Journal of Civil Engineering and Management
ISSN 1392-3730 / eISSN 1822-3605
2023 Volume 29 Issue 2: 131–142
https://doi.org/10.3846/jcem.2023.18356

ANALYSIS OF LABOR RESOURCES WASTAGE IN CHINA'S REAL ESTATE BROKERAGE: FROM THE PERSPECTIVE OF OPPORTUNITY COSTS

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Received 25 March 2022; accepted 2 September 2022

Abstract. Real estate brokerage has experienced the rapid growth over the past two decades in China, with a significant increase of employees. In particular, in the megacities like Beijing, the growth of employees exceeds the growth of real estate transaction volume. This may lead to the wastage of labor resources. In this regard, the optimal employee size (OES) in China's real estate brokerage is proposed from the perspective of opportunity costs, which include both under-size and over-size costs. In the proposed OES models, a real estate brokerage firm makes the optimal decisions of number of employees by minimizing expected opportunity costs. In addition, an iterative algorithm is employed to obtain the optimal employee size in different scenarios. The result reveals that high profit gained from the business does attract more employees than what is needed. By addressing various scenarios based on the game model, it is found that asymmetric competition, the increase of market participants, and demand fluctuations also contribute to the labor resources wastage in real estate brokerage industry. The theoretical analysis results are verified by taking Beijing as the case study. Finally, suggestions for reducing labor resources wastage in real estate brokerage of China are provided.

Keywords: real estate brokerage, labor resource, opportunity cost, optimal employee size.

Introduction

China's real estate industry has experienced the significant rapid growth over the last two decades (Zhou & Hui, 2022). An enormous number of houses were built in different cities. As a result, housing vacancy rates of some cities are high, which is a distinct feature of China's housing markets (Zhang et al., 2016; Glaeser et al., 2017). Due to the long cycle and complex processes of housing transactions, real estate brokerage becomes a necessity in the market. Especially in the first-tier cities like Beijing, the real estate market has been active with rapid price growth (Wang & Xu, 2017), which promotes the development of real estate brokerage industry. As shown in Table 1, the average growth rate of real estate brokerage employees is nearly three times that of the tertiary industry and more than four times that of the whole industry.

In addition, the development of the real estate brokerage industry necessitates more efficiency and efficient delivery of products and services (Nazarko & Chodakowska, 2017). In the real estate brokerage industry, remarkable technological advances such as virtual tours, machine learning algorithms, and digital closing can enhance efficiency and facilitate housing transactions (Barwick & Wong, 2019). However, Table 2 shows that labor productivity of real estate brokerage in Beijing has actually declined. It may lead to the wastage of labor resources and the loss to society.

Table 1. Growth rate of the employed population in some industries in Beijing (2008 to 2018)

Item	Real estate brokerage	Tertiary industry	Total industries
Annual average growth rate	9.81%	3.58%	2.35%

Note: The employment data of real estate brokerage industry are from the data bulletin of Beijing National Economic Census. The data of tertiary industry and total industries are from Beijing Statistical Yearbook 2020.

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Table 2. Housing transaction volume and employed population of Beijing real estate brokerage in 2008, 2013, and 2018

Item	2008	2013	2018
Housing transaction volume (unit)	149,000	245,000	189,000
Employed population	39,000	90,855	99,424
Ratio (unit/person)	3.821	2.697	1.901

Note: The employment data are from the data bulletin of Beijing National Economic Census (No. 2-4), which is the same with Table 1. The data of stock housing transaction volume are from Beijing Real Estate Yearbook (2009, 2014 and 2019).

Nevertheless, according to the survey of Aujuke (58 Anjuke Institute, 2021), in China, 72.1% of the real estate brokerage employees (also called real estate agents in this paper) don't have qualification certificates. The low professional ability of unlicensed personnel will lead to inefficiency of the industry. Figure 1 shows that real estate agents' working years are very short in China. More than 40% of them only worked for less than one year in this industry. Low professional ability and high mobility result in the wastage of social labor resources. More educated labors have entered the real estate brokerage industry. For example, more than 28% of all the agents in Beijing are with at least the bachelor degree (China Real Estate Managers Union & Beike Research Institute, 2021). On the one hand, these highly qualified employees lose the chance of learning specific skills and making contributions for other industries. On the other hand, low professional ability and high mobility of real estate agents increase society instability and hinder sustainable and steady development of the real estate brokerage industry. Therefore, it is meaningful to analyze factors causing the wastage of labor resources and take proactive measures to alleviate it.

Unlike the real estate brokerage industry in other countries, real estate agents in China usually work for real estate brokerage firms. A typical agent uses the resources of a firm, works for bringing income to the firm, and works his own wages based on the contribution to the firm. This means that real estate brokerage firms participate in real estate brokerage activities as market entities. They hire employees to search for buyers and sellers and make matches. Once a match is made, the real estate brokerage firm receives a commission and pays part of it to the agents. Assuming employees are homogenous, the more employees a real estate brokerage firm employs, the more searching and matching activities they will perform. More matches usually lead to more revenue of the firm. Therefore, hiring employees can be seen as an investment for real estate brokerage firms. However, due to the uncertain demand of the market, the potential number of matches is unknown. The investment of a real estate brokerage firm, that is, the size of the employees is usually based on the expected number of matches over a period of time, which is called the supply for matches. When the supply is more than the demand, the firm will suffer the loss of excess investment, which is one decision-making opportunity cost. When the supply is less than the demand, the firm is unable to achieve the optimal amount of business and thus lead to the reduced revenue, which is another decision-making opportunity cost. In this regard, a real estate brokerage firm can determine the optimal employee size with the objective of minimizing the total opportunity cost, i.e., maximizing the expected profits. This paper models the optimal employee size decisions of real estate brokerage on the basis of opportunity costs, analyzes the factors that cause the wastage of labor resources in China's real estate brokerage industry, and puts forward the suggestions for reducing the wastage of labor resources.

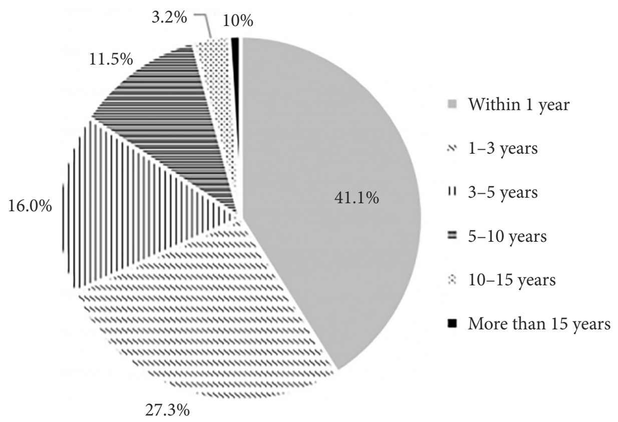


Figure 1. Real estate agents' working years in China (58 Anjuke Institute, 2021)

The remainder of this paper is organized as follows. Section 1 conducts the comprehensive review of related works. Section 2 proposes an optimal employee size model based on opportunity costs and extends it to the competitive environment. In Section 3, the authors provide an algorithm to solve the model. Section 4 discusses the factors influencing the decision-making processes. Section 5 takes Beijing as the case study to verify the theoretical results. It further explains the existence of the phenomenon of the wastage of labor resources. Section 6 presents the policy suggestions to reduce the labor resources wastage. Finally, conclusive remarks are provided.

1. Literature review

A number of researchers investigated the loss of efficiency in the real estate brokerage industry. Competition is one of the causes of inefficiency. Yinger (1981) pointed out that search activities reflect competitions among agents for potential matches. In addition, he stated that the establishment of Multiple Listing Services (MLS) in the United States reduces the inefficiency in the market for broker services because it leads to a decline in agents' search activities without lowering the expected number of matches. Competition in real estate brokerage has some special features. Yavas (2001) showed that the presence of fixed costs in the real estate brokerage makes it impossible to have a competitive commission rate as the equilibrium outcome. Therefore, in order to attract more customers, the brokerage firms will adhere to nonprice competition, such as increased name-brand advertising and employment of more employees to improve services. Also, Zumpano et al. (1993) conducted an empirical study, which shows (1) modest economies of scale persist throughout almost the entire range of output in the real estate brokerage industry, and (2) large firms do not command a competitive advantage over small firms as far as unit costs are concerned. Moreover, they pointed out that economies of scale of a few very large firms have been largely exhausted because the demand for brokerage services cannot be easily predicted given the volatility of the housing market. This has been demonstrated by DeVany and Frey (1981) that excess capacity may be an efficient market response when demand is random and uncertain.

The commission pattern and the inflow of employees will also reduce the efficiency of the real estate brokerage industry. They could affect the competition and thus influence the efficiency of the industry. Hsieh and Moretti (2003) showed that the entry of real estate agents into cities with high housing prices is socially inefficient with the fixed commission rate. Han and Hong (2011) estimated the cost inefficiency due to free entries to the industry and provided the evidence for a loss of economies of scale and wasteful non-price competition in the real estate brokerage industry. Miceli et al. (2007) examined the traditional compensation model for real estate agents under which both the listing and buyer agents are paid by the seller based on a percentage of the property sales price. They argue that it creates substantial transactional inefficiencies for buyers and sellers at both the matching and bargaining stages of a transaction. Barwick and Pathak (2015) pointed out that the agent entry reduces average service quality and causes inefficiency by an empirical study of real estate agents in Greater Boston. Barwick and Wong (2019) also indicated that high commissions and low entry barriers cause social losses including the excess entries of agents and firms, misallocation of labor resources, and low labor productivity. In addition, Zumpano et al. (2003) presented that the Internet use increases search intensity and agent productivity by analyzing data from NAR's survey. Viriato (2019), Benefield et al. (2019) and Saiz (2020) showed artificial intelligence, machine learning as well as other new technologies have the same effect. Osmond et al. (2015) stated that the lack of professional training contributes to the inefficiency of real estate brokerage firms.

China's real estate brokerage market is different from that of developed countries to some extent. Research on China's real estate brokerage market focuses on efficiency, impacts on housing price, transactions, and so on. Regarding the governance, in the United States, real estate brokerage industry has established Multiple Listing Services, which facilitates information sharing and is not available in China. MLS is considered as a key means of standardized development and effective management of the industry, and also provides a broader development space for the future of the industry. Jiang and Song (2011) found that the real estate brokerage industry in China stays in the development phase of non-shared information, causing high information search costs, low market operation efficiency, and a serious waste of resources compared to the United States. Yang et al. (2019) presented that the inefficiency status of the Chinese real estate industry including real estate brokerage increased after 2012 based on the DEA approach. In addition, the principal-agent relationship in Chinese brokerage system is not clear. H. Wang and K. Wang (2012) found that China's brokerage system allows one seller to negotiate with multiple agents and has no exclusive listing to define the principal-agent relationship. Comparatively, the U.S. system seems to have the advantages of transparent and efficient in information gathering. They were also confused the system could survive for such a long period and speculated that the system may have some unknown advantages. Regarding the commission pattern, Y. Zhang and H. Zhang (2014) comparatively examined the effects of the fixed-percentage commission pattern and the flat-fee pattern on the agents' behavior in China based on the economic experiment. They suggested that the related government departments should properly encourage the use of the flat-fee pattern. He et al. (2018) proposed an agent-based resale model to examine the effects of agents' distorted market information towards the market performances. Zhang et al. (2021) found that online property brokerage platforms may decrease the price of second-hand houses and boost the sales of second-hand houses in China.

As mentioned in the introduction section, a large number of workers enter into Beijing real estate brokerage industry. Some of them receive high education and get at least bachelor degrees. The inflow of a large number of employees may lead to the reduction in labor productivity and the loss of social welfare because some of these individuals and firms could have engaged in the production of goods and services in other sectors that is more valuable to society (Barwick & Wong, 2019). Other industries may suffer insufficient labor indirectly. For example, insufficient labor in the construction industry is one important reason of project delay (Chiu & Lai, 2017). Also, shortage of construction workers and ageing workforce become barriers to the adoption of new safety technologies in construction (Yap et al., 2022). Moreover, the excess entry is often associated with a prevalence of inexperienced agents during house price booms. Inexperienced agents take longer to sell properties, which can have aggregate impacts on housing cycles (Gilbukh & Goldsmith-Pinkham, 2021). Low labor productivity can also lead to low industry income (Datta et al., 2005) and high unemployment (Fuchs-Schündeln & Izem, 2012). Nevertheless, the decline of labor productivity will also affect sustainable economic development and be not conducive to social stability (Fedulova et al., 2019). In this regard, the influence of wasting labor resources is harmful for both this industry and other industries. For the real estate brokerage industry, the essence of the wastage of labor resources is the loss of efficiency. The existing literature has discussed the phenomenon of labor resources wastage from the aspect of efficiency loss. Moreover, most of the literature considers the market of developed countries such as the United States and there is little research on the Chinese real estate brokerage industry. This paper attempts to analyze the reasons causing the wastage of labor resources in China's real estate brokerage industry from the perspective of opportunity costs and propose some suggestions for the sustainable development of the real estate brokerage industry in China.

2. The Optimal Employee Size (OES) model

2.1. Background

The Optimal Employee Size (OES) model is to describe the process by which real estate brokerage firms make employee size decisions. Without loss of generality, the model examines the process of a typical decision period. At the beginning of the period, real estate brokerage firms hire employees according to the expectations of market demand. During the period, employees seek out customers and provide services, earn commissions for the firm and themselves. When a real estate brokerage firm employs fewer people than its need, the firm will not be able to handle the amount of business required by the market, and thus to incur opportunity costs. It is called under-size cost. When a real estate brokerage firm hires more employees than its need, the firm will have to pay extra payroll. It is called over-size cost. Firms make optimal employee size decisions by minimizing the sum of these two opportunity costs. The fixed costs per employee include base salary, social security payments, training, licensing fees, etc.

In China's real estate brokerage industry, the charging mode is a fixed-percentage commission pattern. Real estate brokerage firms charge buyers and sellers a percentage of the transaction fee as a commission. The real estate agents' salaries are divided into base salary and performance pay. The base salary is fixed and the performance pay is based on the value of each transaction. Therefore, the firm's income during this period is commission minus the employees' share and subtracts fixed costs (including base salary and other costs). One employee's income during this period is the base salary plus performance pay. Both the firm and employees make decisions based on opportunity costs. When employees choose a job and consider a real estate agent as a candidate, they will choose a real estate brokerage firm if their expected income in the real estate brokerage industry is higher than that in other industries. Unlike the fixed salary for most jobs, real estate agents' salaries vary largely. Some people can only get a basic salary, while some people can get a high salary through more transactions. However, in the fixed-percentage commission pattern, higher housing price leads to higher expected incomes for employees. For example, Beijing is a city with high housing price and thus attract many people to enter the real estate brokerage industry. Because this paper focuses on company decisions rather than employee decisions, employee decisions are not considered in the model.

2.2. Assumptions

Without loss of generality, the assumptions are presented as follows:

- *Assumption 1.* All employees are homogeneous. They have the same ability to work and the same work hours. Overtime is not allowed.
- *Assumption 2.* The company employs or dismisses employees at the beginning of the period and employee size keeps unchanged during the period.
- *Assumption 3.* Transactions (matches) are homogeneous, each transaction corresponds to m employees, with m being a constant.
- *Assumption 4.* The supply of labor is sufficient, and the price of labor remains unchanged.
- *Assumption 5.* The distribution function of the demand in the market is continuous and known.

2.3. The OES model for one real estate brokerage firm

We define "under-size marginal cost" as opportunity cost due to the lack of one employee. Similarly, "over-size marginal cost" is defined as opportunity cost due to the redundancy of one employee.

The expected total opportunity cost (TOC) is evaluated as:

$$E(TOC) = c_u (D-Q)^+ + c_o (Q-D)^+, \tag{1}$$

where c_u is under-size marginal cost; c_o is over-size marginal cost; Q is the number of employees employed by the company; D is the number of employees required for the company's business; $(x-y)^+ = \max(x-y, 0)$. In particular, c_u and c_o can be calculated through the firm's actual data, such as commission rate, costs, etc.

The expected profit $E(P)$ is the difference between maximum revenue and expected total opportunity costs as Eqn (2):

$$E(P) = c_u D - c_u (D-Q)^+ - c_o (Q-D)^+. \tag{2}$$

The decision goal is to maximize the expected profit, which is the same as to minimize the expected opportunity cost. In conclusion, the OES model for one real estate brokerage firm is given as follows:

$$\max_Q E(P) = c_u D - c_u (D-Q)^+ - c_o (Q-D)^+. \tag{3}$$

Based on Assumption 5, the optimal solution of Eqn (3), which is denoted as Q^*, should satisfy:

$$F_D(Q^*) = \frac{c_u}{c_u + c_o}, \tag{4}$$

where $F_D(\circ)$ is the distribution function of D. Let $F_D^{-1}(\circ)$ denote the inverse distribution function of D and thus Q^* could be further expressed as:

$$Q^* = F_D^{-1}\left(\frac{c_u}{c_u + c_o}\right). \tag{5}$$

2.4. The OES model under competition

In the market, there are a lot of companies so that there exist competitions among companies. Inspired by Rajaram and Tang (2001), Zhang et al. (2014) and Y. Zhao and X. Zhao (2016), we propose an OES model that considers alternative competition between real estate brokerage firms. Let n denote the number of firms. Customers arrive in the market and expect to get a match. If their preferred firm is not available, some customers may try to find another firm. That is, if any demand cannot be met by firm i, α_{ij} of the unsatisfied demand will switch to firm j (if available) which is acted as a substitute ($\alpha_{ij} = 0$ for all i), where $\sum_{j=1}^{n}\alpha_{ij} \le 1$. α_{ij} is called as substitution fraction. Assume that all the customers will leave the market if they suffer a second stockout, and each firm has perfect information about the employee size of other firms.

Under the competitive situation, firm i's optimal decision will depend on employee size s of other firms. The expected profit of firm i is set as $E(P_i)$. The effect from substitution will redefine the demand function D_i^s (s means substitution) as:

$$D_i^s = D_i + \sum_{j\ne i}\alpha_{ij}\left(D_j - Q_j\right)^+ . \qquad (6)$$

And the expected profit function of firm i with the substitution can be formulated as follows:

$$\max_{Q_i} E\left(P_i\right) = c_{ui}D_i^s - c_{ui}\left(D_i^s - Q_i\right)^+ - c_{oi}\left(Q_i - D_i^s\right)^+, \quad (7)$$

where c_{ui} and c_{oi} are under-size marginal cost and over-size marginal cost for firm i respectively. When the employee size of other firms $Q_j\left(i \ne j\right)$ are given, D_i^s in Eqn (6) is continuous according to Assumption 5. Therefore, similarly, the optimal employee size of firm i under competition Q_i^* could be expressed as:

$$Q_i^* = F_{D_i^s}^{-1}\left(\frac{c_{ui}}{c_{ui}+c_{oi}}\right). \qquad (8)$$

In addition, Netessine and Rudi (2003) proved that there exists a Nash equilibrium in the competition model and it is unique and globally stable.

3. An iterative algorithm for solving the OES model under competition

Though it is known that a Nash equilibrium do exist in the competitive model, it is still a challenge to obtain the exact solution. To obtain an approximate optimal solution, Hopp and Xu (2008) proposed a static approximation method for dynamic demand substitution. Based on this approach, Huang et al. (2011) and Zhang et al. (2014) developed an iterative algorithm to solve the substitution problem and the cross-selling problem, respectively. In this paper, a similar algorithm is used to solve the OES model under competitive conditions.

The effective demand for each firm under substitution is estimated by the service-rate approximation approach. The service rate function $E\left[\min\left(D_i, Q_i\right)\right] / E\left(D_i\right)$, is used to approximate the proportion of unsatisfied demand for firm i. When Q_i is given, then it can be determined. It should be noted that $\hat{D}_i^s$ in Eqn (9) is an unbiased estimation of D_i^s in Eqn (6), i.e., $E\left(\hat{D}_i^s\right) = E\left(D_i^s\right)$:

$$D_i^s \approx \hat{D}_i^s = D_i + \sum_{j\ne i}\alpha_{ij}D_j\{1 - \frac{E\left[\min\left(D_j, Q_j\right)\right]}{E\left(D_j\right)}\}, \qquad (9)$$

where

$$E\left[\min\left(D_j, Q_j\right)\right] = \mu_j F_{D_j}\left(Q_j\right) + Q_j\left(1 - F_{D_j}\left(Q_j\right)\right), \quad (10)$$

where μ_j and σ_j are mean and standard variance of D_j respectively.

The basic idea of the iteration algorithm is to update D_i^s and Q_i constantly until optimal condition in Eqn (8) $Q_i = F_{D_i^s}^{-1}\left(\frac{c_{ui}}{c_{ui}+c_{oi}}\right)$, i.e., $F_{D_i^s}\left(Q_i\right) = \frac{c_{ui}}{c_{ui}+c_{oi}}$ is satisfied. Suppose that in the t-th iteration the solution is and the approximated effective demand is $\hat{D}_i^{s,t}$. For the (t+1)-th iteration, we calculate the solution Q_i^{t+1} as Q_i from $Q_i^{t+1} = F_{\hat{D}_i^{s,t}}^{-1}\left(\frac{c_{ui}}{c_{ui}+c_{oi}}\right)$. Then with a given Q_i^{t+1} we determine $\hat{D}_i^{s,t+1}$ as D_i^s. When the difference between $F_{D_i^s}\left(Q_i\right)$ and $\frac{c_{ui}}{c_{ui}+c_{oi}}$ is small enough, the iteration could be stopped to get the optimal solution. The step-by-step procedure of the iterative algorithm is described as follows:

Step 1: Choose the initial employee size $\left\{Q_i^0\right\}_{i=1,2,\ldots,n}$, for each firm i:

$$Q_i^0 = F_D^{-1}\left(\frac{c_{ui}}{c_{ui}+c_{oi}}\right), \; i = 1,2,\ldots,n .$$

Step 2: Start the iteration. For the t-th iteration:

(a) Set $\widehat{\mu}_i^{s,t}$ and $\widehat{\sigma}_i^{s,t}$ are mean and standard variation of $\hat{D}_i^{s,t}$ respectively. They are calculated by

$$\widehat{\mu}_i^{s,t} = \mu_i + \sum_{j\ne i}\alpha_{ij}\mu_j\{1 - \frac{E\left[\min\left(D_j, Q_j^t\right)\right]}{E\left(D_j\right)})\}$$

and

$$\widehat{\sigma}_i^{s,t} = \sqrt{\left\{\begin{array}{l} \sigma_i^2 + 2\sum\limits_{j\ne i}\rho_{ji}\alpha_{ij}\sigma_i\sigma_j\{1 - \frac{E\left[\min\left(D_j, Q_j^t\right)\right]}{E\left(D_j\right)}\} \\ +\sum\limits_{j\ne i}\sum\limits_{k\ne i} \begin{array}{c} \rho_{jk}\alpha_{ij}\alpha_{ik}\sigma_j\sigma_k\left\{1 - \frac{E\left[\min\left(D_j, Q_j^t\right)\right]}{E\left(D_j\right)}\right\} \\ \left\{1 - \frac{E\left[\min\left(D_k, Q_k^t\right)\right]}{E\left(D_k\right)}\right\} \end{array} \end{array}\right\}}.$$

(b) Calculate the employee size of firm i, Q_i^t , by

$$Q_i^t = F_{\hat{D}_i^{s,t}}^{-1}\left(\frac{c_{ui}}{c_{ui}+c_{oi}}\right).$$

Step 3: Calculate the difference between $F_{D_i^s}(Q_i)$ and $\frac{c_{ui}}{c_{ui}+c_{oi}}$, ε_i:

(a) Update D_i^s as $\hat{D}_i^{s,t+1}$ with a given Q_i^t.

(b) Calculate $\varepsilon_i = \left| F_{D_i^s}(Q_i) - \frac{c_{ui}}{c_{ui}+c_{oi}} \right|$.

Step 4: Check whether $\varepsilon_i < \delta$ for all i. If it is not within the tolerance, then GOTO Step 2. In this paper we set δ = 0.001.

Step 5: The optimal solutions are as follows: $Q_i^* = \left[Q_i^t \right]$ for all i, where $\left[x \right]$ means rounding x to the nearest integer.

4. Factors influencing optimal employee size decisions

In order to find out the reasons of the wastage of labor resources in China's real estate brokerage industry, the factors leading to large-size optimal decisions should first be identified. In this section, we analyze the factors that influence the optimal employee size decision by setting different values for various parameters. In the analysis, it is assumed that (1) there exist substitutions between companies; and (2) the initial demands faced by the companies are independent of each other. This section considers symmetrical and asymmetric substitution scenarios, respectively. In the scenario of symmetric substitution, the substitution fraction is set to be the same. In the asymmetric scenario, the different substitution fractions reflect the unbalanced strength of the companies.

4.1. Symmetric scenario

For symmetry, the substitution fractions of two firms i and j are equal ($\alpha_{ij} = \alpha_{ji} = \alpha$). To analyze the impact of the number of transactions on the results, let's first consider there are two firms in the market, and then consider the situation of three firms. Let τ be a critical ratio that reflects the profit margin of the brokerage market:

$$\tau = \frac{c_u}{c_u + c_o} = \frac{1}{1 + \frac{c_o}{c_u}}. \tag{11}$$

To be more intuitive, assume that the demand faced by each firm follows a normal distribution with mean μ = 1000, and deviation σ is set differently to show the difference of demand fluctuation. If $\tau < 0.5 (= 0.5) (> 0.5)$, it is taken as low (medium) (high) case regarding critical ratio, and if $\sigma < 200 (= 200) (> 200)$, it is taken as low (medium) (high) case regarding demand deviation. Table 3 lists the parameter settings for the four cases.

In the four cases, the substitution fraction is from 0 to 1 in 0.1 steps. The results of the optimal employee size decision are shown in Figure 2 (two firms' scenario) and 3 (three firms' scenario). Figures 2a and 3a show the effect of critical ratio and substitution fraction on the results respectively. Meanwhile, Figures 2b and 3b show the effect of standard deviation and substitution fraction on the results respectively.

Based on the above analysis, it can be seen that firms make employee size decisions that far exceed the mean of demand (μ) in the cases of high critical ratio. When the substitution rate is equal to zero, there are varying degrees of deviation between the optimal quantity Q_i^* and the mean of demand μ. It indicates a wastage of labor re-

Table 3. Values of parameters in symmetric cases

Case	Critical ratio	Demand deviation
1	Low: 0.2	Low: 200
2	Medium: 0.5	Low: 200
3	High: 0.8	Low: 200
4	High: 0.8	High: 400

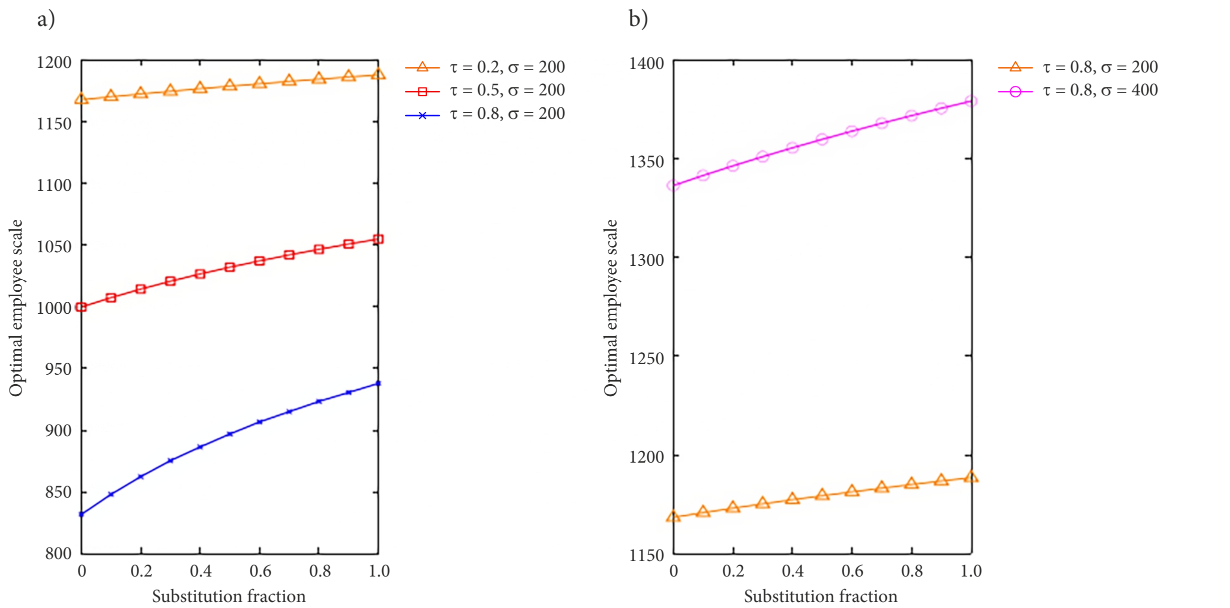


Figure 2. Optimal employee size vs substitution fraction in two-firm condition: a – τ is changed; b – σ is changed

sources, which can be regarded as the wastage of labor resources in the initial stage. By setting Q_i^{s*} as the optimal quantity with substitution, the wastage degree ω_i is defined as:

$$\omega_i = \frac{Q_i^{s*} - Q_i^*}{Q_i^*}. \quad (12)$$

Taking Q_i^*, the optimal quantity of the simple OES model as a benchmark, ω_i is used to judge the wastage of social labor resources, which can be regarded as the wastage of labor resources in the further stage. The average degree of wastage in different cases is shown in Figure 4.

Observation 1. Changes in substitution fractions have an impact on the optimal size.

The optimal employee size in the two-firm scenario (Figure 2) and three-firm scenario (Figure 3) show that, $Q_i^{s*} > Q_i^*$ when $\alpha > 0$. And the optimal size Q_i^{s*} has obviously positive correlation with substitution fraction α.

Observation 2. The optimal size increases with demand fluctuations.

Faced with the same profit margin, optimal scale Q_i^{s*} increases significantly when the standard deviation of demand σ increases from 200 to 400 in both scenarios. The change of standard deviation also doubles wastage degrees of both conditions as can be seen in Figure 4.

Observation 3. A higher profit margin leads to larger optimal size and more serious wastage.

In Figure 2 and Figure 3, the optimal size increases with τ. Although the average wastage degree decreases with profit margin in Figure 4, the reason is that the Initial Stage Wastage is very large with a high-profit margin.

Observation 4. The increase of firm quantity results in more serious wastage.

The optimal size in the three-firm scenario is larger than that in the two-firm scenario. In addition, the wastage degree in the three-firm scenario is also larger than that in the two-firm scenario as shown in Figure 4. It reflects that a firm chooses to hire more employees when facing more participants in the market.

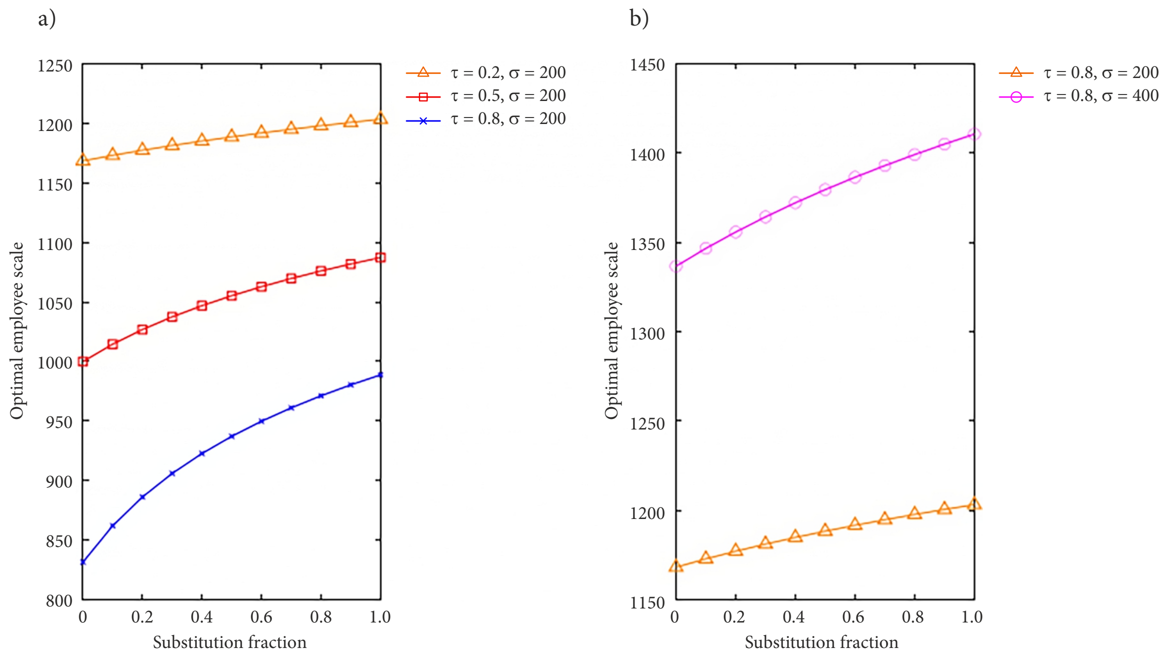


Figure 3. Optimal employee size vs substitution fraction in three-firm condition: a – τ is changed; b – σ is changed

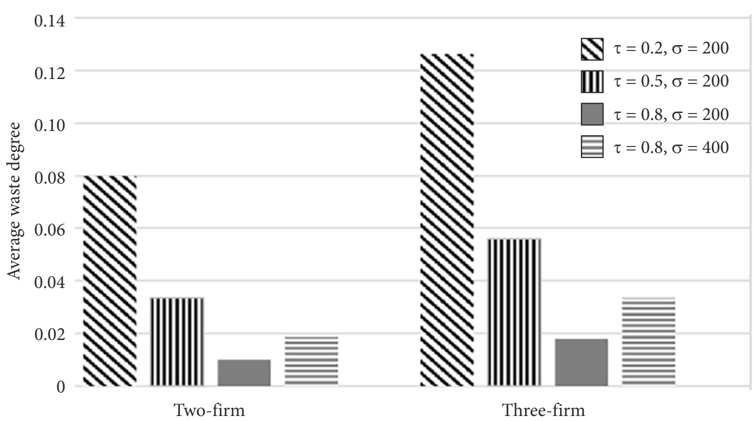


Figure 4. Results of average wastage degree in symmetric cases

4.2. Asymmetric situation

In the asymmetric cases, there are three firms in the market where Firm 3 has the largest competitiveness among three firms while Firm 2 is stronger than Firm 1. Therefore, Firm 3's substitution fraction to Firm 1 and 2 is the largest (set as 0.5). The parameters are listed in Table 4, especially the settings of substitution fractions.

The results of the asymmetric cases are as shown in Figure 5.

Observation 5. The complexity of the competitive environment has a significant influence on the wastage of labor resources.

The optimal employee sizes of asymmetric cases are presented in Figure 5. The influences of parameters are almost the same as the influences in symmetric cases. However, it's notable that the complexity of the competitive environment plays an important role. On the one hand, the total optimal size in the three-firm scenario is larger, that is, the wastage degree of the whole market further increases. On the other hand, the complexity of the competitive environment magnifies the influences of substitution fractions and demand fluctuations. In particular, different substitution fractions make different optimal sizes which is obviously enhanced than symmetric cases. For the actual market which is more complex than the numerical cases, it can be estimated how serious the wastage of labor resources in real estate brokerage would be.

Table 4. Values of parameters in asymmetric cases

Case	Substitution fraction	Critical	Ratio	Demand	Fluctuation
1	$\alpha_{21} = \alpha_{31} = 0.1$	Low	0.2	Low	200
2	$\alpha_{12} = \alpha_{32} = 0.3$	High	0.8	Low	200
3	$\alpha_{13} = \alpha_{23} = 0.5$	High	0.8	High	400

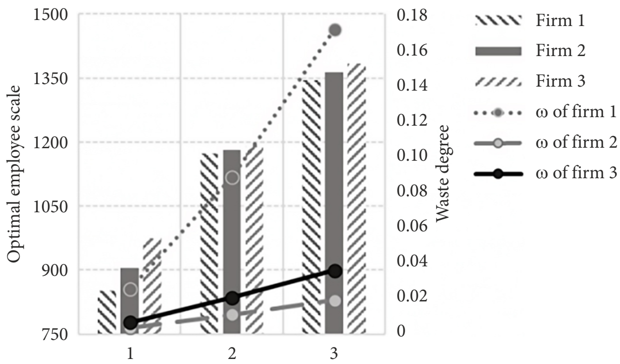


Figure 5. Results of optimal employee size and wastage degree in asymmetric cases

5. Case study: Real estate brokerage industry in Beijing

5.1. Situation analysis of labor resources wastage

The real estate industry in Beijing has developed rapidly in the past two decades, with the housing price rising to a high level. With a large number of housing transactions, the number of real estate agents has increased substantially. However, as a typical city with excessive real estate agents in China, the growth labor resources of the real estate brokerage industry in Beijing exceeds the growth of housing transaction volume, as shown in Table 1 and Table 2. In contrast, in the United Kingdom, there are more than one million housing transactions each year with only 50,000 agents. In the United States, six million housing transactions occur annually under the guidance of 1.3 million agents (Barwick & Wong, 2019). The ratio of housing transaction volumes to agents in the two countries is about 20 and 4.6, respectively. In 2018, the corresponding value of Beijing is 1.9, as shown in Table 2, which indicates that the labor productivity of this industry in Beijing is very low. It can be seen that the labor resources wastage of real estate brokerage in Beijing is serious.

According to the previous analysis, real estate brokerage firms make the optimal employee size decisions from the perspective of opportunity cost. The firms' excessive size decisions and sufficient labor supply have resulted in excess of employees in this industry. Excessive size is led directly by high under-size marginal cost and low over-size marginal cost, while some market factors jointly result in the features of both marginal costs.

5.2. Factors analysis of large optimal employee size decisions

5.2.1. High profit

In China, due to the regulations of the central government, the commission rate of real estate brokerage firms in different areas is almost the same. Due to the fixed-percentage commission pattern, real estate brokerage firms in cities with higher housing price will earn higher profits. In Figure 6, we draw the housing price to income ratio of Beijing and the whole country in the past 10 years respectively with a 30 m^2 per capita living area. Beijing's price-to-income ratio is about twice that of the whole country. On the one hand, high commission results in a high opportunity cost loss for the firm to lose one successful business. On the other hand, the employee will earn a lot once a match is completed from the commission and he will suffer a high expected opportunity cost loss if he doesn't serve as a real estate agent. Therefore, real estate brokerage firms expect to hire more employees to complete as many matches as possible. Similarly, workers also want to serve as real estate agents. It could lead to a massive allocation of labor resources in this industry. However, not every speculator can make money in the industry. This can be illustrated by the fact that 40% of people leave the industry within a year, causing the wastage of labor resources.

5.2.2. Volatile market

China's real estate market has experienced rapid development in the past two decades due to the support of macro policies (Meng et al., 2018). Most of the time, to alleviate the contradiction between supply and demand and curb the rapid rise of housing prices, the central government adopts various policy measures to restrain market demand. There also exist policies to support demand, including policy measures in 2009 and 2014 (Guo, 2017). In addition, compared with developed countries, China's housing market fluctuation is relatively independent of the international housing market, and its operation is mostly affected by economic growth and policy intervention (Yang et al., 2017). Especially in the capital Beijing, its market demand fluctuation is great. Statistics on the transactions of existing and newly built commercial houses in Beijing from 2016 to 2020 are shown in Table 5. It can be seen that the standard deviation and coefficient of variation are very large. The fluctuation of real estate demand increases the allocation of labor resources in real estate brokerage.

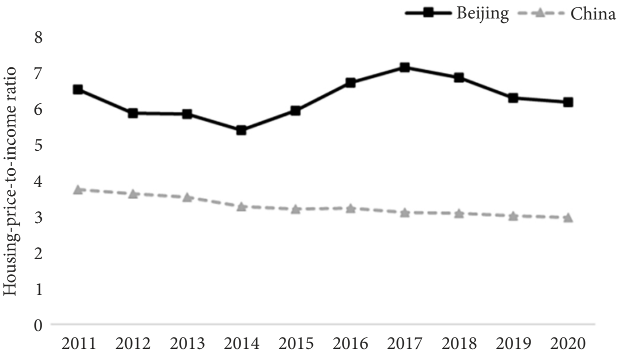
5.2.3. Complicated market environment and fierce competition

According to the fourth economic census of Beijing, at the end of 2018, 6,345 legal entities provided real estate brokerage services in Beijing with employing 99,424 people. With the increase in the number of real estate brokerage firms in Beijing, fierce competition in the industry has intensified. The competitive environment is quite complicated considering the asymmetric distribution of firm capability. In the market, there are giants such as Lianjia and 5I5J, as well as many small and medium-sized firms. In order to compete, some firms even publish fake listings. For example, The Beijing Municipal Commission of Housing and Urban-rural Development (2019) reported 25 real estate brokerage firms had been investigated for publishing false housing listings in 2019. In addition, the commission system may result in a strong motivation for both employees and firms to promote higher housing transaction prices, thus further improving profits. Driven by high profit, malign competition is quite fierce, such as information fabrication which has a great influence on stable social development. The complicated competitive environment will not only lead to the wastage of labor resources but also affect the stable operation of the real estate market.

Table 5. Results of descriptive statistics to transaction number of houses (ten thousand) per year in Beijing from 2016 to 2020

Mean	Standard Deviation	Coefficient of Variation
23.468	6.809	0.290137

Note: Data of transaction number of houses are from Beijing Municipal Commission of Housing and Urban-Rural Development.



Note: Data of housing prices and incomes are from the National Bureau of Statistics of China.

Figure 6. Housing price to income ratio of Beijing and China in 2011–2020

5.3. Real estate brokerage industry under the current shock

At present, China's real estate market is facing a downward situation under the policy of "Houses living, not speculation". Beijing real estate market has introduced policies of "Purchase limit, price limit, sale limit and loan limit". Coupled with the economic recession due to the pandemic, the quantity and sale of housing construction have fallen. In the first half of 2022, the sales area of commercial houses fell 8.7% year on year. The recession of the market will cause some real estate brokerage firms facing the risk of bankruptcy, and many low-skilled employees will have to leave the industry first. However, if the policies could improve the access standard of the real estate brokerage industry, the professional level of practitioners and the over-size marginal cost for the real estate brokerage firms will enhance. The firms will hire the appropriate number of employees. In a volatile market, employee turnover will also be less affected.

Moreover, due to the impact of the COVID-19 pandemic, the share of second-hand house sales and rental business has declined, while the share of new house sales gradually increases. The new house brokerage business is expected to become a new growth point of the industry (Z. Zhang & H. Zhang, 2021). Transactions of real estate brokerage firms have moved from offline to online actively or passively under the pandemic shock. Real estate brokerage business has been combined with the new generation of information technology, which also put forward higher requirements for the professional level of practitioners.

6. Policy discussion

6.1. Under-size marginal cost c_u

High commission leads to high under-size marginal cost c_u. While high housing price under the fixed-percentage pattern results in high commission, although the value of service may not be high. Since commission rates vary little across China, real estate agents in cities with high housing prices can be highly profitable and thus attract large numbers of workers. However, housing prices are affected by many factors, which are difficult to control. Transforming from a fixed-percentage commission pattern to a flat-fee pattern will change the situation of agents' high profit brought by high housing price, which could reduce high profits and better reflect the value of services in a city with high housing price. It may reduce labor resources wastage to some extent.

6.2. Over-size marginal cost c_o

As stated in the introduction, the regulation of China's real estate brokerage industry leads to low professionality of practitioners, and the proportion of certificated ones is very low. Employees' free entry and lack of professionality make c_o is very low. The government should strengthen the supervision of employees, prohibit entry of employees without certificates, and improve the professional ability of employees in the industry. This will not only improve c_o, but also directly improve the transaction efficiency. Better-educated, more-experienced agents can use their time more efficiently to turn showings and tours into deals (Glower & Hendershott, 1988; Benjamin et al., 2007). The availability of experienced and trained human resources is also one of the most important competitive advantages (Lozano-Torró et al., 2020).

In addition, the government should strengthen supervision over the social security of real estate brokerage firm employees. Government authorities could make guidelines to raise the basic salary of employees and pay social insurance in accordance with regulations. It will increase the fixed cost per employee by strengthening basic social security for employees. In this way, the firms will also consider the work plan of employees in the long run. On the one hand, c_o will increase. On the other hand, the professional ability of employees will improve.

6.3. Substitution fraction α

Substitution fraction α is used to characterize competition among real estate brokerage firms. We propose to apply the MLS system to improve the competition among firms. Multiple Listing Service (MLS) is a central information gathering system. It is widely used in the United States and believed that the application of the MLS system can reduce the labor resources wastage in China's real estate brokerage industry. On the one hand, it can be seen that the wastage level gradually increases with the increase of the substitution fraction α. MLS can share part of listing information among firms, reducing the difference of listing resources among different firms to some extent. This means that when the match is not met by the first firm, the probability of being met by other firms is also reduced, that is, α decreases. At the same time, the use of MLS means that listings and buyers can come from different firms, and both will get benefit once a transaction is made. It is similar to the transformation from competitive inventory ordering to centralized inventory ordering (Netessine & Rudi, 2003), which leads to the reduction of labor investment. This is consistent with Allen et al.'s (2021) study, which indicated that a co-listing strategy is associated with a higher probability of sale, that is, efficiency improvement.

On the other hand, it can be seen that the optimal employee size in asymmetric competition is significantly larger than that in symmetric competition. When there are giants in the industry, the labor wastage phenomenon is more serious. Larger firms have a higher substitution rate than smaller firms because of their reputation and influence. As mentioned by Yavas (2001) and Zumpano et al. (1993), real estate brokerage firms compete mainly on non-price competition and large firms have no more advantages in unit costs than small firms. Thus, large firms have a stronger incentive to hire more employees to compete for more market share. In this case, not only the wastage of human resources is more serious, but also the development of other small firms in the industry will be difficult. It may eventually lead to the occurrence of monopoly. The application of the MLS system can make the competition between firms more balanced.

Conclusions

The real estate brokerage industry in China has expanded rapidly over the past two decades and thus attracted a large number of workers, especially in first-tier cities such as Beijing. This paper analyzes the wastage of labor resources in China's real estate brokerage industry and attempts to explain the reasons. Labor resources wastage is the embodiment of efficiency loss of the industry. Contrary to most existing literature, which mainly focus on the efficiency loss of the industry and then labor resources wastage, this paper studies the wastage of labor resources through analyzing the optimal employee size (OES) decisions of real estate brokerage firms from the perspective of opportunity cost. Real estate brokerage firms will make decisions by minimizing expected costs, which consist of under-size cost due to the shortage of employees and over-size cost due to the redundancy of employees.

The optimal employee size models for a single firm and multiple firms in the competition environment are established respectively. Substitution fractions are used to characterize competition among firms. Then an iterative algorithm is used to solve the model and the impact factors of the model results are analyzed. The model results reveal that high profit gained from the business does attract more employees than what is needed. In other words, wastage of labor resources actually happens. By various scenarios analysis based on the game model, it is found that asymmetric competition, the increase of market participants, and demand fluctuations also contribute to the labor resources wastage in real estate brokerage industry.

Next, the current situation of Beijing real estate brokerage is discussed as a case study. Based on the actual data and information, this paper summarizes the characteristics of the real estate brokerage industry in Beijing and then explains the factors of labor resource wastage with the results of the model, which are high profits, volatile market, complicated market environment and fierce competition respectively. The case study verifies the results of the theorical analysis. Finally, from the three aspects involved in the proposed model: under-size marginal cost, over-size marginal cost, and substitution fraction, we discuss the policy suggestions to reduce labor resources wastage in China's real estate brokerage industry and promote the steady development of the industry, which could be considered as a reference for other cities in the similar situation.

This study has several limitations. One limitation is that the determination of related parameters in actual is difficult, which indicates that the guiding value of this paper to a theoretical level. Another limitation is that the setting of scenario analysis is relatively simple. We only consider the asymmetric and symmetric competition situation. Future research could consider more complicated scenarios such as whether or not there is a monopoly in the market and compare the results under various scenarios. Moreover, empirical research based on sufficient data is also a valuable direction in the future.

Acknowledgements

We gratefully acknowledge the support of National Natural Science Foundation of China (NSFC) under Grant [72021001] and [72174019], and Beijing Municipal Natural Science Foundation under Grant [9212012].

Funding

This work was supported by National Natural Science Foundation of China (NSFC) under Grant [72021001] and [72174019], and Beijing Municipal Natural Science Foundation under Grant [9212012].

Author contributions

All authors met the criteria for authorship of the Journal of Civil Engineering and Management. Qiuhong Zhao conceived the idea and designed the framework of the article. Mingrui Ding were responsible for the construction of model, algorithm and results analysis. Chengfeng Wu was responsible for data collection and the case study. Mingrui Ding and Qiuhong Zhao wrote the draft of the article. Yashuai Li was responsible for policy discussions, the review of the manuscript and providing suggestions.

Disclosure statement

The authors did not receive financial support from any firm or person for this article or from any firm or person with a financial or political interest in this article. They are not currently an officer, director, or board member of any organization with a financial or political interest in this article.

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