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RESEARCH ARTICLE

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Industry effect of job hopping: an agent-based simulation of Chinese construction workers

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Abstract Job hopping affects the development of industries in terms of efficiency and quality of work. It is a problem for the Chinese construction industry, where excessive job hopping is detrimental to meeting the current daunting challenges involved in the industry's transformation and efficiency improvement. To provide an exhaustive analysis of this effect, game theory is combined with social relationship networks to create an agent-based simulation model. Simulation results indicate that the frequent job moves of Chinese construction workers have a negative effect on their skill development, employment, and worker relationships, as well as results in sharp increase in employer labor costs. The findings point to the need to act for the benefit of workers and employers and maintain the development of the industry.

Keywords job hopping, agent-based simulation, construction industry, effect, China

1 Introduction

The frequent occurrence of construction safety and quality accidents is a current cause for concern in China. One of the critical reasons for this situation is the high frequency of job hopping among construction workers who serve as the basis of all management and production activities in the industry (Sun et al., 2017b). According to Bai and Li's (2009) field survey, 73.3% of construction workers have moved between employers, whereas Sun et al.'s (2015) survey showed that 82% of construction workers have changed employers in the industry. The construction industry has an abnormally high rate of worker job hopping compared with many other industries.

Studies have shown that job hopping has varying effects on individual incomes (Grand and Tahlin, 2002), work efficiency, and technical ability (Sargent et al., 2003; Hancock et al., 2011); and frequent changes of employers have a negative effect on employees' development (Dane and Brummel, 2013). However, current studies on construction worker job movement have mainly focused on influencing factors and countermeasures (Brown et al., 2009; Lalé, 2012) and are usually restricted to such simple methods as surveys or literature review, whereas job movement is a typical complex labor organization problem with wide coverage and high uncertainty across the industry (He et al., 2014). Its complexity is manifested in group behavior selection derived from individual behavior selection and the associated influence of social networks (Liu and Smith, 2016). Agent-based simulation is a bottom-up system simulation method that is highly applicable to such complex social-technical systems in its capability to predict macrolevel outcomes through microlevel multi-agent interactions; it is suitable for studying the effect of job-hopping construction workers (Rixen and Weigand, 2014).

In the present study, we adopt an agent-based simulation approach by combining game theory with social network theory in creating an agent-based simulation model to reveal the effect of construction worker job hopping on those involved and the healthy development and smooth transition of China's construction industry. This study contributes to the literature in several ways. It broadens the use of agent-based simulation and affirms its legitimacy in simulating the labor market and analyzing the problem of job movement. Findings show that frequent movements of construction workers restrict their skill upgrade, increase

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labor costs of the industry, and deteriorate the relations in their social networks. Some practical countermeasures are proposed to inhibit the excessive movements.

2 Literature review

Job hopping is an important aspect of employment movement. The Dictionary of Modern Labor Relations defines job hopping as the change of workers' jobs, through which workers gives up their original job role and acquire a new one (Yuan, 2000). Two types of perspectives of job hopping have been distinguished; one focuses simply on the job transition from one employer to another (Bartel and Borjas, 1978; Loprest, 1992; Gottschalk, 2001), whereas the other focuses on the change in job type, e.g. the change from a construction worker to a chef (Kambourov and Manovskii, 2009; Lalé, 2012). Some studies have also combined the two perspectives (Bachmann et al., 2010). Here, construction worker job hopping is defined as a situation where workers plausibly change employers within the construction industry (Sun et al. 2018).

Research into job hopping exists in all types of industry. A research interest is the influencing factors involved. Economists generally believe that economic benefits and expectations of wage increases are direct factors for job hopping; this notion is supported by Pérez and Sanz (2005) and Bai and Li (2008). Job hopping is a more effective way for workers in low-level labor markets, such as construction workers, to receive higher pay than in high-level labor markets (Wu, 2011). However, sociologists have proved that job hopping is also affected by many non-economic factors, especially social relations (Granovetter, 1985), the strength of relations (Bian and Ang, 1997), and trust (Zhai, 2003). On the basis of Chinese contexts, interpersonal relationships have already become another direct factor for job hopping. Many migrant workers in the construction field can only rely on relatives and fellow villagers to find work in the cities (Fu, 2008). Moreover, other environmental, organizational, and individual factors have been identified as exerting an indirect effect on job hopping (Maslach and Leiter, 1997; Zhou and Huang, 2012). Along with influence factors, corresponding control countermeasures have also been proposed. Taplin and Winterton (2007) emphasized the importance of adopting a management style that promotes harmonious labor relations. Regulating the order of the labor market and implementing guarantee measures to secure workers' rights can also limit a high rate of job hopping (Stevens, 2004).

However, the characteristics of construction production, together with the construction administrative system in China, determine that construction worker job hopping has salient features that are different from other industries. The existence of construction worker teams depends on construction projects. Every project has different goals, a different production context, and a unique production plan; thus, construction workers are typically temporary teams formed as quickly as they are discontinued (Mitropoulos and Memaria, 2012); the end of a project is usually accompanied by the movement of many workers (Qi et al., 2013). However, the flow of work and manpower fluctuates over the construction project lifecycle (Thomas et al., 2003); work becomes less as the project progresses and additional workers become less useful (Watkins et al., 2009). Therefore, construction workers face the problem of frequent layoffs and periods of unemployment between jobs (Gomar et al., 2002), which increases the likelihood of their movement. Sun et al.'s (2015) survey found that 82% of construction workers changed jobs, and 43.2% left before completing their work.

Here, we distinguish between natural employment movement, where workers move away after their construction tasks are complete, and abnormal employment movement caused by the external environment or personal factors that arbitrarily entice workers away from employers, whether or not the construction project is finished (Sun et al. 2017). The empirical analyses of Brown et al. (2009) and Kaiser et al. (2015) showed a positive relationship between firm performance and natural employment movement under certain circumstances. Natural employment movement is also of great significance to labor market operation and labor resource allocation. However, the movement of construction workers in China seems to go beyond normal with frequent job hopping, which continues to cause a series of industrial problems. As a result, neither construction companies nor subcontractors are willing to recognize training the workers as their responsibility (Forde and Mackenzie, 2004), thereby leaving workers' rights and interests unsecured (Zhao, 2008). This condition will result in poor technical abilities of construction workers and cause quality and safety risks in construction production (Marsden, 2004; Mackenzie et al., 2010). Job dissatisfaction is another aspect, which in turn enhances their intention to move, thereby creating a vicious circle. Increased in-depth research is needed to clarify the effect of construction worker job hopping on the industry, and targeted countermeasures must be developed.

3 Research methods

3.1 Agent-based modeling (ABM) and simulation

ABM is a simulation modeling technique that reflects complex group behaviors by simulating individual behaviors, attributes, and interindividual interactions (Axelrod, 1997). In ABM, a system is modeled as a collection of autonomous decision-making entities called agents. Each agent individually assesses the situation and decides based on a set of rules (Bonabeau, 2002). Typically, an agent-based model has three elements, that is, 1) a set of agents, their attributes, and behaviors; 2) a set of agent relationships and methods of interaction, which define with whom and how agents interact, respectively; and 3) the agents' environment, in which the agents interact in addition to other agents (Macal and North, 2010). Patterns, structures, and behaviors emerge through repetitive competitive interactions, instead of being explicitly programmed into the models. This "bottom-up" approach of ABM makes it most suitable for the analysis of complex, self-organizing, and self-adaptive social systems, which are composed of agents who interact with and influence each other.

ABM has been applied in a wide range of areas and has occupied an important position in sociology simulation since its emergence. Its applications in the labor market range from studying market structure and market power (Tesfatsion, 2001) to analyzing unemployment problems under different situations (De Grande and Eguia, 2006). Job hopping and employment movement in the construction labor market arise from workers' individual decisions and the interactions through the workers' social networks. ABM is applicable in simulating the actual situation of job hopping and its industrial effect.

ABM can be performed using either general all-purpose programming languages or specially designed software and toolkits that address the special requirements of agent modeling. In view of the complexity of the modeling tools, the cost of using them, and the modeling requirements of our study, we use *Netlogo* to perform the agent-based simulation. *Netlogo* provides an integrated development environment for modelers, uses a code or model editing program to organize model construction, and provides a built-in mechanism to compile or interpret and then execute models.

3.2 Two networks in the agent-based model

The main influence factors for construction worker job hopping can be summarized in two aspects, that is, workers' own demands and social relations. Accordingly, we establish a game relation network and social network of construction workers to simulate the entire process of construction worker employment movement.

The game relation network is based on evolutionary game theory, which differs from classical game theory in focusing more on the dynamics of strategy change. On the basis of Maslow's hierarchy of needs (Maslow, 1943), four types of games with different rules, payoffs, and mathematical behaviors have been developed in the network to explore the dynamic evolution of the labor market from the perspective of worker demands and interests.

Wellman and Berkowitz (1988) indicated that a social network is a relatively stable structure composed of social relations between a set of social actors (e.g., individuals or organizations). The social network perspective provides a set of methods for the analysis of the effect of social relations on behaviors. It acts on individual behaviors through information transmission, convergence, and other human factors. Many studies (e.g., Granovetter (1973) and Bian and Ang (1997)) have confirmed that social networks serve as an important informal information channel through which workers are matched to jobs because the market economies are imperfect in circulating labor market information through formal means. Wen and Zhou (2007) argued that social relations have a strong effect on employment movement by influencing the information transmission process. Therefore, we embed the social network into the agent-based model to increase the accuracy of the simulation.

Although traditional studies use game theory and dynamic social networks to explain job hopping in the labor market, few have integrated these two research perspectives to establish a system that covers individual behavioral choices and relational structures of construction workers and organizations. An agent-based model that combines a multilayer game relation network and social network is developed in the following sections to address the intricacies of the job-hopping phenomenon further.

4 Development of an agent-based model of construction worker job hopping

Our simulation experiment mainly studies the interactive behavior between two types of agents, namely, construction workers and employers (represented by construction teams), which are referred to as "workers" and "contractors" in the model, respectively. To study the operating mechanism of the construction labor market, we assume that both types of agent consistently make rational self-interested decisions. In addition, individual active movement behavior between organizations are selected because it is the most common and fundamental of the different types of employment movement behavior involved.

On the basis of the literature review, construction worker employment movements can be summarized as being influenced by social relationships and the workers' own demands. Correspondingly, we establish a social network and game relationship network of construction workers to simulate the entire employment movement process.

4.1 Social network model

4.1.1 Indicator setting

Two indicators, namely, strength and scale of relationships, are introduced to describe the workers' social relationship structure. The average count is adopted.

1) *Strength of relationships* mainly includes the strength of the workers' social interrelationships and relationships between workers and employers.

2) *Scale of relationships* shows the number of nodes in each worker's social relationship network.

4.1.2 Model construction

The social network system involves the network structure, strength, and scale of social relations, as well as the formation, transition, and extinction of social relations (Scott, 2017). The network structure and scale of social relations affect information dissemination in the construction labor market, whereas the strength of social relations affects workers' employment movement decisions. The linkage with the game relationship network is realized by the following:

1) Establishment of the initial social network: An initial social network is established between the workers and their relatives/friends in the industry.

2) Establishment of a new social network: When a worker finds a new employer, a new social network is established among the worker, the employer, and other workers. Generally, the strength of the new worker's relationship with the employer is stronger than that with other workers.

3) Strengthening relationships: When workers choose not to move, their social relationships strengthen with time.

4) Weakening relationships: When workers choose to move, the strength of their social relationships weakens with time.

5) Discontinuing relationships: Our survey found that each construction worker maintains a regular contact with five contractors. Therefore, weak social relationships with strength lower than 0.2 are assumed to be extinct (dead).

4.2 Game relationship network model

4.2.1 Indicator setting

Four indicators, namely, the employment movement rate of workers, labor price, training costs, and extent of the work guarantee system, are introduced to measure the game's relationship between workers and employers.

1) *Employment movement rate of workers*: the quit rate (Qr) is used to describe worker employment movement, as shown as follows:

$$Qr_t = \frac{Qw_t}{W_t} = \frac{\sum Qw_{i,t}}{\sum W_{i,t}},$$

where $Qw_{i,t}$ is the number of workers who quit a construction team at time t, and $W_{i,t}$ is the total number of workers that still belong to a construction team at time t after some workers quit.

2) *Labor price*: This indicator is measured by the average salary of workers (*Payment*).

3) *Training costs* (TC_t): The costs to employers of providing workers with technical training can be expressed as follows:

$$TC_t = \begin{cases} 0 & (W_{\min} \leqslant W) \\ TC_0 + TC_{t-1} * \left(\frac{W_{t-1}}{W_t} - 1 \right) & W < W_{\min} \end{cases},$$

where W_t denotes the number of workers in a construction team at time t, TC is the training costs, and $W_{\min}$ is the minimum worker demand of a construction team.

4) *Extent of the work guarantee system* (Wg_t): The popularity of guarantee measures taken by employers to secure workers' jobs is used to describe the degree to which workers' basic rights and interests are secured. The guarantee measures include signing labor contracts and providing social insurance, as shown as follows:

$$Wg_t = \frac{Gw_t}{W_t} = \frac{\sum Gw_{i,t}}{\sum W_{i,t}},$$

where $Gw_{i,t}$ denotes the number of workers whose jobs have been secured in a construction team at time t, and $W_{i,t}$ is the total number of workers that still belong to a construction team at time t after some workers quit.

4.2.2 Model construction

Various factors influence construction workers' employment movement behavior. Here, four factors are involved in constructing the game-relationship network model. These factors comprise *labor interests*, such as salary and remuneration of workers and costs arising from workers moving jobs; *work guarantee system*, which is embodied in such guarantee measures as signing labor contracts and providing social insurance; *technical training* mechanism; and recognition and promotion of *personal value*, which involves the following:

1) Establishment of the initial game relationship network: Workers choose the employer that provides the highest payment and establish an initial employment relationship with it. During the game, the employers who provide high payment keep attracting workers. We assume that one team can recruit up to 15 workers, whereupon spreading recruitment information discontinues.

2) Modeling labor interests: As two game bodies, the workers decide whether to move, whereas the employers decide whether to spread recruitment information and whether to increase their payments. The analysis is based on infinitely repeated game theory. The labor interest game tree is illustrated in Fig. 1.

The probability (P_{ci}) of workers choosing to move is

$$P_{ci} = \begin{cases} 0 & Payment_{ci} < Paymentc_{0,t} + MC \\ 1 - R_{Sci} & Payment_{ci} \geqslant Paymentc_{0,t} + MC \end{cases},$$

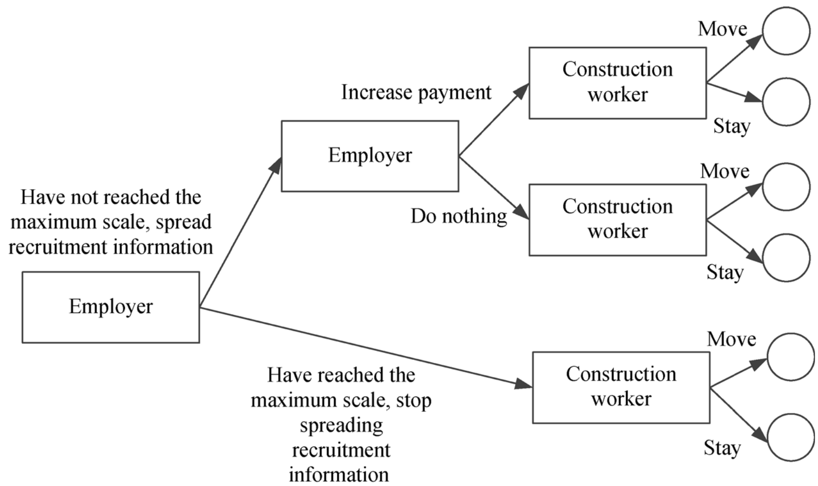

Fig. 1 Labor interest game tree

where *MC* denotes employment movement costs (according to our survey, CNY 200 is the cost incurred by a construction worker to move from one employer to another), c_i represents the employers who spread hiring intentions and payment information to workers, and c_0 denotes the employers who are currently employing workers. denotes the positive effect of relationship strength on retaining workers when competitors offer higher payment.

With initial monthly salary ($Paymentt_0$), the payment adjustment strategy of employers in each round of the game is

$$Payment_t = \begin{cases} Payment_{t-1}, \ \inf = 0, (W \geqslant W_{\max}) \\ Payment_{t-1}, \ \inf = 1, \ (W_{\min} \leqslant W < W_{\max}), \\ Payment_{t-1} + SI, \ \inf = 1, (W < W_{\min}) \end{cases}$$

where W denotes the number of workers currently employed by employers, SI is the amount of salary increase, and inf is a 0–1 variable representing whether to spread payment information. Initial payment in the simulation is set as CNY 3300, and salary increase is CNY 150 based on the salary data from "National Report on Migrant Worker Monitoring and Survey" (National Bureau of Statistics of China, 2016).

3) Modeling work guarantees: In the work guarantee game, employers decide whether to spread recruitment information and whether to enhance the guarantee measures; meanwhile, workers decide whether to move accordingly. The work–guarantee game tree involved is illustrated in Fig. 2.

On the basis of our investigation, we summarize four types of work guarantee conditions that construction workers expect most, that is, on time wages, social insurance, work security facilities, and stable labor contracts. However, few employers provide all these

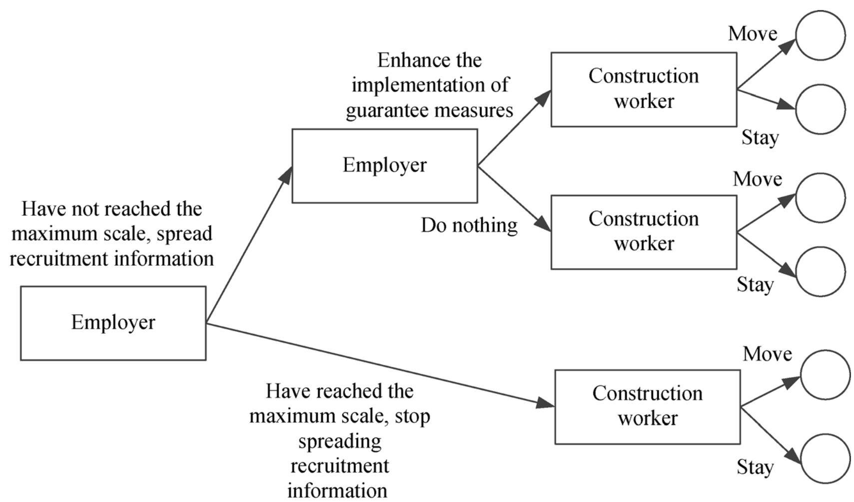

Fig. 2 Work guarantee game tree

conditions simultaneously; when two of them are met (even if basically met), workers usually choose not to move. Therefore, we assume that workers choose not to move when the extent of the work guarantee system (*WorkGuarantee*) is 0.4 or more.

In this case, the probability of workers choosing to move is

$$P_{ci}\begin{cases} 0 & WorkGuarantee_{c0,t} \geqslant 0.4 \\ 1-RS_{ci} & WorkGuarantee_{c0,t} < 0.4 \end{cases},$$

where $c0$ refers to the employers who currently employ workers.

Employers use two work guarantee strategies, that is, enhancing guarantee measures to restrict the workers' employment movement when the number of workers is below minimum demand (less than 6); otherwise, they do nothing.

We assume that enhancing the guarantee measures will increase the extent of the work guarantee system by 0.1 (*WorkGuaranteeIncrease*, $WI = 0.1$); the investigation results show that construction workers' salary generally increases by 10% at the beginning of each year. The work–guarantee adjustment strategy of employers in each round of the game is

$$WorkGuarantee_t\begin{cases} WorkGuarantee_{t-1} & W_{\min} \leqslant W \\ WorkGuarantee_{t-1} + WI & W < W_{\min} \end{cases}.$$

4) Modeling personal value recognition: In this game, employers decide whether to provide technical training depending on the number of workers, and workers decide whether to move. The personal value-recognition game tree involved is illustrated in Fig. 3.

If the employer provides technical training for workers and sets up a technical hierarchy system to approve their personal values, then a considerable reduction will be observed in the probability of workers moving, assumed to be 30%. Otherwise, we assume a 20% increase in probability (with regular contact with five contractors, in which 20% is the probability that a worker will move to one of his familiar contractors). The 0–1 variable *Personalvalue* is used to represent the presence or absence of the employer having a technical training and technical hierarchy system to approve the workers' personal values, where

$$\text{Personalvalue} = \begin{cases} 1, & \text{providing technical training and setting up technical hierarchy system} \\ 0, & \text{not providing technical training or setting up technical hierarchy system} \end{cases},$$

In this case, the probability of workers choosing to move is

$$P_{ci} = \begin{cases} 0.7(1-RS_{ci}) & Personalvalue = 1 \\ 1.2(1-RS_{ci}) & Personalvalue = 0 \end{cases}.$$

Three possible game strategies can be used by the employers in deciding whether to provide technical training and set up a technical hierarchy system. These strategies are (1) not providing training or setting up a hierarchy system out of cost saving considerations when the number of workers has reached basic demand (between 6 and 15); (2) providing appropriate technical training for workers to restrict their employment movement when the number of workers is less than 6 and the training costs are within an acceptable range; and (3) not providing technical training when the training costs per capita are extremely high to afford even if the number of workers is below the basic demand.

The costs involved in providing technical training and

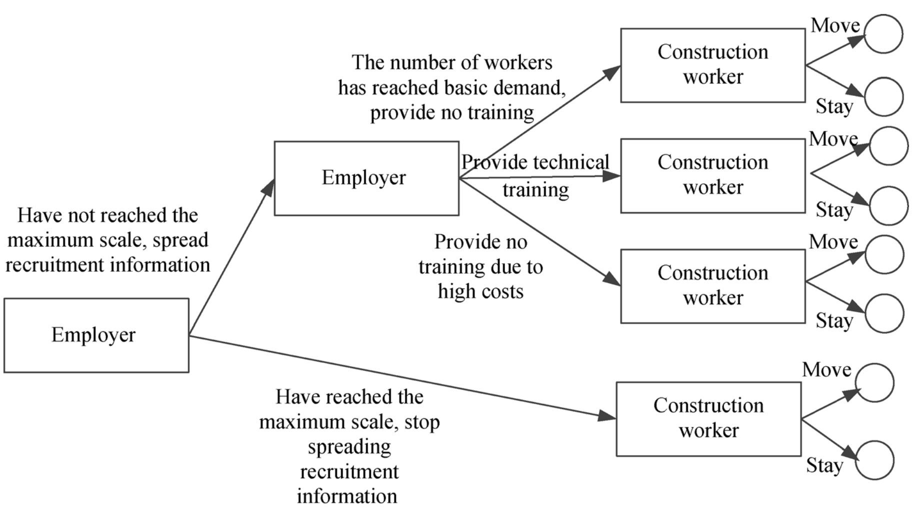

Fig. 3 Personal value-recognition game tree

setting up a technical hierarchy system are denoted by the variable *Trainingcost*,*TC*, which has a baseline value of TC_0 and an upper limit of CNY 400. The training costs higher when the employer employs fewer workers, which can be expressed as follows:

$$TC_t = \begin{cases} 0 & (W_{\min} \leqslant W) \\ TC_0 + TC_{t-1} * \left(\dfrac{W_{t-1}}{W_t} - 1 \right) & (W < W_{\min}) \end{cases}.$$

Therefore, the training strategy in the game is

$$Personalvalue_t = \begin{cases} 0 \ (TC_{\max} < TC_t \text{ or } TC_t = 0) \\ 1 \ (TC_0 \leqslant TC_t \leqslant TC_{\max}) \end{cases}.$$

4.3 Dynamic evolution mechanism of the agent-based system

In the agent-based simulation model, the dynamic evolution of the agent-based system is realized by the strength of social relationships being renewed by the game results and game information transmitted across the social and game relationship networks. The probability of workers' job hopping will change as employers adopt different strategies. Game information is transmitted through the linkage between the two networks, thereby simulating the workers' employment movement behavior. The flowchart of the dynamic evolution simulation is provided in Fig. 4.

5 Results of the simulation and the effects of its outcomes on the industry

We ran the model in Netlogo (the Netlogo code is omitted here) to simulate the workers' employment movement behavior and analyze the effects on the industry in terms of worker skill development, labor costs, and employment and worker interrelationships.

5.1 Operation of the simulation

Table 1 lists the variable parameter values used in the simulations.

The supply–demand relationship contributes directly to the employment movement rate of workers. We can retrieve employment movement rates with different baseline values by setting the supply–demand relationship to different levels, which enables us to explore the influence of workers' employment movement behavior on the indicator variables. Table 2 provides the number of worker sets and the corresponding employment movement rates. The reason for the 7% rise of average employment movement rate when the labor market shifts from "extremely short supply" to "short supply" is the assumption of market clearing in the simulation model. An agent without any labor relation or social relation will be automatically cleared from the market. In an extremely tight market, many contractors quit because the employment costs are extremely heavy to afford. Only contractors that satisfy construction workers' demands for payment, work guarantee, and personal value recognition remain. Workers are less likely to move when their needs have been met.

5.2 Effect from the perspective of game theory

5.2.1 Slow skill upgrading of construction workers

The variable *Trainingcost* is taken as the main indicator of worker skill level. The simulation results of employment movement rates and average training costs per capita under different supply–demand situations are shown in Figs. 5 and 6, where the situations from left to right are of "extremely short supply," "short supply," "balanced," and "excess supply," respectively. These results show that the average employment movement rate reaches 17% when supply is short and 10% when supply is extremely short while simultaneously imposing high average training costs on the employers. Meanwhile, in the over-supplied or balanced situation, worker employment movement only occurs during the initial stage of simulation. With the disappearance of employment movement, training costs also fall to zero.

The simulation indicates that when demand exceeds supply in the construction labor market, workers will frequently move jobs, thereby making improving or even fostering their skill level difficult. Employers must provide technical training in case of quality problems or safety incidents, which explains the high training costs involved. By contrast, when supply exceeds demand, workers will tend to stay where they are, thereby steadily improving their skill level to satisfy production requirements and lowering their training costs. Accordingly, the high employment movement of workers negatively affects their skill improvement, thereby posing a longer-term threat to the industry's development.

5.2.2 Increase in labor costs

Payment and the extent of the work guarantee system (*WorkGuarantee* or *Wg*) are used to measure the employers' labor costs. The trends obtained from the simulation are shown in Figs. 7 and 8. From the figures, the average payment provided by employers ascends linearly in an extremely tight market with an employment movement rate of 10%, thereby reaching CNY 21800; in the tight market with an employment movement rate of around 17%, the average payment is a stable value of approximately CNY 4730. In addition, the extent of the work

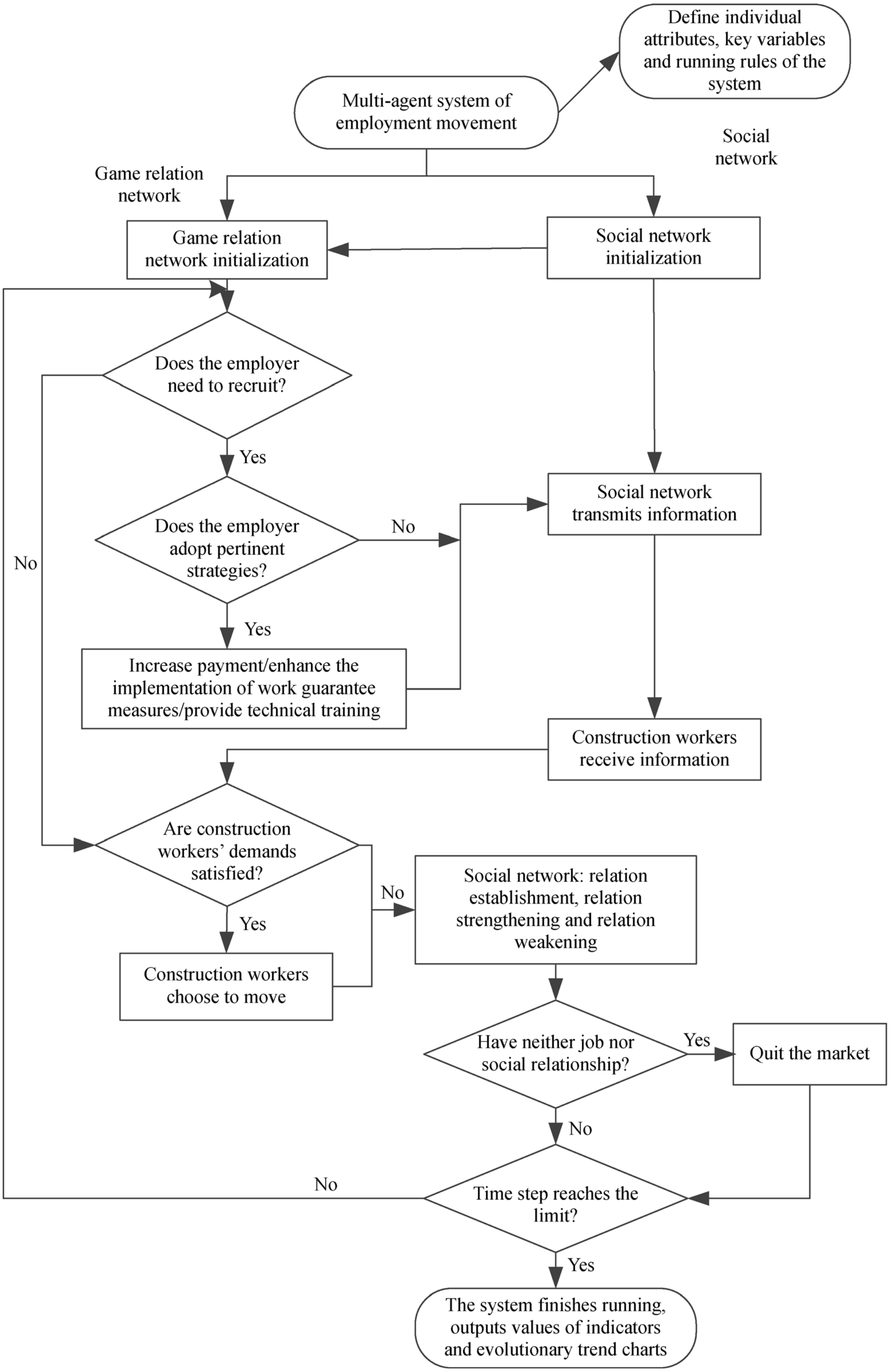

Fig. 4 Flowchart of the dynamic evolution simulation

guarantee system increases in these supply–demand situations, which leads to the inevitable increase in labor costs. Conversely, workers tend to move jobs only in the initial stage of simulation in the balanced or oversupplied market, where the average payment is a stable CNY 4150 and 3050, respectively. The extent of the work guarantee system also reduces in the first two situations, and overall labor costs remain relatively low.

Table 1 Variable configuration in the simulation experiment

Variable name	Variable value
Number of workers, i	180
Number of employers, j	12
Run time, T	20
Initial monthly salary, $Payment_0$	N (3,300, 150)
Scale of a workers' initial social relationships	6
Scale of an employer's initial social relationships	10
Strength of initial social relationships, RS_0	N (0.6, 0.1)
Strength of workers' new social interrelationships	RS_{nw}~N (0.25, 0.01)
Strength of workers' new social interrelationships and relationships with employers	RS_{nc}~N (0.40, 0.02)
Rate of relationship strengthening	20%, $RS_t = 1.2^* RS_{t-1}$
Rate of relationship weakening	20%, $RS_t = 0.8^* RS_{t-1}$
Strength of relationship discontinuations	0.2
Limits of team scale, W_{max}, W_{min}	15, –6
Employment movementcosts, MC	200
Salary increase, SI	350
Initial extent of the work guarantee system	$WorkGuarantee_0$~N (0.20, 0.01)
Baseline value of the extent of the work guarantee system	0.4
Increase in extent of the work guarantee system, WI	0.1
Personal value recognition variable, *Personalvalue*	*Personalvalue* ~(0, 1)
Initial training costs, $Trainingcost_0$	200

Table 2 Number of workers and corresponding employment movement rates

Supply–demand situation	Number of workers	Average employment movement rate	Maximum employment movement rate
Extremely short supply	60	0.10	0.15
Short supply	120	0.17	0.22
Balance	180	0.03	0.20
Excess supply	240	0.00	0.10

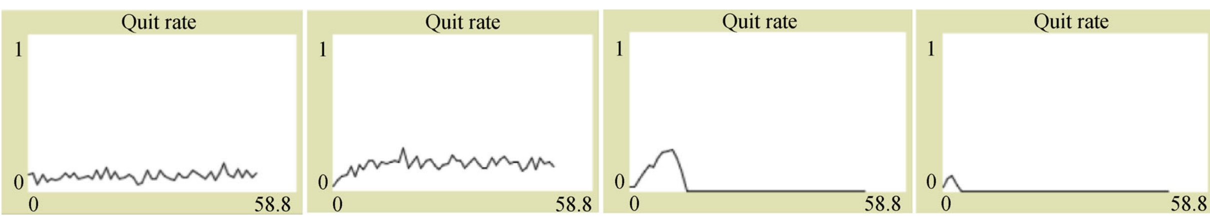

Fig. 5 Employment movement rates for four supply–demand situations

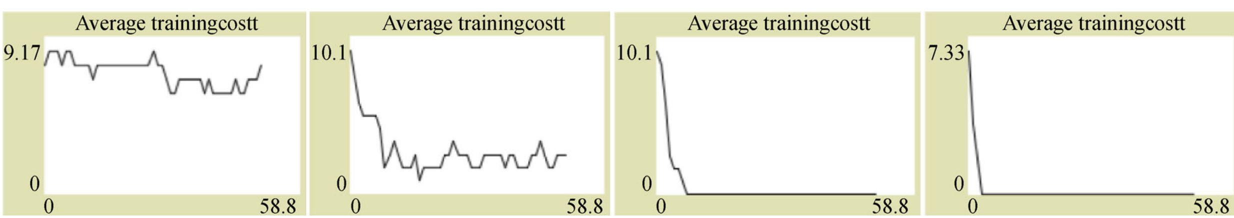

Fig. 6 Average training costs for four supply–demand situations

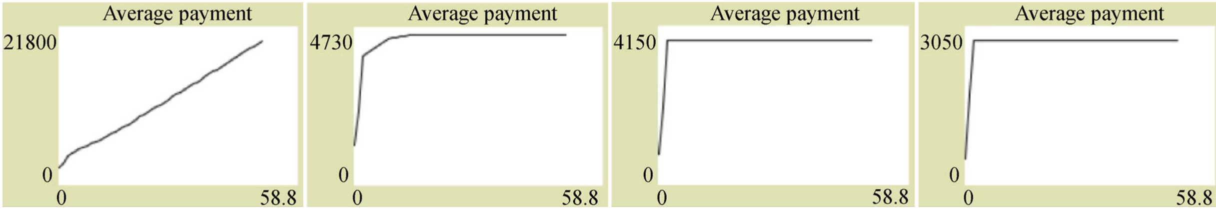

Fig. 7 Average payment in the four supply–demand situations

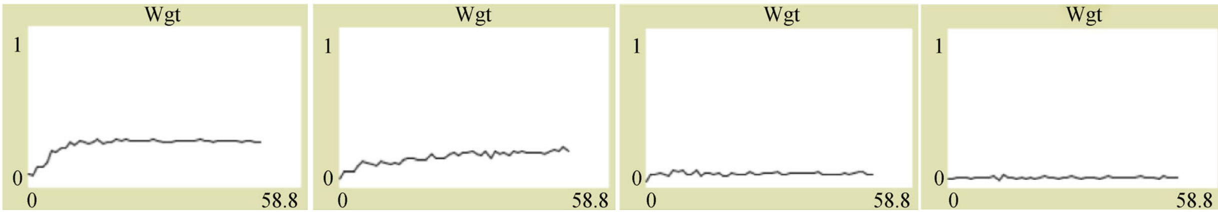

Fig. 8 Extent of the work guarantee system in the four supply–demand situations

The simulation indicates that a high employment movement rate accounts for increasing labor costs and obstructs the healthy and stable development of construction enterprises.

5.3 Effect from the perspective of social networks

5.3.1 Deterioration in employment relationships

The organization of the construction labor market in China relies largely on social networks (Bian and Ang, 1997; Sun et al., 2017a). Good social relationships are important for maintaining loyal worker loyally, whereas high employment movement can be responsible for the deterioration of social relationships. Therefore, maintaining good employment relationships is important in retaining labor teams.

The simulated strengths of social relationships in conditions of excess and short supply are shown in Fig. 9. The red line represents the strength of the workers' social interrelationships, and the blue line represents the strength of the social relationships between workers and employers.

When supply exceeds demand, a rapid rise is observed in the strength of social relationships between workers and employers during the initial stage of simulation, thereby approaching the maximum value of 1. Thus, once workers have established an employment relationship with an employer, they will remain in the fixed labor organization for a long period without moving, which promotes a good social relationship with the organization and other workers in the organization. Such stable employment relationships hold down the employment movement rate, and vice versa.

When demand exceeds supply, the strength of the workers' social interrelationships still rises sharply to approach the maximum; however, the strength of the social relationships between workers and employers is significantly lower. Thus, the extensive worker employment movement arising from short supply will seriously affect employment relationships and deteriorate the relationships between workers and employers. The deterioration breaches trust between the two sides, reduces future willingness to sign labor contracts or provide work guarantees, and further exacerbates employment movement behavior. The construction labor market will therefore be trapped in a vicious cycle, thereby adversely affecting the stable operation of the entire industry.

5.3.2 Weakening of relationships between construction workers

Through the indicator scale of relationships, we can analyze the industry-wide quantitative structure of the

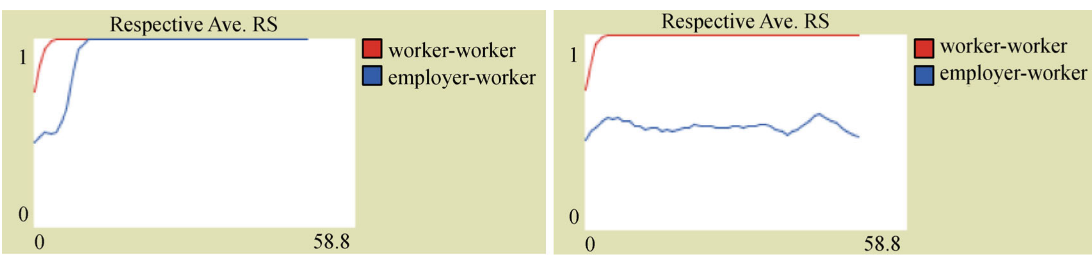

Fig. 9 Social relationship strength

workers' social interrelationships to investigate the mechanism behind relationship development. The trends of the social relationship scale and numbers of dead relationship under situations of excess and short supplies are shown in Figs. 10 and 11, respectively.

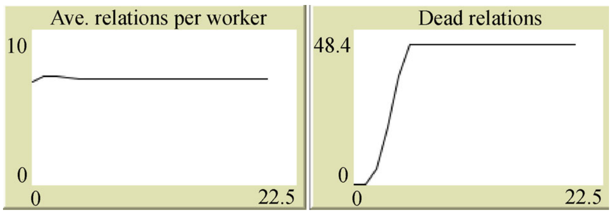

Fig. 10 Social relationship scale and number of dead relationships under excess supply

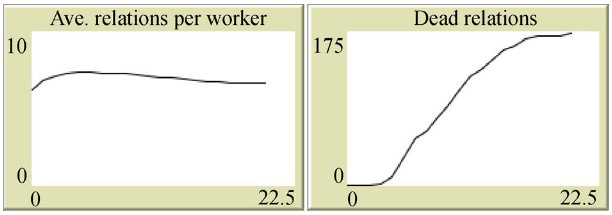

Fig. 11 Social relationship scale and number of dead relationships under short supply

When supply exceeds demand, the scale of the workers' social relationships slightly expands initially and quickly stays at an average of 7. The number of dead relationships also quickly reaches its highest value and remains constant for the remaining time. The social network is gradually stabilized because of the reduced worker employment movement. Small groups of workers with stable members begin to develop, thereby strengthening relationships within the groups.

When demand exceeds supply, the scale of the workers' social relationships fluctuates without reaching a stable point after an initial slight expansion. The number of dead relationships continues to increase. This result indicates that the highly employment movement of workers makes fostering social networks difficult, whereas the original social relationships continue to weaken and die. Poor relationships with others hinder workers from feeling a sense of belongingness and cohesion. Consequently, an abnormal employment movement of workers may even intensify, which can otherwise be contained by strong worker interrelationships.

6 Discussion

6.1 Theoretical implications

By drawing insights from game theory and social network theory, this study develops an agent-based model to simulate the mechanism of employment movement based on benefit games between construction workers and employers and the social relations of workers. The simulation results demonstrate the negative effects of a high movement rate in China's construction industry, which fills a theoretical gap in this field. Consistent with the previous research of Forde and Mackenzie (2004), the results confirm that training workers with no long-term attachment to the employer, manifested as a sustained high training cost in the simulation, is not in the employers' long-term interest. Another implication from the perspective of game theory is the positive relationship between movement rate and labor costs, including wages and costs of implementing work guarantee measures. As suggested by Bai and Li (2007), the principal reason for worker movement is dissatisfaction with income. Forde and Mackenzie (2004) found that employers are most likely to increase pay for new workers when facing a labor shortage. These previous studies focused on the relationship between wages and movement from the view of an individual worker or single organization, whereas the agent-based simulation provides a holistic and industrial perspective to understand the problem, which indicates that a high movement rate can cause great cost pressure on the industry.

This study also advances the social network literature by demonstrating the relationship between social networks and employment movement. Granovetter (1973) proposed a hypothesis concerning the strength of weak ties, arguing that useful job information mainly comes through networks of weak ties of infrequent interaction or of low intimacy. However, studies in the Chinese context indicate the opposite. Strong ties and relationships with authority tend to be more important for job seekers in China (Bian and Ang, 1997). The agent-based model simulates the evolution of the strength of the construction workers' social relations and reveals the negative correlation of employment movement and employer–worker relation strength. This condition provides theoretical support for the argument that a high movement rate weakens the advantage of job seekers, which goes against the development of construction workers and the industry.

6.2 Practical implications

On the basis of the simulation results, several practical implications can also be obtained to help employers effectively retain construction workers and control excessive job hopping. That is, (1) *establish a training system that matches the labor export market.* Employers should ensure that workers are provided with necessary training and are certified accordingly before they start working, such that the employment movement of workers will be discouraged by increased employment movement costs. (2) *Moreover, employers should establish a technical* *incentive and salary performance system by employers.* Through bonuses and other means, employers can encourage workers to improve their skills and motivation. Employers should develop a rational competitive mechanism among workers to increase their sense of participation, achievement, and company loyalty. (3) *Furthermore, employers must establish an insurance guarantee system for the labor market.* Basic insurances, including personal insurance, social insurance, and pensions, should be provided for workers to secure their basic rights and interests. The guarantee system is beneficial for strengthening the employment relationships and enhancing workers' sense of belongingness, which will effectively reduce employment movement behavior.

6.3 Limitations and avenue for future research

This study has several limitations. First is the data source for the initial variable values. Most variable values in the agent-based model are set according to our field investigation results; however, some of the data are difficult to obtain, and thus we use several estimated values. We try our best to make the estimations approximate reality; however, they have yet to be fully tested by practice. The agent-based model can be optimized if accurate data can be collected through further research. The second limitation is the lack of a quantified relationship between the employment movement rate and its industry effect. The results of the agent-based simulation show the differences in industrial consequences with a high movement rate compared with a low movement rate; however, the regularity in the relationship remains vague and needs further research. The third limitation is that the study does not use the agent-based model to verify the effectiveness of the practical suggestions. In Section 6.2, we propose three countermeasures to mitigate the negative consequences of a high movement rate. These countermeasures act on the labor market system by influencing the variables in the system; theoretically, their results can be predicted by agent-based simulation. Future research is needed to verify the effectiveness of these measures and provide a reliable basis for practice.

7 Conclusions

Job hopping is widespread in all industries today. Normal employment moves are conducive to the healthy development of an industry; however, an excess can lead to a series of industrial problems. This study examines the problem of high construction worker job movement in China, providing a more in-depth analysis through an agent-based simulation model based on game theory and social network theory. Multiple influence factors of job movement are included in the model. They interact and work together on the behaviors of workers and employers. Macrolevel industrial consequences can be visualized through the simulation, which enables the analysis of effects of construction worker job hopping on the industry.

The results confirm our assumption that frequent worker moves lead to a series of problems in the industry. With a high movement rate, worker skill levels can hardly be improved, leading to an insupportable increase in labor costs for employers. A deterioration in employment relationships and a weakening of relationships between workers are inevitable consequences, thereby curbing the development of the entire industry. Practitioners must remain alert and take certain solutions. The results suggest that employers should establish training systems, technical incentive, salary performance mechanisms, and insurance guarantee systems for construction workers to alleviate the problem of excessive movement. This study authenticates the power of ABM as a simulation method for studying construction worker employment movement behavior and its industrial effect. Highly accurate data for the model and confirmatory simulations are expected in future research.

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