transparency in solving the problems of zombies. Finally, Retolaza et al. (2016) link the corporate leveraged operations and the risk involuntarily assumed by third parties to explore the problem of moral hazard. This study indicates that it is inevitable that zombies that have high leverage and operate under negative assets will let third parties take risks. It implies that exists the problem of information asymmetry. In summary, considering the information asymmetry in the relevant research of zombie enterprises is an important core of the analysis problem. Therefore, our paper hopes to prove the evidence of the existence of information asymmetry through the data of Chinese listed iron and steel enterprises.

Since the measurement method for zombie enterprises in this article is based on China's iron and steel industry, the relevant literature is also compiled for the explanation. He et al. (2013) used data from 50 companies in China's iron and steel industry to evaluate the changes in energy efficiency and productivity from 2001 to 2008. Through the conventional data envelopment analysis model and the Malmquist Productivity Index (MPI), it is found that many factories are inefficient, with an average energy efficiency of only 61.1% and an annual productivity growth rate of 7.96%. Tan et al. (2016) found that government investment improved the performance of zombie enterprises through the 2005–2007 data set of Chinese companies, which in turn crowded out the growth of private companies. The main method comes from the continuous financing of poorly managed enterprises and the expansion of their ability to undertake large-scale projects with the support of the government. And take the loss-making Shandong Iron and Steel Group in 2009 with the support of the local government to take over the profitable Rizhao Iron and Steel Holding Group as an example. Moreover, Montali (2018) pointed out that the main reason for China's slow economic growth is the large, inefficient, and debt-laden state-owned enterprises within the system. And as many as 13% of Chinese listed companies are considered zombie enterprises, and the root of this phenomenon lies in the improper allocation of resources and capital. Among them, the iron and steel industry is a good example of credit-promoting overcapacity. Although there is not much literature specifically discussing zombie enterprises in China's iron and steel industry, it still gives us a glimpse of the problems that exist in the industry.

Finally, concerning the measurement method of zombie enterprises, this study provides a measurement method that differs from the previous literature. Our measurement

method is based on the extended structure of Melitz (2003), which measures the actual operating conditions of the enterprise through the actual technical efficiency and demand index of the enterprise. If the actual operation of the company is below the zero cutoff profit condition and continues to survive in the market, it can be considered to have the characteristics of zombies. The research method started with the Melitz (2003) heterogeneous firm model, most of which are used in the field of international trade. For example, the past international trade literature: Helpman et al. (2004), Ghironi and Melitz (2004), Yeaple (2005), Bernard et al. (2007), Melitz and Ottaviano (2008) are all based on heterogeneous productivity environments. The main research scope of the related literature covers comparative advantage, wages, exports, foreign direct investment (FDI), outsourcing et al. Furthermore, the past literature on the measurement of zombie enterprises is mostly based on the financial report of the enterprise, which is described respectively as follows: Caballero et al. (2008) define the zombies by constructing a simple CHK standard. The basis of this standard is that troubled enterprises must receive a large amount of interest relief, which makes their interest payments lower than the interest payments of healthy enterprises. Fukuda and Nakamura (2011) have revised the CHK standard to include the profitability standards and the condition that the healthy companies' pre-tax profits after deducting non-operating income should not be negative. The above amendments reduce the likelihood that the CHK standard will identify a health company as a zombie. Urionabarrenetxea et al. (2018) developed an EZIndex based on data from Spain in 2010–2014 and used it to measure zombie enterprises. This index includes four important dimensions for measuring zombie businesses: extension, contagion, recovery signs, and immediacy. In addition, this study has developed a ranking method for zombies based on risks and changes over time.

All in all, the causes, influences, and measurement methods of zombie enterprises have always been the focus of the literature. After collating relevant literature, our study attempts to provide a future research direction for the measurement of zombies and the information asymmetry between the actual operation of the enterprise and the capital or financial market based on existing research.

3. Theoretical framework

This study is aimed at the phenomenon that the company's overall operating net profit (after deducting government subsidies) is negative but still operated. The purpose of deducting government subsidies is to separate the effects of government support. Our research tries to determine whether it is a zombie enterprise by integrating relevant indicators of production and financial aspects. Compared with the previous literature which used financial indicators as a benchmark, this paper extends the basic structure of the Melitz (2003) model. And the heterogeneity setting of this article includes the heterogeneity of the two variables, namely the technical efficiency and the demand index. Technical efficiency comes from the manufacturer's production ability, which means the reciprocal of the unit cost of the product. When the cost is lower, it means that the higher of technical efficiency of the manufacturer, the more secure the profit of the manufacturer; otherwise, the technical efficiency is low. The demand index reflects individual preferences, Aw and Lee (2014) define it as product quality or brand name, and this article further extends to the company's asset growth rate, solvency, and other

financial indicators. More specifically, the demand index is broadly generalized in this study to refer to individuals (consumers or investors) perceived preferences for a firm's goods or operations. The improvement of the demand index will help individuals increase their confidence in purchasing the company's products or operating the company. It will widely affect the preferences for manufacturers' products, capital, and financial markets. The above two variables will be randomly drawn from a joint probability distribution and have an impact simultaneously on the manufacturer's profit. It can be observed that the combination of technical efficiency and demand index will have different changes under the same profit, such as (high technical efficiency, low demand index) or (low technical efficiency, high demand index). Therefore, the measurement standards for zombie enterprises will cover a wider range by integrating the production and financial aspects.

3.1. Preferences

In the setting of the demand side, to satisfy the above assumptions about the confidence of the enterprise's asset growth rate, solvency, and other financial indicators to the individuals in purchasing a company's product, securities, or its company operation, the demand index (a_i) is set to Cobb-Douglas function form, that is $a_i(K) \equiv k_1^{\beta_1} k_2^{\beta_2} \cdots k_n^{\beta_n}$, $k_i \in K$. Where K is a set that contains all the financial indicators k_i that may be used to measure the zombie enterprises and gives the measurement weight β of each financial indicator, and further satisfies $\sum_{i=1}^n \beta_i = 1$. In addition, the utility of an individual comes from the consumption of a continuous variety of products as follows:

$$U = \left\{ \int_{i \in I} [a_i(K) q_i]^\rho di \right\}^{\frac{1}{\rho}}, \rho \in (0, 1) \quad (1)$$

As mentioned above, $a_i(K)$ is the consumer's specific demand index for the related product of an enterprise, and $q(i)$ is the consumption quantity of the product category *AccessisdeniedAccessisdenied*. The I is represented as a collection of all possible product categories. Through the descriptions of the utility function, when the individual's demand index for individual products increases, it means that individuals can further improve their confidence in individual products, securities, or the company operates through relevant financial indicators so that the utility of individuals is improved; otherwise, it decreases. It is also assumed that the substitution elasticity between categories of products is a fixed value ε ($\varepsilon \geq 1$), and $\varepsilon = 1/(1 - \rho)$. At the same time, considering the maximization utility with the budget constraint $\int_{i \in I} p_i q_i di = R$, the demand function of each product category I can be derived as follows:

$$\hat{q}_i = R \hat{P}^{\varepsilon-1} (\hat{p}_i)^{-\varepsilon} \quad (2)$$

Where $\hat{q}_i \equiv a_i(K) q_i$ is defined as the individual demand index-adjusted quantity; $\hat{p}_i \equiv p_i / a_i(K)$ is defined as individual demand index-adjusted price. In addition, $\hat{P} = \left[\int_{i \in I} [p_i / a_i(K)]^{1-\varepsilon} di \right]^{\frac{1}{1-\varepsilon}}$ represents the individual demand index-adjusted composite price index of the entire industry. R represents the total expenditure for the entire

industry. The logical equivalence of equation (2) comes from the inverse relationship between price and quantity in the law of demand. This implies that even if the price and quantity in the formula are adjusted by the demand index, they still satisfy the basic logic of the law of demand. According to \hat{q}_i and \hat{p}_i , after the adjustment of the individual demand index, when the individuals' confidence in an individual product, securities, or the reliability of company operation is increased, the number of products that is willing to purchase will increase. The real price in the hearts of individuals is declined because the confidence and trust in this product increased, and it will be more attractive to buyers.

3.2. Production

In terms of supply-side setting, this paper extends the basic settings of Melitz (2003) and Aw and Lee (2014), which described the total production cost of an individual manufacturer as a function of individual output, productivity, and fixed operating cost. Productivity comes from individual manufacturers' technical efficiency and demand index. Here, the technical efficiency of individual manufacturers is defined as $\mu \in (-\infty, \infty)$, and the price of the unit production factor is set to p_μ . Therefore, the quantity of the required production factor for the unit product is $1/\mu$. Then the total cost function is presented in the following form:

$$TC_i = f + \frac{p_\mu a_i^\eta}{\mu_i} q_i \quad (3)$$

The logical equivalence of Equation (3) comes from the fact that total cost is a function of fixed operating costs and variable costs. This also implies that in addition to constant fixed costs, the changes in total costs come entirely from the technical efficiency and individual demand index. Here, setting $\varphi_i \equiv \mu_i a_i^{1-\eta}$ represents individual manufacturers' productivity and is proportional to the individual's demand index for a product; it is inversely proportional to the factor input required per unit of output. When individuals have more confidence in the manufacturer's product or company operation, it implies that the manufacturer needs to pay a certain degree of effort to meet their needs. The higher technical efficiency of a unit product would cause the lower total production cost of a manufacturer. $\eta (0 < \eta < 1)$ represents the production cost elasticity of the demand index and which is assumed to be a constant value and consistent with each manufacturer. This means that when this elasticity value increases, it will lead to an increase in the manufacturer's production cost. This also means that as the value of η increases, the demand index will have a positive and greater impact on production costs; vice versa. Because the capital or financial market investors may have different η values for individual steel enterprises, based on a general setting, this study sets the η value to 0.5. In addition, f is the fixed operating cost that is faced by the manufacturer.

3.3. Profit maximization

Under the structure of heterogeneous firms, the behaviors of firms can be described in stages as follows: Firstly, the potential competitors in the market will calculate the present value of expected future profit at the current period and compare it with the free entry cost (f_e). If the expected profit exceeds the free entry cost, the firm chooses to enter the market; otherwise

won't enter. Second, after the manufacturer enters the market, a productivity combination of technical efficiency and demand index will be randomly drawn from a joint probability distribution $g(a, \varphi)$. And all the manufacturers that choose to enter the market will face a fixed operating cost and decide whether to stay in the market. Therefore, under the premise of considering the technical efficiency and demand index, the maximum profit of the manufacturer is as follows:

$$\max_{p_i} \pi_i(a, \varphi) = \left[\left(p_i - \frac{p_\mu a_i^\eta}{\mu_i} \right) q_i - f \right] \quad (4)$$

Where p_i and q_i are the prices and the quantity determined by manufacturer i , respectively. According to the maximum profit conditions, the optimal pricing for individual manufacturer i is:

$$p_i = \frac{p_\mu a_i^\eta}{\rho \mu_i} \quad (5)$$

The logical equivalence of equation (5) comes from the fact that the firm's pricing is based on the impact of the cost side. This implies that the commodity price setting is a function of technical efficiency, demand, index, and markup in this study. From equation (5), the optimal pricing for a manufacturer i is a function of technical efficiency and demand index. When the individual's demand index for a manufacturer is higher, it means that the individual manufacturer can satisfy the confidence of individuals in the product or the performance of the company's operation by their financial indicators, so they are more able to set high prices in the pricing. According to the above description, the impact of manufacturers' technical efficiency and demand indices on their optimal pricing is different. The manufacturer's markup ($1/\rho$), which is assumed to be a fixed value and represents the same monopoly among individual manufacturers, obtains a positive profit. By equation (5), the demand index-adjusted revenue and profit functions of individual manufacturers can be further obtained, as follows:

$$r_i(a, \mu) = R(\hat{P})^{\varepsilon-1} \left[\frac{p_\mu a_i^{\eta-1}}{\rho \mu_i} \right]^{1-\varepsilon} \quad (6)$$

And

$$\pi_i(a, \mu) = \frac{1}{\varepsilon} r_i(a, \mu) - f \quad (7)$$

3.4. Determinations of zombie enterprise

This paper extends Melitz's (2003) basic structure to derive the minimum productivity level of firms that can survive in the market through FE condition (Free entry

condition)¹ and ZCP condition (Zero cutoff profit condition),² and to ensure there is a single equilibrium.³ In addition, this paper attempts to measure the decision method of zombie enterprises which is different from the previous literature through the integration of production and financial aspects. Following the description of Antràs and Helpman (2003) and Helpman et al. (2004), we can further rewrite the manufacturer's ZCP condition and present as follows:

$$\frac{1}{\varepsilon} R(\hat{P})^{\varepsilon-1} (1/\rho)^{1-\varepsilon} \varphi^{\varepsilon-1} = f \Rightarrow ZCPcondition$$

The logical equivalence of this zero-profit condition comes from the fact that the profit of an individual enterprise in Equation (7) is established under the condition that the profit is zero. This implies that when the ZCP condition is established, a productivity threshold will exist, making the enterprise's operating profit zero. According to the above equation, a specific combination of productivity, φ^* , which satisfies the ZCP condition can be obtained, and it is implied that when $\varphi > \varphi^*$, the operating profit of the manufacturer is greater than zero; otherwise, when $\varphi < \varphi^*$, the operating profit is less than zero. Therefore, this paper attempts to judge zombie enterprises through the above measurement. When the productivity of an individual manufacturer is greater than φ^* , the operating profit of the manufacturer is greater than zero, which means that the impact of various financial indicators on individuals and the performance of technical efficiency can make it continue to operate and obtain positive profits; otherwise, it should withdraw from the market, if it continues to operate in the market, it can be further identified as a zombie enterprise.

Since the productivity of the manufacturer comes from the influence of demand index and technical efficiency, the ZCP condition can be further rewritten as follows:

$$\mu_i = \frac{p_\mu a_i^{\eta-1}}{\rho \hat{P}} \left[\frac{\varepsilon f}{R} \right]^{\frac{1}{\varepsilon-1}}, \varepsilon > 1 \quad (8)$$

Equation (8) is the equal-zero profit curve⁴ when the manufacturer's operating profit is zero, which means that is all possible combinations of demand index and technical efficiency under the premise that the manufacturer's operating profit is zero. By the equal-zero profit curve, all the productivity combinations can be divided into two regions and are defined as Region I and Region II, respectively. In the upper right of the zero-profit curve, the region I, the combination of productivity in this region will make the manufacturer's operating profit higher, and the less likely it is to be judged as a zombie

¹The free entry condition depends on the potential manufacturer's discounted value for future expected profit is greater than the entry cost (f_e). The free entry condition of this paper is $\bar{\pi} = \frac{\delta f_e}{1-G(a^*, \mu^*)}$, $\bar{\pi} = \bar{\pi}_d$, where $G(\cdot)$ is the joint cumulative probability distribution of technical efficiency and demand index. The specific combination of demand index and technical efficiency, (a^*, μ^*) , which makes the manufacturer's expected profit to zero.

²After entering the market, the zero profit condition of the manufacturer is $\bar{\pi} = \left[\left(\frac{\varphi(a^*, \mu^*)}{\varphi^*(a^*, \mu^*)} \right)^{\varepsilon-1} - 1 \right]$.

³See Melitz (2003), APPENDIX B, 1719-1720.

⁴The first-order condition of zero profit curve is $\frac{\partial \mu_i}{\partial a_i} = (\eta - 1) a_i^{\eta-2} \frac{p_\mu}{\rho P} \left[\frac{\varepsilon f}{R} \right]^{\frac{1}{\varepsilon-1}} < 0$ and the second-order condition is $\frac{\partial^2 \mu_i}{\partial a_i^2} = (\eta - 1)(\eta - 2) a_i^{\eta-3} \frac{p_\mu}{\rho P} \left[\frac{\varepsilon f}{R} \right]^{\frac{1}{\varepsilon-1}} > 0$, so that it is a convex curve toward the origin.

enterprise; otherwise, the combination of productivity in the lower left of the zero-profit curve will include (low demand index, low technical efficiency), which will make the operating profit of the manufacturer less than zero, and it means that the performance of the financial indicators and the technical efficiency cannot make the operating profit to be positive. Therefore, the manufacturer is supposed to exit the market. If it continues to operate in the market, it may be judged as a zombie enterprise. It is worth mentioning that the combination of different levels of demand index and technical efficiency will lead to different levels of manufacturer's productivity, and it is indeed observable the situation that matches in the real market competition environment. The first figure below shows the above descriptions and presents them as follows.

4. Simulation and empirical analysis

The research path and strategy of this paper will be carried out through the following steps: first, according to the characteristics of China's steel industry, establish a theoretical framework suitable for discussing the issue of zombie enterprises; second, conduct simulation and empirical analysis through the theoretical model, and obtain main conclusions; finally, conduct robustness analysis and deal with endogeneity problems. The above steps are described below.

First of all, on the characteristic and applicability of the model. Since the types of products produced by enterprises in the iron and steel industry are similar but differ in product quality, this characteristic satisfies the basic assumptions of the heterogeneous firm's trade model under monopolistic competition. And according to the setting under the monopolistic competition framework in this manuscript, the substitution elasticity of products between enterprises is set as $\varepsilon \geq 1$. And according to Lu (2007), the estimated value of substitution elasticity of China's iron and steel industry is $\varepsilon = 2.988$, so taking China's iron and steel industry as a case meets the basic setting of this model framework.

To further test the effectiveness of the zombie enterprise measurement method, this paper uses the panel data of China's iron and steel industry for simulation and

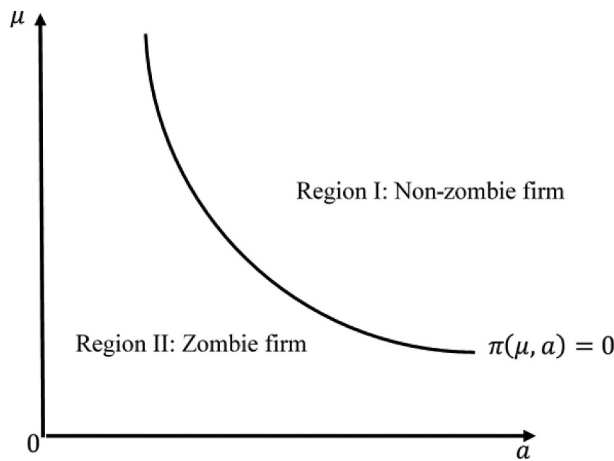


Figure 1. The determinations of zombie firm.

empirical analysis. In terms of simulation analysis, this paper analyzes based on Equation (8). Based on the 2003–2022 data of China's iron and steel industry, our article simulates the situations of 28 Chinese-listed iron and steel enterprises by considering the demand index and the technical efficiency in different years. And respectively give the enterprise number (Ent.1 to Ent.28) to facilitate the distinction. On the premise that the annual average of the non-financial operating costs of 28 listed enterprises in China is taken as the minimum operating cost of the enterprise, and further calculates whether the enterprise is in the region with $ZCP < 0$ in the current year (i.e., the region II in Figure 1). It also means that the enterprise should be withdrawn from the market, if it continues to operate under this situation in the market for a few years, it can be further identified as a zombie enterprise.

In terms of empirical analysis, this paper constructs a regression model to test the impact of the gap between the profit of the listed iron and steel enterprise and the zero-profit level on the enterprise's net profit. The above profit gap mainly comes from the technical efficiency and demand index. Moreover, it also tests the cross-influences on the enterprise's operating profit through the individuals' expectations of the Return on Equity (ROE) of listed iron and steel enterprises and their actual operating capacity. And trying to highlight the impact of information asymmetry on the causes of zombie enterprises. Hence, in the selection of the main variables, this study chooses the profit gap, the interaction item between the demand index and technical efficiency, the ROE index, and the interaction item between the ROE and profit gap as the focus of this research. The basis for selecting these variables comes from the theoretical model of this study and the topics to be discussed and focuses on the impact of these independent variables on corporate net profits. The choice of control variables includes the total number of employees employed, total capital, net cash flow from operating activities, and income tax expenses. The basis for selecting control variables in this study is mainly based on theory and related financial indicators. Theoretically, the total number of employees directly affects the company's net profit through variable costs; the total capital is related to the net profit through the return on total capital and the total profit; the net cash flow of the company's operating activities is normally equal to the net profit plus the depreciation of fixed assets and the amortization of intangible assets; finally, according to the net profit calculation formula, it can be known that the corporate income tax expense directly affects the size of the corporate net profit. The final step is to help this study obtain more precise and robust conclusions through robustness analysis and handling endogeneity problems.

4.1. Data source and processing

This paper sets the research period from 2003 to 2022. The main source of simulation and empirical analysis data is the Wind database. This study selects the relevant data and financial statements of 28 Chinese-listed iron and steel enterprises to estimate the enterprises' total factor productivity (TFP) and demand index. And as the quantitative basis for subsequent simulation and empirical analysis. In addition, because the problem of Chinese zombie enterprises has always existed, it did not only appear after the 2008 financial crisis. The financial crisis has only highlighted the existence of Chinese zombie enterprises. Relevant reports and the official documents issued by the Chinese government also indirectly confirm

the existence of this actual situation. For example, a 2016 report by the National Academy of Development and Strategy of the Renmin University of China pointed out, “Since 2001, the number of zombie enterprises in listed enterprises has continued to rise. It reached its peak around 2013 . . .”. In addition, the “Opinions on Resolving Overcapacity in the Iron and Steel Industry to Achieve Development Out of Difficulties” issued by the State Council of China in 2016 also showed the seriousness of the problem of zombie enterprises in China’s iron and steel industry after the 2008 financial crisis. It can be seen that the data interval from 2003 to 2022 used in this paper is reasonable.

To estimate the technical efficiency, this paper uses the methods of Olley and Pakes (1996), Levinsohn and Petrin (2003), Wooldridge (2009), and Robinson (1988) to estimate the TFP of 28 Chinese listed iron and steel enterprises. This study also uses the correction of Akerberg, Caves, and Frazer (2015) to estimate under the OP method and LP method. Table 1 presents the descriptive statistics results under the five TFP methods. It was found that the average TFP estimated by the five methods was between 6–9.5 except for the OP method. The main reason for the difference in the average value of TFP is that the proxy variable used under the OP method is “investment”, while under the LP, WRDG, and ROB methods, it is “intermediate inputs”. Table 2 presents the estimation results under the five methods. This paper finds that the coefficient values of capital under LP, LP-ACF, and OP-ACF methods are not significant. Therefore, this research tends to use the TFP results under the OP, WRDG, and ROB methods for subsequent discussions.

This paper selects the relevant data of 28 Chinese-listed iron and steel enterprises from 2003 to 2022 and further sorts them into short panel data. In addition, the estimation of the demand index mainly uses the relevant financial indicators⁵ in the

Table 1. Descriptive statistics of estimated values under five TFP methods.

	obs	Mean	Std. Dev.	Max	Min
LP	550	9.204	0.818	3.366	11.283
LP-ACF	550	6.888	0.709	1.542	8.621
OP	550	3.143	0.526	−1.051	8.126
OP-ACF	550	7.524	0.715	2.080	9.308
WRDG	550	8.521	0.765	2.862	10.456
ROB	550	9.059	0.810	3.251	11.117

Data source: Wind database, and calculated by this study.

Table 2. The estimation results under five TFP methods.

Inoutput	LP	LP-ACF	OP	OP-ACF	WRDG	ROB
lnL	0.115** (0.065)	0.422*** (0.067)	0.203** (0.101)	0.264*** (0.050)	0.137*** (0.032)	0.136** (0.064)
lnK	0.136 (0.095)	0.086 (0.124)	0.602** (0.260)	0.161 (0.215)	0.179*** (0.030)	0.132* (0.072)
obs	545	545	278	278	516	516

“lnL” means taking the natural logarithm of the number of employees; “lnK” means taking the natural logarithm of the capital.

Data source: Wind database, and calculated by this study.

Standard errors are in parentheses. * $p < 0.1$, ** $p < .05$, *** $p < .01$.

⁵The main financial indicators used in the estimation of the demand index include net profit, owners’ equity, return on total assets, fixed asset turnover ratio, debt asset ratio, operating expense ratio, capital reserves, earnings per share, operating margin, debt to tangible assets ratio, return on equity(ROE) and net present value(NPV).

financial report data of Chinese-listed iron and steel enterprises in the Wind database and gives the same weight to each financial indicator. In many relevant kinds of literature, a certain number of consecutive years of losses is used as the criterion for identifying zombie enterprises. An enterprise’s net present value (NPV) is often used as an important basis to help determine zombie enterprises. Therefore, this study also incorporates this important indicator into the simple weighted average calculation of the demand index. Since individuals in the goods, the financial or capital market may have inconsistencies in the importance of individual financial indicators, this will lead to different settings for the weights of individual financial indicators in the minds of each person. Therefore, considering that all individuals have different preferences for individual financial indicators, it is reasonable to set the weights of all indicators to be consistent under the concept of average.

4.2. Simulation analysis

Figure 2 presents the trend of the annual average technical efficiency estimated by OP, WRDG, and ROB methods and the annual average demand index for 28 Chinese-listed iron and steel enterprises from 2003 to 2022. Figure 3 specifically shows the changes in

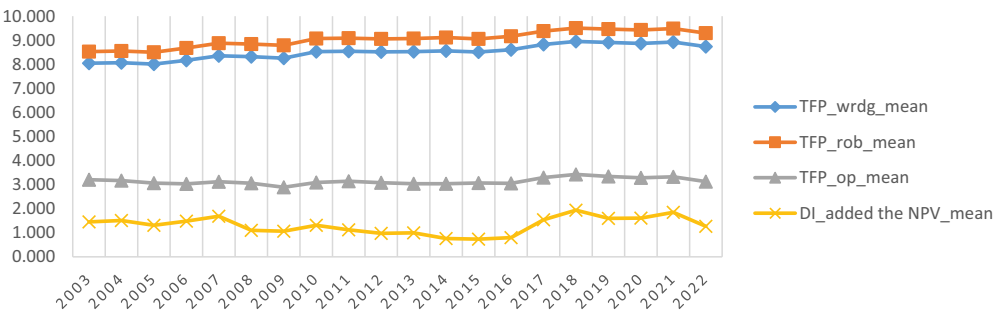


Figure 2. Average technical efficiency and demand index of 28 listed iron and steel enterprises in China from 2003 to 2022. Source of data: Wind database, and calculated by this study.

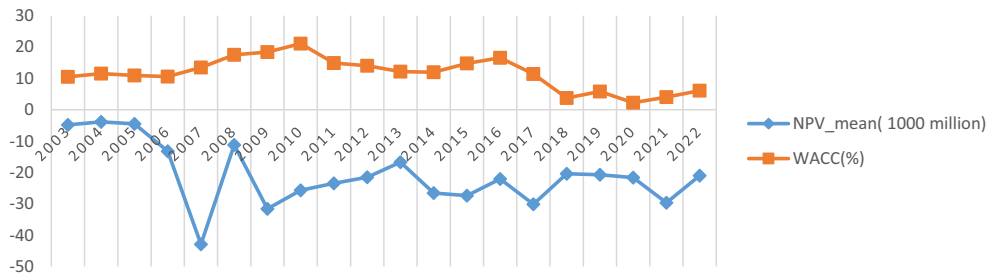


Figure 3. Average NPV and WACC (%) of 28 listed iron and steel enterprises in China from 2003 to 2022. Source of data: Wind database, and calculated by this study.

the annual average net present value and weighted average cost of capital (WACC) of 28 steel-listed enterprises.

It can be seen from Figure 2 that under the WRDG and ROB methods, the annual average technical efficiency of 28 Chinese listed steel enterprises from 2003 to 2022 has a slight upward trend, but there is no significant change under the OP method. The annual average demand index showed a downward trend from 2007 to 2016, which is inseparable from the 2008 financial crisis. After 2017, the average annual demand index gradually picked up, which should be related to a series of supply-side reform policies introduced by the Chinese government. In addition, it can be observed from Figure 3 that the annual average NPV of the 28 iron and steel enterprises has been negative for many years, and has a downward adjustment effect in the calculation of the demand index. Based on the above, the difference between the enterprise's technical efficiency and the individual's demand index (or capital or financial market) can be observed. This seems to allow us to make reasonable inferences about the possible negative impact on operations after the 2008 subprime mortgage crisis.

Simultaneously, this also makes us wonder whether any of China's listed iron and steel enterprises in 2007–2016 has fallen into Region II of Figure 1. In the simulations of each year, the $ZCP = 0$ plays an important role. Based on the ZCP condition, our paper calculates the combinations of all possible technical efficiencies and demand indices for each year at $ZCP = 0$ and links them into a curve. In the setting of parameters,⁶ the annual average salary of 28 Chinese-listed steel enterprises is used as the price of unit production factor (p_μ). The annual average price of 28 iron and steel enterprises is regarded as a comprehensive price index (\hat{P}). In addition, the average annual revenue of medium and large iron and steel enterprises in China is used to replace the average annual expenditure of consumers in the iron and steel industry (R). And I use the annual average value of the non-financial operating costs of 28 listed enterprises in China as the minimum operating cost of the enterprise. Moreover, this paper uses the substitution elasticity of China's iron and steel industry as a parameter which is calculated by Lu (2007), i.e., $\varepsilon = 2.988$. Finally, this paper makes a simple assumption for the production cost elasticity of the demand index is $\eta = 0.5$. Based on the above settings, our article estimates the curve of $ZCP = 0$ in each year from 2003 to 2022. Due to space limitations, this study only presents the simulation results from 2007 to 2016 under the WRDG method.⁷ The combination of production efficiency and demand index of listed iron and steel enterprises is shown in Figure 4:

The first few years of the subprime mortgage crisis seemed to be under control, but after 2012, more and more steel enterprises fell into Region II in Figure 1 year by year, and the severity of this situation reached its peak in 2016 when we

⁶The parameters in this article use RMB 100,000 as the unit of counting. Here, the annual average salary and the annual average price all use the original value. The annual average expenditure is replaced by the annual average revenue under the balance of payments concept, and the logarithmic value is taken.

⁷The simulation results under the ROB method are similar to those under the WRDG method. However, the simulation result under the OP method is that the 28 listed iron and steel enterprises all fall into Region II in Figure 1 during 2007–2016.

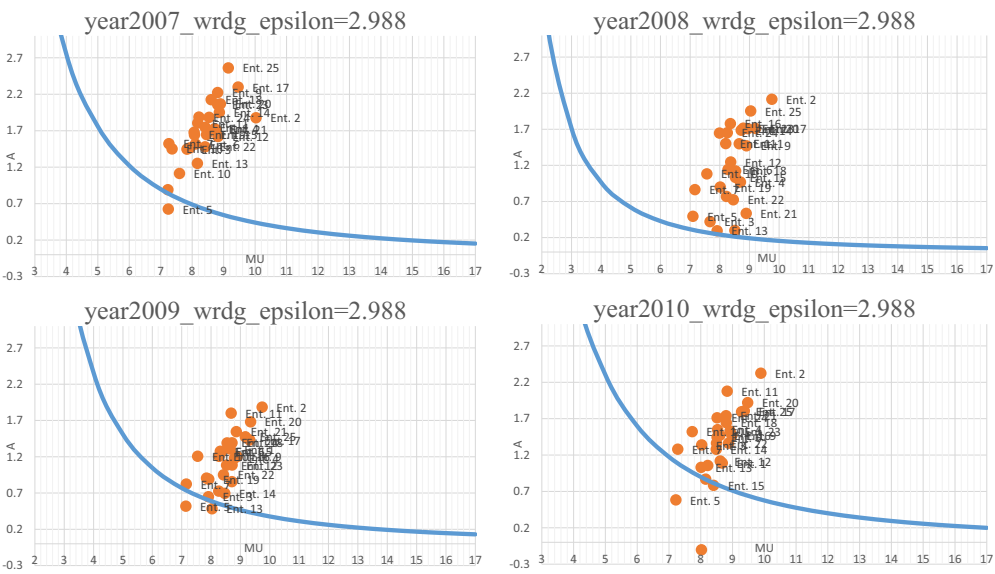


Figure 4a. continue

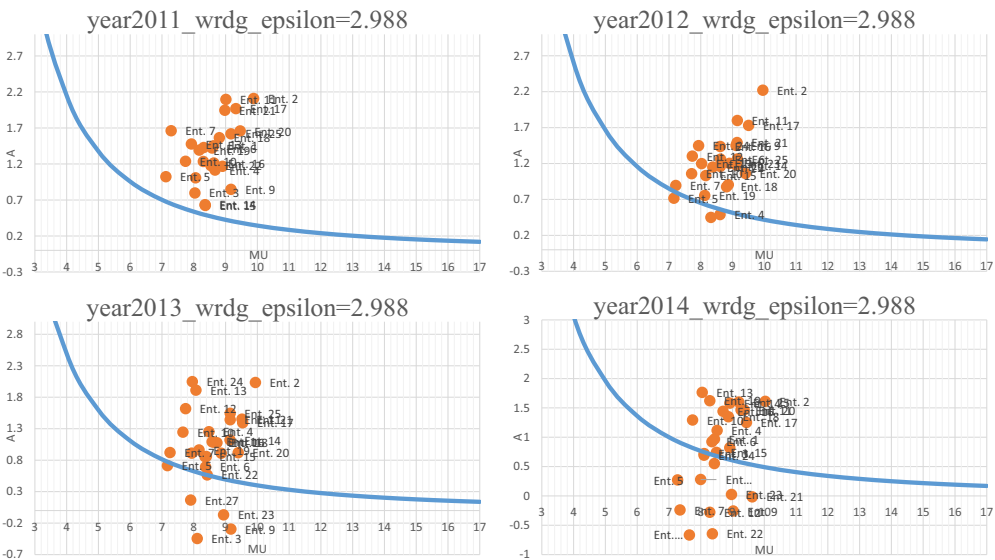


Figure 4b. continue

observed it. The deteriorating performance of China's listed steel enterprises can also be indirectly evidenced by the fact that the annual average NPV of listed steel enterprises in Figure 3 has been negative for many years. This also responds to our description above, if this enterprise continues to operate under this situation (i.e.,

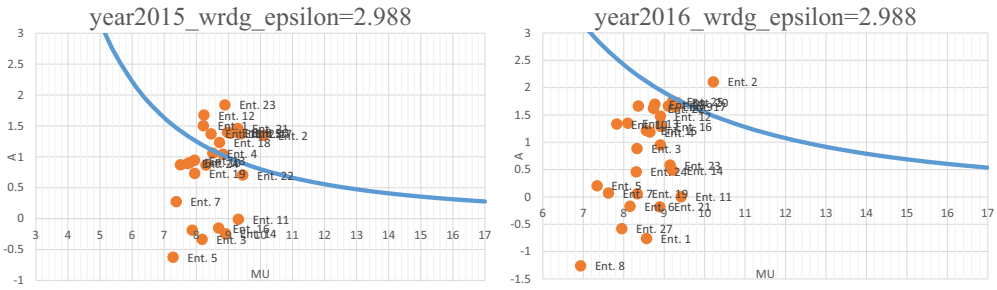


Figure 4c. Simulation of the operating performance of 28 listed iron and steel enterprises in China from 2007 to 2016.

ZCP < 0) in the market for a few years, it can be further identified as a zombie enterprise.

4.3. Empirical analysis

To analyze the efficiency of this estimation method, we use the short panel data of 28 Chinese-listed iron and steel enterprises from 2003 to 2022 for regression analysis. The basic regression model is set as follows:

$$\begin{aligned} \ln np_cgs_{it} = & \beta_0 + \beta_1 zcp_gap_{it} + \beta_2 di_tfp_{it} + \beta_3 roe_{it} + \beta_4 roe_zcp_{it} \\ & + \beta_5 \ln employment_{it} + \beta_6 \ln total_capital_{it} + \beta_7 \ln cf_oa_{it} \\ & + \beta_8 \ln income_tax_{it} + \varepsilon_{it} \end{aligned} \quad (9)$$

Our paper sets a regression model, where *AccessisdeniedAccessisdenied* is represented as the net profit (after deducting government subsidies) of a Chinese-listed iron and steel enterprise *AccessisdeniedAccessisdenied* at period *AccessisdeniedAccessisdenied*. *zcp_gap_{it}* is represented as the profit gap compared to ZCP = 0, and it implies that if the gap is larger, which would present better the company's operating conditions and higher net profit. Therefore, I expect this variable to have a positive impact on net profit. *di_tfp_{it}* is the interaction term of the demand index and the TFP. It shows the simultaneous impact of forces from market investors and firm production on a firm's net profit, with other explanatory variables held constant. This study expects the sign of this interaction term to be positive. *roe_{it}* is the rate of return on common stockholders' equity, which is an important indicator of a company's profitability. Our research expects that the effect of this variable on net profit is positive. Moreover, *roe_zcp_{it}* = *roe_{it}* × *zcp_gap_{it}* is the interaction term, which simultaneously considers the impact of the company's profitability indicators and the company's actual operating performance on net profit. This paper expects that if the information asymmetry problem does not exist, the effect of this interaction term on net profit is positive. Finally, control variables include total number of employees employed (*lnemployment_{it}*), total capital (*lntotal_capital_{it}*), net cash flow from operating activities (*lncf_oa_{it}*), and income tax expense (*lnincome_tax_{it}*). ε_{it} is the error term.

Table 3. Empirical analysis of profit gap which compared to ZCP = 0.

zcp_gap_wrdg	OLS	FE(1)	FE(2)	FGLS	MLE
tfp_wrdg	−0.331*** (0.045)	−0.362*** (0.070)	−0.274*** (0.065)	−0.330*** (0.046)	−0.331*** (0.050)
di_npv	−3.047*** (0.311)	−2.435*** (0.349)	−2.848*** (0.303)	−2.828*** (0.306)	−2.792*** (0.276)
ditfp_wrdg	0.332*** (0.035)	0.259*** (0.036)	0.305*** (0.033)	0.306*** (0.033)	0.302*** (0.032)
constant	3.797*** (0.355)	4.102*** (0.585)	3.532*** (0.546)	3.800*** (0.381)	3.810*** (0.405)
R-square	0.242	0.214	0.352	0.240	-
F test(Prob>F)	-	0.000	0.000	-	-
LM test(Prob >chibar2)	-	-	-	0.000	-
Hausman Test(Prob >chi2)	-	-	-	0.020	-
LR test(Prob >chibar2)	-	-	-	-	0.001
ID FE	NO	YES	YES	NO	NO
Year FE	NO	NO	YES	NO	NO
Obs	550	550	550	550	550

Data source: Wind database, and calculated by this study.

Standard errors are in parentheses. * $p < .1$, ** $p < .05$, *** $p < .01$.

Before performing regression analysis on Equation (9), our study constructed a regression model to discuss the impact of technical efficiency, demand index, and interaction term on zcp_gap_{it} . This paper still selects the results under the WRDG method for discussion.⁸ The model is set as follows,

$$zcp_gap_{it} = \alpha_0 + \alpha_1 tfp_{it} + \alpha_2 di_npv_{it} + \alpha_3 ditfp_{it} + v_{it} \quad (10)$$

Where tfp_{it} is the total factor productivity and represented as the technical efficiency of a Chinese-listed iron and steel enterprise i at period t . di_{it} is the individual's specific demand index for the related product of a Chinese-listed iron and steel enterprise i at period t . $ditfp_{it}$ is the interaction term of the demand index and the TFP. v_{it} is the error term.

4.3.1. Results of empirical analysis

Based on Equation (10), our research respectively uses mixture regression, fixed-effects (within) regression, random-effects GLS (FGLS) regression, and random-effects MLE regression. The results are summarized in Table 3 as follows,

This paper finds that no matter which one of the regression models in Table 3, the technical efficiency and demand index are significantly negative for the dependent variable (zcp_gap_{it}) at the significant level of 1%. This result seems to be contrary to general expectations. However, as can be seen from Figure 1, given a lower level of demand index (or firm TFP), increasing the firm's TFP (or demand index) still hurts the profit gap. Therefore, this result is still justified. However, if the intersection term of the demand index and TFP is considered at the same time, it shows a significantly positive result. This means that an enterprise with a higher demand index from market investors and a higher production ability will inevitably have a significantly positive profit gap. In

⁸Since the regression results under the OP and ROB methods are consistent with those under the WRDG method, this article only presents the regression results under the WRDG method due to space limitations. If readers need it, please contact the author for it.

Table 4. Empirical analysis on zombie measurement of 28 listed iron and steel enterprises in China.

Innp_cgs	Model 1(WRDG)					Model 2(ROB)				
	OLS	FE(1)	FE(2)	FGLS	MLE	OLS	FE(1)	FE(2)	FGLS	MLE
zcp_gap	0.512*** (0.128)	0.456*** (0.129)	0.505*** (0.119)	0.482*** (0.127)	0.483*** (0.127)	0.524*** (0.135)	0.459*** (0.138)	0.579*** (0.128)	0.488*** (0.135)	0.490*** (0.078)
ditfp	0.116*** (0.014)	0.124*** (0.014)	0.111*** (0.016)	0.121*** (0.014)	0.121*** (0.008)	0.105*** (0.013)	0.112*** (0.013)	0.100*** (0.015)	0.110*** (0.013)	0.110*** (0.008)
roe	0.032*** (0.004)	0.034*** (0.005)	0.031*** (0.005)	0.033*** (0.005)	0.033*** (0.003)	0.033*** (0.005)	0.035*** (0.005)	0.032*** (0.006)	0.034*** (0.005)	0.034*** (0.003)
roezcp	-0.007*** (0.002)	-0.008*** (0.002)	-0.007*** (0.002)	-0.008*** (0.002)	-0.008*** (0.001)	-0.008*** (0.002)	-0.008*** (0.002)	-0.008*** (0.002)	-0.008*** (0.002)	-0.008*** (0.001)
Inemployment	-0.281*** (0.107)	-0.235*** (0.102)	-0.023 (0.124)	-0.252*** (0.101)	-0.253*** (0.085)	-0.305*** (0.112)	-0.259*** (0.109)	-0.032 (0.122)	-0.277*** (0.107)	-0.278*** (0.084)
Intotal_capital	0.478*** (0.075)	0.444*** (0.082)	0.312*** (0.135)	0.460*** (0.078)	0.461*** (0.068)	0.489*** (0.081)	0.456*** (0.088)	0.297*** (0.133)	0.472*** (0.083)	0.473*** (0.068)
Inncf_oa	0.115*** (0.042)	0.086*** (0.038)	0.009 (0.040)	0.096*** (0.036)	0.097*** (0.038)	0.117*** (0.042)	0.090*** (0.038)	0.009 (0.039)	0.100*** (0.037)	0.100*** (0.038)
Inincome_tax	0.143*** (0.063)	0.121*** (0.046)	0.106*** (0.038)	0.127*** (0.052)	0.128*** (0.027)	0.143*** (0.063)	0.122*** (0.047)	0.106*** (0.037)	0.128*** (0.052)	0.128*** (0.027)
constant	1.287*** (0.666)	1.646*** (0.683)	2.079* (1.151)	1.488*** (0.572)	1.480*** (0.600)	1.390* (0.685)	1.723*** (0.682)	2.294* (1.175)	1.576*** (0.583)	1.566*** (0.598)
R-sq	0.732	0.729	0.753	0.731	-	0.734	0.732	0.759	0.733	-
F test(Prob>F)	-	0.000	0.000	0.000	-	-	0.000	0.000	-	-
LM test(Prob >chibar2)	-	-	-	-	-	-	-	-	0.000	-
Hausman Test(Prob >chi2)	-	-	-	0.412	-	-	-	-	0.558	-
LR test(Prob >chibar2)	-	-	-	-	-	-	-	-	-	-
ID FE	NO	YES	YES	NO	NO	NO	YES	YES	NO	NO
Year FE	NO	NO	YES	NO	NO	NO	NO	YES	NO	NO
Obs	474	474	474	474	474	474	474	474	474	474

Data source: Wind database, and calculated by this study.
Standard errors are in parentheses. * $p < .1$, ** $p < .05$, *** $p < .01$.

addition, we found that the related tests performed significantly better in the fixed-effects model than the other regression models in Table 3. In the fixed-effects regression model, The F test in FE(1) and FE(2) is $P = 0.000 < 0.01$ and $P = 0.000 < 0.01$ respectively, so the two-way fixed effects model is significantly better than mixture regression and FE(1). In addition, in the FGLS model, the LM test for individual-specific effects is $P = 0.000 < 0.01$, and it is considered that the FGLS model should be selected. Finally, in the random-effects MLE model, the Likelihood-ratio test has $P = 0.001 < 0.01$, that is, there exist individual random effects, and the mixture regression should not be chosen. Finally, the Hausman test supports the use of the fixed-effects model rather than the random-effects model. In summary, the fixed-effects model is the better choice. It easily observes in Table 3 that the impact of the demand index on the profit gap is greater than the technical efficiency. This also means that the influence of individuals' preferences for enterprises on net profits is relatively important.

Afterward, this study conducted regression analysis on Equation (9). This study presents the results of using mixture regression, FE, two-way FE, FGLS, and MLE models under the WRDG and ROB methods, respectively. The relevant results are shown in Table 4 below.

According to the results of Model 1 (WRDG) and Model 2 (ROB) in Table 4, this paper finds that all the profit gap coefficient values (zcp_gap_{it}) have little difference and have a significant positive impact on net profit, and in mixture regression, FE, two-way FE, FGLS Both the MLE model and the MLE model meet the 1% significance level test. It means that the greater the difference between the actual profit of the enterprise and the $ZCP = 0$ in the current year, the company's operating performance is better. The estimated values of the interaction term ($ditfp_{it}$) of all models under WRDG and ROB methods are also similar, and it has a significant positive impact on the net profit of the enterprise at the 1% significance level. This result supports the previous expectation of this study, that market investor preferences and the company's production performance will simultaneously positively affect the company's development.

Moreover, the coefficients of roe_{it} perform well in all regression models and are statistically significant at the significant level of 1%. This seems to indicate that the capital or financial market positively impacts the company's net profit through the rate of return on common stockholders' equity in the current year. In practice, it is often observed that zombie enterprises with poor operating performance continue to survive after obtaining funds through the financial or capital markets. The occurrence of this situation seems puzzling. Some literature in the past has also tried to discuss this issue, and the conclusion is that some troubled banks have given loans to underperforming borrowers to avoid losses on their balance sheets. The deeper reason for this apparent problem may be information asymmetry. To test the existence of the information asymmetry problem, this study uses an interaction term ($roe zcp_{it}$) that can represent the actual operating conditions of steel enterprises (zcp_gap_{it}) and the preferences of individuals in the financial or capital market for individual enterprises (roe_{it}) to verify this problem. According to the previous empirical analysis results, zcp_gap_{it} and roe_{it} have significant and positive effects on the enterprise's net profit respectively. This result

is in line with our expectations. However, more interestingly, this study finds that the coefficient of the intersection term has a significant negative impact on the enterprise's net profit in all regression models of Table 4. This seems to be the opposite of our intuition. The impact of the financial or capital market on the enterprise's net profit through the rate of return on common stockholders' equity has changed while simultaneously considering the actual operating conditions. It implies the existence of information asymmetry between the financial or capital market and the actual operation of the enterprises in the Chinese iron and steel industry. This also means that the enterprise whose operating performance is in the region of $ZCP < 0$, is because of the problem of information asymmetry, which instead enables the enterprise to continue to operate. It is worth mentioning that the net profit in this study has deducted the impact from government subsidies, so the effect of Chinese government support can be excluded. This problem will be more serious after 2008, which leads to these listed iron and steel enterprises in the region of $ZCP < 0$ having the characteristics of zombie enterprises.

In the analysis of other control variables in Table 4, the signs of most of the control variables ($lnemployment_{it}$, $lntotal_capital_{it}$, $lncf_oa_{it}$) are in line with the expectations of this study, and most of them are significantly different from 0. It is worth noting that the estimates for income tax expense ($lnincome_tax_{it}$) have a positive sign and are significant with at least two stars in all models. This seems to be contrary to most people's expectations. However, looking at the original data, it is found that some of the 28 Chinese listed iron and steel enterprises had negative income tax expenses during the research period of this paper. This also indirectly proves the loss of some iron and steel enterprises. Therefore, after considering the deferred income tax assets at the same time, the income tax expense is negative. Finally, the positive sign of the estimated income tax expense would be reasonable after considering the above explanation.

4.3.2. Robustness and endogeneity analysis

This subsection will conduct a robustness analysis on the results of Table 4 above, so another financial indicator to measure the company's operating efficiency – return on assets (ROA) will be used as a substitute for the ROE indicator. In addition, because there may be a causal relationship between the profit gap and net profit, which will lead to the existence of endogeneity problems, this study will also use the instrumental variable method (IV) to deal with it. First, discuss the robustness analysis after replacing the ROE indicator with the ROA indicator, and the results are presented in Table 5 below:

Same as Tables 4, 5 still uses mixture regression, FE, two-way FE, FGLS, and MLE models for robustness testing under the WRDG and ROB methods, respectively. After replacing the ROE indicator with the ROA indicator, this study found that under all models, the impact of the profit gap (zcp_gap_{it}), ROA (roa_{it}), and interaction item ($ditfp_{it}$) on the company's net profit was significantly positive at the 1% significance level, and this result is robust. It is noteworthy that the interaction term ($roazcp_{it}$) used to verify the existence of the information asymmetry problem, after using the ROA indicator to replace the ROE indicator, most results have at least one star with a significantly negative impact (the mixture regression and two-way FE in Model 1 (WRDG) are excepted). This means that the existence of the information asymmetry problem between the preferences of market investors and the actual operating

Table 5. Robustness analysis of zombie measurement for 28 listed iron and steel enterprises in China.

Innp_cgs	Model 1(WRDG)					Model 2(ROB)				
	OLS	FE(1)	FE(2)	FGLS	MLE	OLS	FE(1)	FE(2)	FGLS	MLE
zcp_gap	0.674*** (0.138)	0.659*** (0.135)	0.577*** (0.144)	0.669*** (0.137)	0.668*** (0.129)	0.823*** (0.141)	0.770*** (0.132)	0.752*** (0.150)	0.805*** (0.138)	0.801*** (0.138)
dtfp	0.111*** (0.014)	0.121*** (0.015)	0.100*** (0.015)	0.115*** (0.014)	0.115*** (0.010)	0.100*** (0.013)	0.110*** (0.014)	0.091*** (0.014)	0.104*** (0.013)	0.104*** (0.009)
roa	0.096*** (0.020)	0.107*** (0.021)	0.107*** (0.022)	0.100*** (0.020)	0.100*** (0.016)	0.113*** (0.021)	0.124*** (0.022)	0.121*** (0.023)	0.117*** (0.020)	0.117*** (0.017)
roazcp	-0.033 (0.022)	-0.044* (0.023)	-0.026 (0.019)	-0.037* (0.022)	-0.037*** (0.014)	-0.053** (0.020)	-0.061*** (0.021)	-0.044** (0.018)	-0.055*** (0.020)	-0.056*** (0.015)
Inemployment	-0.264*** (0.081)	-0.272*** (0.090)	0.061 (0.141)	-0.263*** (0.076)	-0.263*** (0.094)	-0.295*** (0.086)	-0.303*** (0.098)	0.035 (0.144)	-0.295*** (0.082)	-0.295*** (0.094)
Intotal_capital	0.555*** (0.073)	0.556*** (0.086)	0.269** (0.117)	0.560*** (0.077)	0.560*** (0.078)	0.579*** (0.075)	0.583*** (0.089)	0.292** (0.116)	0.585*** (0.079)	0.586*** (0.077)
Inncf_oa	0.122*** (0.040)	0.085** (0.037)	-0.018 (0.038)	0.108*** (0.036)	0.107** (0.044)	0.122*** (0.040)	0.083** (0.037)	-0.021 (0.038)	0.109*** (0.037)	0.106** (0.044)
lnincome_tax	0.082 (0.056)	0.050 (0.044)	0.029 (0.035)	0.066 (0.052)	0.064* (0.033)	0.082 (0.057)	0.052 (0.044)	0.031 (0.034)	0.068 (0.053)	0.066** (0.033)
constant	0.297 (0.805)	0.816 (0.995)	2.013 (1.190)	0.430 (0.817)	0.449 (0.718)	0.228 (0.811)	0.753 (1.012)	1.929 (1.198)	0.342 (0.822)	0.373 (0.723)
R-sq	0.708	0.704	0.722	0.708	-	0.711	0.707	0.729	0.711	-
F test(Prob>F)	-	0.001	0.000	0.005	-	-	0.001	0.000	-	-
LM test(Prob >chibar2)	-	-	-	0.102	-	-	-	-	0.007	-
Hausman Test(Prob >chibar2)	-	-	-	-	0.006	-	-	-	0.058	-
ID FE	NO	YES	YES	NO	NO	NO	YES	YES	NO	0.008
Year FE	NO	NO	YES	NO	NO	NO	NO	YES	NO	NO
Obs	410	410	410	410	410	410	410	410	410	410

Data source: Wind database, and calculated by this study.
Standard errors are in parentheses. * $p < .1$, ** $p < .05$, *** $p < .01$.

Table 6. Endogeneity analysis (pooled-data effect).

Innp_cgs	Model 1(WRDG)					Model 2(ROB)				
	OLS	TSLS	LIML	GMM	IGMM	OLS	TSLS	LIML	GMM	IGMM
zcp_gap	0.512*** (0.097)	0.673*** (0.210)	0.673*** (0.210)	0.699*** (0.202)	0.699*** (0.202)	0.524*** (0.100)	0.660*** (0.208)	0.660*** (0.208)	0.683*** (0.200)	0.683*** (0.200)
diftp	0.116*** (0.013)	0.118*** (0.014)	0.118*** (0.014)	0.120*** (0.013)	0.120*** (0.013)	0.105*** (0.012)	0.105*** (0.012)	0.105*** (0.012)	0.106*** (0.012)	0.106*** (0.012)
roe	0.032*** (0.006)	0.033*** (0.006)	0.033*** (0.006)	0.033*** (0.006)	0.033*** (0.006)	0.033*** (0.006)	0.034*** (0.006)	0.034*** (0.006)	0.034*** (0.006)	0.034*** (0.006)
roezcp	-0.007*** (0.002)	-0.008*** (0.002)	-0.008*** (0.002)	-0.008*** (0.002)	-0.008*** (0.002)	-0.008*** (0.002)	-0.009*** (0.002)	-0.009*** (0.002)	-0.009*** (0.002)	-0.009*** (0.002)
Inemployment	-0.281*** (0.072)	-0.299*** (0.075)	-0.299*** (0.075)	-0.300*** (0.076)	-0.300*** (0.076)	-0.305*** (0.075)	-0.336*** (0.077)	-0.336*** (0.077)	-0.338*** (0.077)	-0.338*** (0.077)
Intotal_capital	0.478*** (0.064)	0.458*** (0.071)	0.458*** (0.071)	0.457*** (0.071)	0.457*** (0.071)	0.489*** (0.066)	0.479*** (0.070)	0.479*** (0.070)	0.479*** (0.071)	0.479*** (0.071)
Inncf_oa	0.115** (0.046)	0.122*** (0.047)	0.122*** (0.047)	0.120*** (0.046)	0.120*** (0.046)	0.117** (0.046)	0.124*** (0.047)	0.124*** (0.047)	0.122*** (0.046)	0.122*** (0.046)
Inincome_tax	0.143*** (0.044)	0.142*** (0.043)	0.142*** (0.043)	0.142*** (0.043)	0.142*** (0.043)	0.143*** (0.044)	0.142*** (0.043)	0.142*** (0.043)	0.142*** (0.043)	0.142*** (0.043)
constant	1.287** (0.517)	1.505*** (0.549)	1.505*** (0.549)	1.513*** (0.550)	1.513*** (0.550)	1.390*** (0.526)	1.654*** (0.563)	1.654*** (0.563)	1.666*** (0.563)	1.666*** (0.563)
R-sq	0.852	0.721	0.721	0.720	0.720	0.734	0.725	0.725	0.724	0.724
Obs	474	450	450	450	450	474	450	450	450	450
Overid test(Prob>chi2)	-	0.662	-	0.662	0.664	-	0.693	-	0.693	0.694

Data source: Wind database, and calculated by this study. Standard errors are in parentheses. * $p < .1$, ** $p < .05$, *** $p < .01$.

Table 7. Endogeneity analysis (panel instrumental variable method).

	Model 1(wrdg)					Model 2(rob)				
	FE(TSLS)	FD	RE(TSLS)	FE(GMM)	FD(GMM)	FE(TSLS)	FD	RE(TSLS)	FE(GMM)	FD(GMM)
Innp_cgs										
zcp_gap	0.280 (0.369)	0.772** (0.249)	0.513* (0.283)	0.280 (0.283)	0.772** (0.246)	0.257 (0.366)	0.819** (0.240)	0.493* (0.280)	0.257 (0.363)	0.819** (0.238)
diftp	0.121** (0.010)	0.122** (0.011)	0.121** (0.009)	0.121** (0.010)	0.122** (0.011)	0.111** (0.009)	0.107** (0.011)	0.109** (0.008)	0.111** (0.009)	0.107** (0.011)
roe	0.033** (0.004)	0.040** (0.004)	0.033** (0.003)	0.033** (0.004)	0.040** (0.004)	0.034** (0.003)	0.041** (0.004)	0.034** (0.003)	0.034** (0.003)	0.041** (0.004)
roezcp	-0.008** (0.001)	-0.010** (0.002)	-0.008** (0.001)	-0.007** (0.001)	-0.010** (0.002)	-0.008** (0.001)	-0.011** (0.002)	-0.008** (0.001)	-0.008** (0.001)	-0.011** (0.002)
Inemployment	-0.265** (0.104)	-0.019 (0.189)	-0.274** (0.091)	-0.265** (0.103)	-0.019 (0.187)	-0.277** (0.103)	-0.015 (0.186)	-0.304** (0.091)	-0.277** (0.102)	-0.015 (0.184)
Intotal_capital	0.446** (0.080)	0.152 (0.122)	0.455** (0.077)	0.446** (0.079)	0.152 (0.120)	0.451** (0.076)	0.130 (0.121)	0.471** (0.074)	0.451** (0.075)	0.130 (0.120)
Inncf_oa	0.084** (0.043)	0.005 (0.043)	0.102** (0.040)	0.084** (0.042)	0.005 (0.042)	0.086** (0.043)	0.001 (0.042)	0.105** (0.040)	0.086** (0.043)	0.001 (0.042)
Inincome_tax	0.123** (0.031)	0.068* (0.041)	0.128** (0.029)	0.123** (0.030)	0.068* (0.040)	0.124** (0.031)	0.065 (0.040)	0.129** (0.029)	0.124** (0.031)	0.065 (0.040)
constant	2.094** (0.839)	0.075 (0.056)	1.689** (0.662)	- (0.000)	0.075 (0.055)	2.155** (0.804)	0.075 (0.055)	1.805** (0.655)	- (0.000)	0.075 (0.054)
R-sq	0.715	0.670	0.723	0.658	0.530	0.716	0.681	0.725	0.659	0.541
Obs	450	382	450	450	382	450	382	450	450	382

Data source: Wind database, and calculated by this study.
Standard errors are in parentheses. * $p < .1$, ** $p < .05$, *** $p < .01$.

conditions of enterprises can still be verified after replacing different enterprise operating indicators, and this result is still robust.

Second, this study will conduct an endogeneity analysis. As explained above, there may be a causal relationship between net profit and profit gap, so we need to control the endogeneity problem of the profit gap. The instrumental variable method (IV) is a powerful econometric method to solve this problem. It is well known that perfect instrumental variables are not easy to exist, but this research still tries to find instrumental variables suitable for the profit gap. In this study, the added value of total operating income and the lagged one-period of profit gap are selected as instrumental variables finally. At the same time, under the WRDG and ROB methods, this study uses OLS, Two-Stage Least Square (TSLS), Limited Information Maximum Likelihood (LIML), Generalized Method of Moment (GMM), and Iteration Generalized Method of Moment (IGMM) to estimate the pooled-data effect of individual independent variables. Thereafter, an over-identified test is performed to determine whether all instrumental variables are exogenous. The results are presented in Table 6 below.

It can be easily observed from Table 6 that after controlling the endogenous problem of the profit gap, no matter whether in model 1 (WRDG) or model 2 (ROB), the estimated values of each independent variable are almost the same under all estimation methods. Over-identified tests also support that all instrumental variables are exogenous. The main independent variable (zcp_gap_{it} , $ditfp_{it}$, roe_{it} , $roezcp_{it}$) has no significant change in the coefficient value and the sign of the net profit after controlling the endogenous problem, and it is statistically significant at the 1% level of significance, so it is almost consistent with the previous conclusions of Table 4. Even by using the panel instrumental variable method to deal with the results are still basically the same. Table 7 below presents the results of the panel instrumental variable method under Model 1 (WRDG) and Model 2 (ROB) and estimates TSLS and GMM after dealing with fixed effects (FE) and first-order difference (FD) respectively. Through Table 7, it can be found that the influence of several main independent variables on net profit is not much different from the results in Table 6 in terms of coefficient value and significance.

4.3.3. Results integration and comparison

Through the simulation and empirical analysis of the zombie enterprise measurement method in this research, it is found that reasonable results can be obtained after considering the technical efficiency of the actual operation of the enterprise and the demand index of individuals' preference for the enterprise simultaneously. During 2007–2016, most enterprises gradually fell into the dangerous edge of the definition of zombie enterprises ($ZCP < 0$). It is worth mentioning that the measurement method in this study is different from other zombie enterprise measurement methods that purely use three consecutive years of negative operating profit or lower-than-average interest payments (such as the CHK or FN-CHK method). The ZCP in this paper also considers the actual operations of the enterprises and individuals' preferences for the enterprises. This method can avoid misjudgments by enterprises that are operating well and have great development potential when they obtain negative profits in the short term.

In addition, the measurement period of this study is from 2003 to 2022, it will be more severe for these China's listed iron and steel enterprises on the verge of danger after the

2008 financial crisis. According to the 2019 annual research report of the National Academy of Development and Strategy of China, among the five industries with the highest proportion of zombie enterprises in China, the iron and steel industry ranks first and the proportion is as high as 51.43%. This gives indirect support for the measurement method of this study. Finally, through the empirical analysis of this research, it is also observed that there is a problem of information asymmetry between financial or capital market individuals and the actual operation of the enterprise. This shows that financial or capital market individuals have information gaps on the actual operating conditions of enterprises. This is manifested in the continuous bank loans and financial support for these problematic companies. This will cause the problem of zombie enterprises to worsen. Compared with the past literature on zombie enterprises and information asymmetry, the results of this study also support the results of past related literature in some respects.

5. Conclusion

Most of the literature on the study of zombie enterprises in the past was measured by the performance of corporate financial reports. However, most of the leveraged operations of enterprises cannot be easily disclosed in financial reports, which also causes information asymmetry between the financial or capital market and the actual operation of enterprises. Therefore, this study constructs a measurement method of zombie enterprise and integrates corporate financial reports and actual operational status. Based on the data of 28 listed steel enterprises in China, and through the simulation and empirical analysis of listed steel enterprises, the effectiveness of the measurement method is verified. The data sources are mainly from the data of the Wind database. The data range is the 28 listed steel enterprises from 2003 to 2022.

This study extends the basic structure of Melitz (2003), and the productivity of an enterprise comes from the technical efficiency and the demand index. Technical efficiency is the manufacturer's production ability, and the demand index reflects the individual preference for the enterprise's product quality, brand name, or operation. Based on the above settings, the simulation and empirical analysis of this paper obtained the following results. Based on the results of the simulation analysis, this paper finds that the performance of 28 Chinese-listed iron and steel enterprises from 2007–2016 is not outstanding. After the subprime mortgage crisis in 2008, along with the supply-side structural reform in 2015, the actual operating conditions of most listed iron and steel enterprises gradually fell into the region of $ZCP < 0$. Our study finds that the interaction term of technical efficiency and demand index has a significantly positive effect on the profit gap (compared with $ZCP = 0$). This means that considering the impact of the production and consumption side at the same time is positive for the business performance of enterprises. In addition, the impact of the financial or capital market on the enterprise's operating profit through the ROE is significantly positive, which indicates that the support from the financial or capital market will contribute to the improvement of the enterprise's operating profit. But what is interesting is that the interaction term of ROE and profit gap has a significantly negative impact on net profit, which means that there may be information asymmetry between the support of financial or capital market investors and the actual operation of the enterprise. This means that enterprises with poor real operations (i.e., $ZCP < 0$) may continue to survive in the market with support

from the financial or capital markets with information asymmetry. The above descriptions are verified by the fact that some listed iron and steel enterprises have poor actual operations but are still alive in the market. The policy implication and guiding effect of this study are that the government can more accurately integrate and improve problematic companies through the measurement method of zombie enterprises. In the early stage when zombie enterprises cause a series of financial and capital market chaos, they can find problems faster and propose solutions. In addition, the existence of information asymmetry is often caused by the system. Therefore, after discovering that information asymmetry has caused the problem of zombie enterprises, it is a feasible solution to start from the direction of institutional mechanism design.

Because the iron and steel industry is an upstream supplier of raw materials, our paper uses the financial indicators of iron and steel enterprises as the downstream producers' or individuals' preferences for their products to calculate the demand index. Although it is understandable to give consistent weight to the financial indicators in the demand index. In the future extension, the measurement of the demand index should be further optimized. Hence, the limitation of this study lies in how to improve the accuracy of investors' estimation of the demand index of individual enterprise preferences. Since the demand index comes from the relevant indicators in the corporate financial report, how to choose the correct indicator and the weight of each indicator will be the key point. In the direction of the solution, it can point to a questionnaire survey of individuals in different industries, focusing on which financial indicators are more concern by individuals. This will help the accuracy of the demand index estimation. Finally, this approach should be further extended to other industries to increase the range of relevant data. Or study other countries as cases to test the measurement method of this study.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The fund of the Department of Education of Guangdong Province (ID: 2019WTSCX149).

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