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Effects of Industrial Relocation on Chinese Regional Economic Growth Disparities: Based on System Dynamics Modeling

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Abstract: The economic growth of China has led to increasing growth disparities between regions. Such disparities are uncontrolled and are severely negative symptoms in the process of economic development. On the basis of system dynamics (SD) modeling and the relationship between industrial relocation and regional economic growth, we construct a model of the interrelationship between the two aforementioned phenomena. The model is an effective and creative exploration for examining effects of industrial relocation on Chinese regional economic growth disparities. The SD model is employed in this study to build an inter-regional labor migration SD model, an inter-regional capital migration SD model, an intra-industry SD model, an intra-regional population SD model, and an intra-regional SD model which are based on realities in labor and capital flow from the view of industrial relocation. VENSIM software is utilized to perform a system simulation based on the data of the eastern, middle, and western regions from 2000 to 2010. Results show that industrial relocation gradually narrows the relative disparity in GDP among the three regions. Moreover, the absolute one is enlarged continuously. The absolute and relative disparities in per capita GDP among eastern, middle, and western regions generally exhibit decreasing trends.

Keywords: industrial relocation; economic growth disparity; system dynamics (SD) modeling; China

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1 Introduction

Since the reform and opening-up in 1978, Chinese government has formulated major regional development strategies, such as Eastern Priority Development, Western Development, Northeast Revival, and Rise of Middle China, which have resulted in rapid economic and social development, as well as facilitating industrialization and urbanization in the entire country. However, it is also accompanied with these achievements that increasing intra-regional economic growth disparities have become a significantly and severely negative problem. The analysis of 1979 to 2008 panel data of 31 Chinese provinces (not including the Hong Kong Special Administration Region (SAR), the Macao SAR and the Taiwan Province of China) indicates that the unbalanced development among provinces has been aggravated since 1991. Convergence clubs exist as a consequence of the internal disparities among three regions, namely, the eastern, middle, and western regions. The disparities among these regions continue to widen (Peng and Liu, 2010), which had affected the present distribution patterns and social order in the country, thereby leading to a series of contradictions in China′s economic, political, and social development. Meantime, with the integration of economic development, actively taking industries

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from the developed regions has become a reference for developing areas to facilitate economic transition and sustainable development. However, whether industrial relocation can rapidly and effectively narrow economic gaps or not requires further research.

Most existing literature on effects of industrial relocation on regional economic growth focuses on macroscopic effects from the perspectives of emigration and immigration areas, particularly the positive influence on industry-immigration areas (Lin, 2003; Wang, 2008). Industrial relocation is a promising opportunity for a developing region because new industries play an important role in increasing employment, enhancing industrial competency, and flourishing local economy. Industrial relocation not only promotes industrial upgrading in industry-immigration regions (Wu and Zhao, 2004; Quan, 2005), but also optimizes the industrial structures in industry-emigration regions (Nie and Zhao, 2000; Liu, 2009; Zhang, 2009). In addition, industrial relocation influences regional development by element flow, industrial connection and technology spillover (Zhang, 2001; Zhang, 2010; Wang and Qi, 2012) and promotes the flow of labor force, capital, technology, and other production factors among regions (Chen and Ge, 2008). These advantages indicate that industrial relocation strengthens the relationship among regional internal elements, thereby reinforcing inter-regional economic ties. When industrial relocation and regional economic growth interact with each other, the effective relocation of industries creates more reasonable and effective industrial structures, and promotes the economic development of entire regions; in turn, regional economic growth further promotes the optimization of industrial structures and regional industrial relocation (Wang, 2008). Regional economic contact advances industrial relocation, and then narrows regional economic disparities and facilitates the coordination and integration of regional economies (Wei, 2003; Zhao and Wang, 2005). However, it is also accompanied by negative effects especially for these industry-immigration regions, such as dependency on foreign investment (Zhu, 2006), reduction of the effectiveness of industrial structures (Wan, 2011), and pollution and deterioration of natural environments (Wei and Liu, 2006; Tang and Yuan, 2010).

System dynamics (SD) has been employed to build a mathematical simulation model by diagnosing the actual system and analyzing the causal relationship constraints among system variables as well as to perform a dynamic simulation of the actual system′s behaviors (Wang, 1994). SD does not emphasize optimal solutions; instead, it seeks the opportunity to improve system′s behaviors by combining the simulation with economic analytical methods, which is highly significant to social and economic analysis (Zhao, 1992; Xu and Zhou, 2006), and has been used extensively in various fields, such as business (Wu *et al*., 2010; Duran-encalada and Paucar-caceres, 2012), natural resource and environmental protection (Saysel *et al*., 2002; Fong *et al*., 2009; He *et al*., 2011), building (Benjamin and Lawrence, 2010), policy making (Mohamed *et al*., 2010), urban development, and industrial transformation (Liu *et al*., 2005; Luan *et al*., 2010; Lu *et al*., 2012). However, studies that simulate effects of industrial relocation on regional economic growth disparities by SD are scarce.

Therefore, this study employs SD to examine the interaction mechanism between industrial relocation and Chinese regional economic growth disparities, and to analyze and predict their relationship. This study provides important innovative contributions in the research method and model building.

2 Data and Methodology

2.1 Data and model hypothesis

The data in our study mainly include gross domestic product (GDP), permanent population at the year-end, birth rate, death rate, population in urban and rural areas and their respective average wages, foreign direct investment (FDI), gross output value of each industry, total investment in fixed assets of provinces (municipalities, or autonomous regions) from *China Statistical Yearbooks* (NBSC, 2001–2011) that comprehensively explain economic information. Other indicators are certain parameters that reflect manufacturers′ and governments′ behaviors, such as elastic coefficients of the production function and direct input coefficients of input-output table. To eliminate the influence of price on GDP and domestic investment, we take the GDP parity index as a price index. This paper divides China into the eastern, middle, and western regions. The eastern region includes: Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan, Liaoning, Jilin and Heilongjiang. The middle region includes:

Shanxi, Anhui, Jiangxi, Henan, Hubei and Hunan. The western region includes: Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang. The data in this study do not include those of the Hong Kong SAR, the Macao SAR and Taiwan Province of China.

We use absolute disparity coefficient and relative disparity coefficient of GDP to measure regional economic growth disparity (Yang, 1989). The absolute disparity coefficient means the difference value of the biggest regional value of GDP and the smallest one which can be seen in Equation (1). The relative one means the departure of GDP in each region from the average which can be seen in Equation (2).

$$R = Y_{\max} - Y_{\min} \tag{1}$$

where R is the absolute disparity of GDP; $Y_{\max}$ is the biggest value of GDPs of regions; and $Y_{\min}$ is the smallest value of GDPs of regions.

$$S = \sqrt{\sum_{i=1}^{n}\left(Y_i - \overline{Y}\right)^2 \Big/ n} \Big/ \overline{Y} \times 100\% \tag{2}$$

where S is the relative disparity of GDP; Y_i is the value of GDP of region i; $\overline{Y}$ is the average value of GDPs of regions; n is the number of regions. The bigger the value of S is, the bigger the regional relative economic growth disparity will be.

In this paper, we choose seven representative industries (manufacturing; finance intermediation; real estate; information transmission, computer services and software; hotels and catering services; leasing and business services; culture, sports, and entertainment) to study effects of industrial relocation on regional economic growth disparity in China. The basic criteria for selecting the mentioned industries are that an industry should represent the direction of regional economic growth, and that the industry should have a significant place in regional economic growth as well as being relatively independent without close technical relations with other industries. We also choose and consider sunset industries and sunrise ones. In our model, we use the GDP and other data of these industries mentioned above to stimulate the value of GDP of each region.

Furthermore, considering difficulties in data organization and model building, we formulate several assumptions to clearly interpret the relationship between industrial relocation and Chinese regional economic growth disparities. First, the migration of capital and labor forces occurs only within the same industry among different regions. Second, each region implements related supporting policies and measures about industrial relocation—an assumption which also holds in reality. Third, labor forces migrate only from rural to urban areas or among different regions. For example, rural labors migrate from the middle China to the cities in the eastern and western regions. We do not calculate labor migration among cities because of the lack of data. Fourth, industrial relocation occurs only in China and FDI is only regarded as part of capital investment. The SD model framework on industrial relocation and regional economic growth disparities constructed is shown in Fig. 1.

The analysis framework of our model can be divided into three levels, namely, inter-regional, intra-industry, and intra-regional ones. In our model, a causal analysis diagram is firstly established between all factors. VENSIM software is then used to construct the desired SD model by means of several equations and models. Causality is the foundation of SD modeling. Causal analysis can be employed to determine the causal connection between all the factors in the system, which can be described by casual feedback loops. The cause-and-effect diagram that contains feedback loops is a description of the internal structure of the actual system. In the following figures of causal feedback loops, '+' and '–' indicate that the factors at both sides of the arrow have positive and negative causal relationships, respectively. The cause-and-effect feedback loop has polarity, and its polarity is positive when the feedback loop contains even negative causal links; its polarity is negative when the feedback loop contains odd negative causal links.

In inter-regional analysis and modeling, the inter-regional migration of labor force and capital is used to simulate industrial relocation and to construct an inter-regional SD model. In intra-industry analysis and modeling, the causality between output values and the production factors of regional industries is analyzed to build the industrial production function in the form of C–D and to construct an intra-industry SD model. In intra-regional analysis and modeling, SD models of the seven industries were connected with the intra-regional population SD model to construct an intra-regional SD model for the simulation and prediction of GDP and per capita GDP of each region and to predict China's regional economic growth disparities.

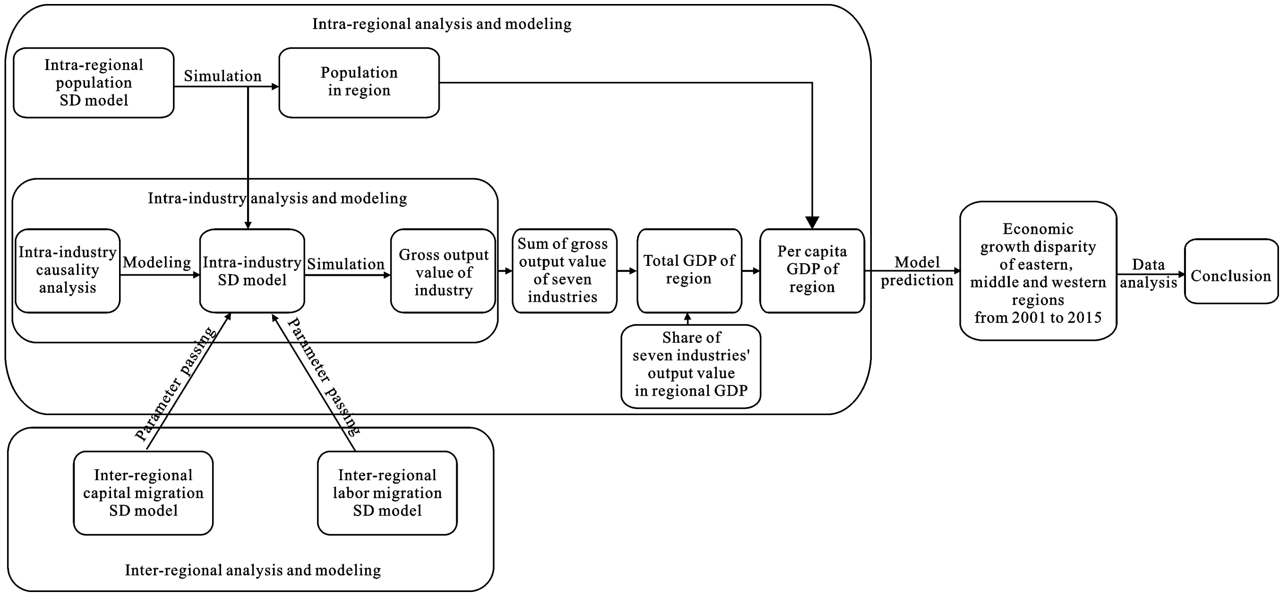

Fig. 1 Framework of SD model of industrial relocation and regional economic growth disparity

2.2 Inter-regional analysis and modeling

Capital, labor force, and other factors for industrial production are assumed to migrate freely among regions (eastern, middle, and western regions) but not among different industries to describe inter-regional industrial relocation. Figure 2 shows the cause-and-effect feedback diagram of capital flow among eastern, middle, and western regions in the textile and clothing industry.

2.2.1 Inter-regional labor migration SD model

A large proportion of labor forces in China have currently migrated from rural to urban areas and from under-developed to developed areas; this phenomenon is called China′s unique ′Migrant Worker Tide′. With the increasing demand for labor forces in urban areas, the improvement of the employment environment of farmers in cities, and the rapid urbanization in China particularly in the 21st century, the number of migrant workers in cities is expected to increase further and continuously affect China′s economic and social development. Therefore, inter-regional labor migration is regarded in our study as an important model to describe industrial relocation. The number of labors migrating between regions is assumed to depend on the following factors: the cost of migration, the desired wage in the immigration area (equal to urban wage multiplied by one labor efficiency coefficient), and the number of la-

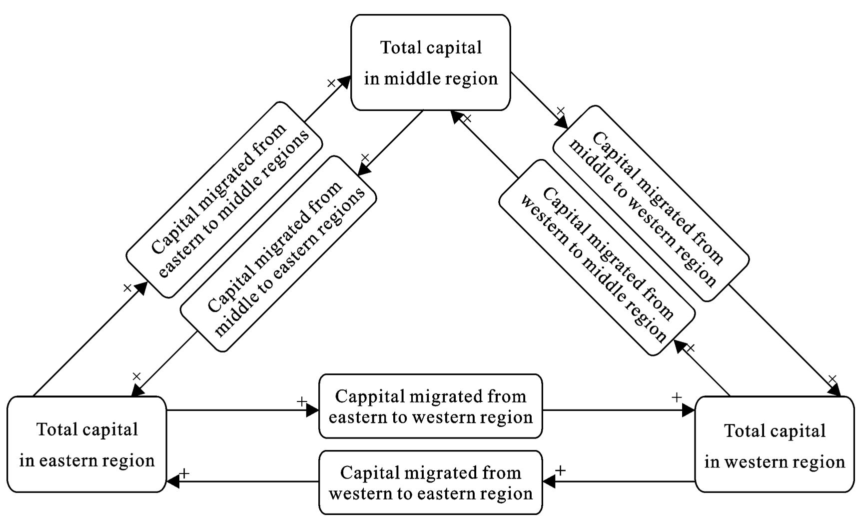

Fig. 2 Inter-regional capital migration casual feedback loop

bors migrating between regions in the previous period. The labor migration equation of this model is as follows:

$$M_{r,u} = \phi_m \aleph_{r,u} \left[\frac{(\phi_{ru} - \phi_c) W_{u,\text{NA}}}{W_{r,\text{A}}} \right]^{\omega_m} \times L_r^{t-1} \tag{3}$$

where $M_{r,u}$ is the total number of labors migrating from rural region r to the non-agricultural sectors of urban region u. $W_{u,\text{NA}}$ is the average wage of non-agricultural sectors in urban region u; $W_{r,\text{A}}$ represents the average wage of the agricultural sector in rural region r; ϕ_{ru} denotes the skill difference of labors between rural region r and urban region u, or the equivalent to the wage difference between local and immigrant labors; ϕ_c stands for the migration cost which is expressed by a certain percentage of the urban salary; and ω_m reflects the elastic velocity of migration. Many surveys show that the wage of rural labors immigrating to the city is about half of that of the urban residents (For example, according to *The Latest Survey Report of Chinese Rural Migrants*, the average monthly wage of rural migrants in early 2007 was equal to 85.4% of that of national workers in November 2005. The monthly actual working time of rural migrants is far more than the average working time of urban workers; thus, a rural migrant's real hourly wage accounted for only 62.8% of the hourly wage of one national worker). Therefore, ϕ_{ru} is assigned a value of 0.7, ϕ_c is assigned a value of 0.2 and ω_m is allotted a value of 0.8 (Xu and Li, 2008). $\aleph_{r,u}$ is the labor migration intensity coefficient from rural region r to urban region u, and reflects the actual flow of inter-regional labor migration. It is calculated according to the actual data about labor migration and wage gap coefficient in 2007. L_r^{t-1} represents the total number of regional rural labors in the last period t–1. ϕ_m is a coefficient whose value is 1 if the net income of migration is greater than the income without migration; otherwise, its value is 0.

Because a surplus of labor exists in China's rural areas and a certain skills gap exists between rural and urban residents, we further assume that a local urban labor is equivalent to an effective labor force, and a rural labor force migrating to the city is equivalent to ϕ_{ru} effective labor (or labors). At the same time, we assume that the equilibrium in the labor market is decided by the total supply and demand for effective labors in various regions. The labor migration SD model is established in VENSIM software.

2.2.2 Inter-regional capital migration SD model

The inter-regional capital migration SD model describes industrial capital migrating from one region to another but in the same industry. Obtaining data on capital migration is highly difficult because no clear statistical information is available. In this paper, we adopt the following function to simulate the capital migration of these seven industries.

We take a certain regional industry in one year (e.g., financial intermediation of the eastern region in 2002) as an example. Its investment comprises two components: the internal investment in the same year and the migrated capital. We assume that all migrated capital is from financial intermediation of other regions, and $Invest_{\text{m}}^{2002}$ that indicates the value of eastern migrated capital from other regions in 2002 can be calculated by using the function below:

$$Invest_{\text{m}}^{2002} = Invest^{2002} - GOV^{2001} \times \tau \tag{4}$$

where $Invest^{2002}$ refers to total industrial capital investment, which can be expressed by total investment in fixed asset of the industry in 2002. GOV^{2001} is the gross output value of the industry in 2001, and τ denotes the reinvestment rate which can be expressed directly by the direct input coefficient of input-output table. In the capital migration SD model, gross output value of the industry, total investment in fixed assets, and direct input coefficients of input-output table are calculated and predicted by table functions.

2.3 Intra-industry analysis and modeling

2.3.1 Causal relationship between industrial output and all factors

The output value of industries is influenced by many factors. Birth rate and death rate determine the population of a region and affect its population aged 16 and over. In addition, the inflows of labor forces from external areas influence the employment in the region. With all other conditions unchanged, a growth in industrial employment population increases the gross output value of the industry, which is also influenced by capital, regional advantages, policies, and other relevant factors. Figure 3 shows the diagram of the feedback loop in the intra-industry.

2.3.2 Intra-industry SD model

The intra-industry SD model describes each element that affects the industrial output value and their relationships. We construct a production function in loga-

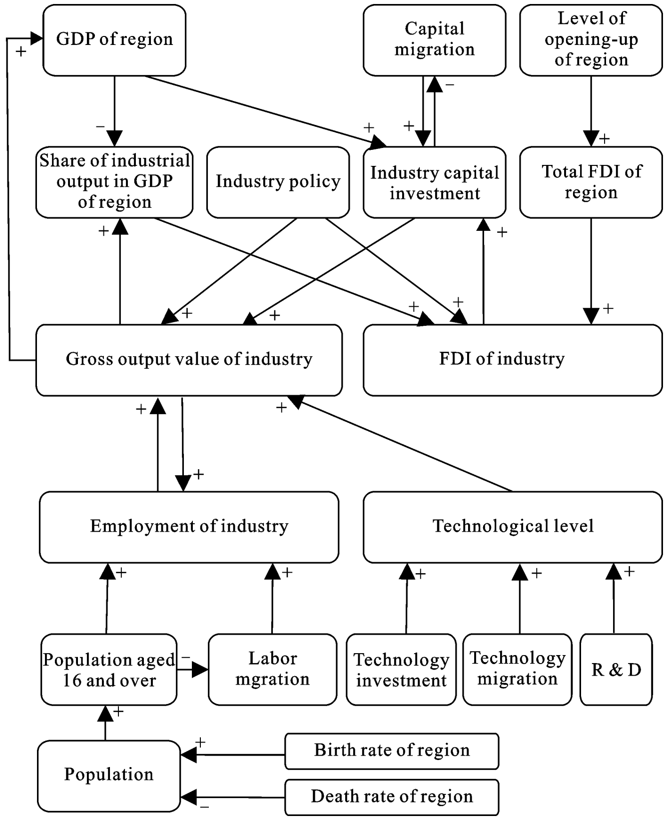

Fig. 3 Intra-industry causal feedback loop

rithm form for a certain industry on the basis of the C–D production function in Equation (5):

$$\ln Y = c + \alpha \ln K + \beta \ln L + \gamma P + \mu \tag{5}$$

where c is the total factor productivity rate (including management, quality of labor force, advanced technology, *etc*.); Y denotes the gross output value of the industry; K is capital (including FDI, total investment in fixed assets of the industry and capital migrated from other regions); L is the labor input (represented by the employment of the industry); and P represents the industry policy, which is a virtual variable. Industrial policy parameter P equals 1, indicating that each industry in each region has relevant industrial supporting policies; otherwise, it equals 0. α is the elastic coefficient of capital output; β is the elastic coefficient of labor output; γ is the elastic coefficient of policy and μ is a random interference. Using this equation, we build the intra-industry SD model which can simulate the annual changes of the industry.

2.4 Intra-regional analysis and modeling

The growth of regional GDP comes from the increase in the intra-regional outputs of various industries. To maintain the integrity of data and the consistency of statistical standards as well as to reflect the current economic development and emerging industries, seven industries were selected in this study. The statistics show that the total output values of these seven industries account for nearly 50% of the regional GDP.

2.4.1 Intra-regional population SD model

The population SD model provides the annual changes in the population and the number of labors in the eastern, middle, and western regions. State variables, namely, $N_{i,t}$ and $L_{i,t}$, respectively represent the population and the number of labors of region i in the period t. Rate variables, such as $r_{i,tb}$, $r_{i,td}$ and $r_{i,tl}$, respectively represent the birth and death rates and the rate of population aged 16 and over of the regional population. We construct two functions to stimulate the population and labors in each region (Equation (6) and Equation (7)). Then they are outputted to the intra-regional SD model.

$$N_{i,t} = N_{i,t-1} \times \left(1 + r_{i,tb} - r_{i,td}\right) \tag{6}$$

$$L_{i,t} = N_{i,t-1} \times r_{i,tl} \tag{7}$$

where $N_{i,t-1}$ is the population of region i in the period t–1, t = 2001, 2002, …, 2011.

2.4.2 Intra-regional causality between GDP and influencing factors

Regional GDP growth results from the increase of the output value of each industry in the region. Analyzing these industries' growing can be used to reflect the changes and growth of GDP in the region. Figure 4 is the intra-regional causal feedback loop of economic growth of each region.

2.4.3 Intra-regional SD model

Cause-and-effect relationship analysis is performed to further confirm the relationship between system structure and the model variables. The intra-regional SD model is utilized to describe the relationship among the seven industrial outputs, regional GDP, and per capita GDP, and to simulate GDP and per capita GDP of each region every year. The relationship dynamics model utilized to determine the relationship between the seven industries and regional GDP also can be seen in Fig. 1.

3 Simulation Results and Discussion

3.1 Adjustment parameters and alternatives

The four main parameters determining labor and capital migration are used as adjustment variables as shown in Table 1. VENSIM software is implemented to repeatedly test and control results of the model according to the changes of these adjustment variables. Based on the SD simulation of various programs, the regional economic disparities of GDP and per capita GDP in the eastern, middle, and western regions are obtained.

To make the stimulation results comparable, all adjustment variables are assigned their values under four conditions. First, the unchanged variables in the years of the original data according to *Chinese Statistical Yearbooks* are used to predict the results in other years. Second, variables that control labor migration are changed to predict the results in other years. Third, variables that control capital migration are changed to predict the results in other years. Fourth, variables that indicate labor and capital migration are changed to predict the results in other years and to obtain the four alternatives of industrial relocation and Chinese regional economic growth disparities. Then we choose one best set of results under each condition. Therefore, we get four alternatives about effects of industrial relocation on regional economic growth disparities. Results of the four alternatives about regional relative disparity coefficient of GDP can be seen in Fig. 5.

3.2 Stimulation results

By comparison and analysis, we believe the result of the forth alternative is most acceptable, which can reflect

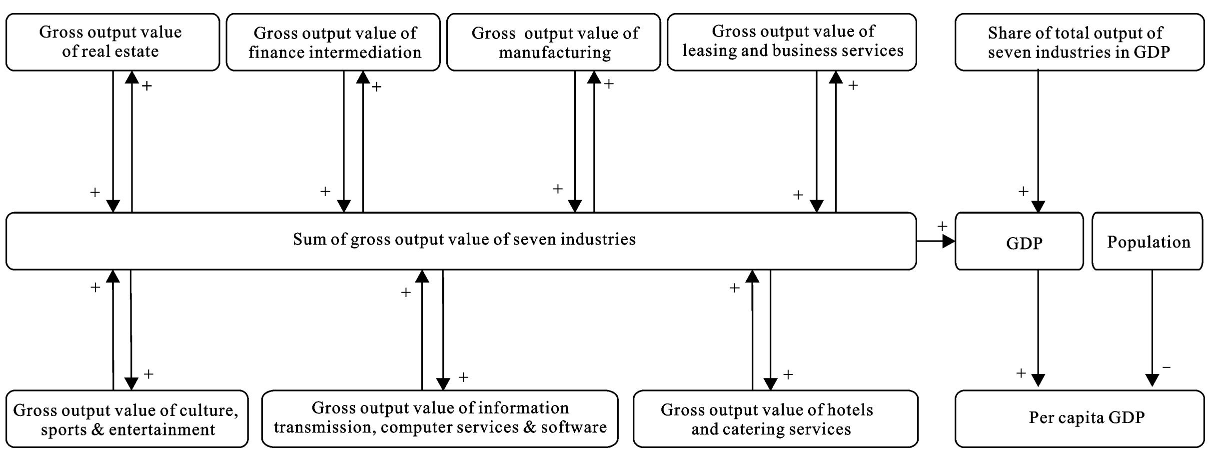

Fig. 4 Intra-regional causal feedback loop

Table1 Adjustment variables

Variables	Meaning of variables	Value interval
ϕ_c	Migration cost which is expressed by a certain percentage of urban salary	[0.1, 0.3]
ω_m	Elastic velocity of migration	[0.7, 0.9]
$\aleph_{r,u}$	Migration intensity coefficient from rural region to urban region, and reflects actual flow of inter-regional labor migration	[0.2, 0.5]
τ	reinvestment rate which can be expressed directly by the direct input coefficient of input-output table	[0.1, 0.5]

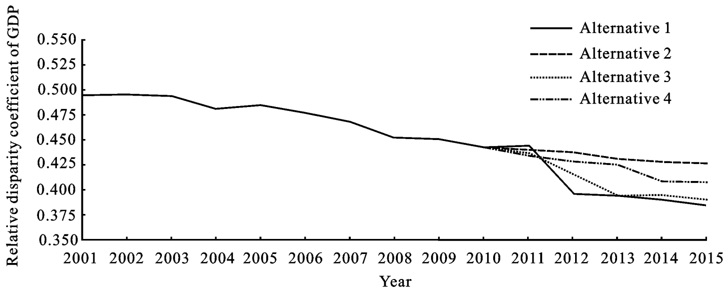

Fig. 5 Regional relative disparities of GDP under four alternatives

well that industrial relocation can not only promote economic growth in the middle and western regions, but also decrease relative economic growth disparities among the three regions and thus strengthen regional coordinated development. Because of strong industrial migration in its inner areas, the eastern region still keeps quick economic growth and development. According to the fourth alternative, the relative disparity between the eastern, middle, and western regions is decreasing. We obtain the simulation results shown in Table 2 by VENSIM software.

At constant prices, the relative disparity in GDP among the eastern, middle, and western regions is narrowed gradually; however, the absolute disparity continues to widen. In 2015, the absolute disparity between the eastern and western regions will be 5.884×10^{11} yuan and that between the eastern and middle regions will be 5.548×10^{11} yuan. In 2010, the one between the eastern and western regions was 4.739×10^{11} yuan and that between the eastern and middle regions was 4.599×10^{11} yuan. Aside from primary accumulated factors, the eastern region has more advantages than the middle and western regions in terms of native locational advantages, high economic development level, and excellent soft and hard environment. Therefore, their absolute disparities in the coming years are expected to continue to expand. With regard to per capita GDP in constant prices, the absolute and relative disparities among the eastern, middle, and western regions exhibit declining trends. In 2015, the absolute disparity between the eastern and western regions will be 364.47 yuan and that between the eastern and middle regions will be 253.41 yuan. In 2010, the one between the eastern and western regions was 383.80 yuan and that between the eastern and mid-

Table 2 Stimulation results of GDP and per capita GDP of three regions

Year	GDP (10^8 yuan (RMB))			Per capita GDP (yuan)		
	Eastern	Middle	Western	Eastern	Middle	Western
2001	6218	2413	2336	1130.99	672.05	649.34
2002	6216	2411	2342	1123.36	667.54	647.08
2003	6377	2481	2402	1145.21	683.23	659.40
2004	6682	2681	2568	1191.15	734.44	700.43
2005	6997	2797	2666	1236.79	761.81	741.13
2006	7130	2861	2768	1248.52	774.52	765.72
2007	7394	3028	2929	1282.46	814.51	806.92
2008	7787	3282	3170	1340.13	877.00	867.92
2009	7689	3255	3144	1295.97	914.38	855.89
2010	8090	3491	3351	1312.99	978.23	929.19
2011	8504	3763	3562	1343.59	1052.01	982.80
2012	8999	4037	3781	1410.26	1124.99	1038.39
2013	9474	4225	4039	1473.80	1171.15	1102.15
2014	9872	4567	4328	1524.30	1260.18	1175.28
2015	10426	4878	4542	1590.94	1337.53	1226.47

dle regions was 334.76 yuan. Because we consider the migrants from underdeveloped areas in the middle and western regions to developed areas in the eastern, middle, and western regions, the result shows a decreasing population in the middle and western regions, which then leads to a faster reduced gap of per capita GDP between these two regions. However, we do not consider the possibility of large-scale migration of the western population. If the phenomenon is taken into account, the per capita GDP of the western region in China will increase more quickly.

From the perspective of labor input, labor migration can indeed improve regional allocative efficiency of labors and speed up economic growth. Therefore it can decrease economic disparities among the eastern and western regions and differences between the urban and the rural. It also can lower and smooth down obstacles in further labor migration and solve the problem of labor shortage in the eastern region of China. However, the simple acceleration of labor migration cannot always effectively reduce regional disparity of economic growth. In contrast, it can bring some social problems, such as only elders and children staying at home in undeveloped rural areas.

From the perspective of capital input, the effect of capital on western economic development is not obvious. In the current development of the western region, it is important to actively guide the capital to move toward the middle and western regions, aside from considering the rising fixed asset investments of these regions. Given superior locational advantages and efficient soft and hard investment environments, coupled with the theory ′the western spatial pattern is uneconomical′ (Yang, 2003), it is difficult to guide large-scale foreign investment toward the middle and western regions. It will entail a long time to narrow the economic disparities among the three regions.

The success of past SD models illustrates that what often prevents progress is not a lack of resources, technical knowledge, or a genuine commitment to change (John, 2001). The requirement is a meaningful system-thinking capacity or the capability to learn about the complexity of the world and determine the best solutions through which we can create the future we aspire for. There are so many limitations in our model. For example, we consider only the relocation of several industries, and not all possible industries. Industrial relocation is also influenced by policy uncertainty, and we can not quantify the relationship between regional policy and industrial relocation behaviors. Meanwhile, our model does not consider the negative effects of enterprise production on the local economy, such as the deterioration of ecological environments and excessive consumption of natural resources. Although factors such as transportation and natural resources play an important role, we restrict the model to capital and labor because of the size and complexity of the model. Extending the model to consider these important elements will enhance our understanding of the role of industrial relocation in regional economic growth. More complicated models of industrial relocation can be examined to test the robustness of the SD model and the findings derived from it.

In sum, as a first attempt to incorporate SD modeling into industrial relocation research, our study provides a model that enables the examination of dynamic feedback during industrial relocation. This model provides a platform that can be easily extended in future research to investigate the complex interactions of various factors that affect regional industrial relocation and economic growth.

4 Conclusions

Industrial relocation is a complex system with multiple interfaces which follow the nonlinear interaction mechanism. The interaction of multiple feedbacks also causes exponential growth, super-stable convergence, short-term mutation, and time lags in the system. Therefore, stimulating industrial relocation with simple econometric models is rather difficult. We use SD models to analyze and design theoretical and empirical models for studying effects of industrial relocation on regional economic growth disparities.

The simulation of industrial relocation in China indicates that industrial relocation does not only promote economic growth and improve living standards, but also decreases the inter-regional relative economic disparities. In our model, the elastic velocity of migration and the migration intensity coefficient are important factors that influence labor movement among regions. We carefully consider the income disparity between rural and urban areas, and the number of off-farm workers. In future regional economic development, the government should narrow economic growth disparities and formulate related policies and measures to promote the coordinated development of urban and rural regions. Industrial relocation should be appropriately handled. Tax-sharing mechanisms should be innovated to enable benefit sharing among areas, and to simultaneously promote social development and avoid more serious polarization between rich and poor areas. Furthermore, the western region of China should accelerate its opening to the outside world to improve the soft environment for investors and industrial development. Moreover, the western region should use its rich and unique natural, biological, and human resources to form competitive advantages, reduce the geographical space for habitats to obtain scale economy and trading efficiency, and take full advantage of technology, information networks, and advanced e-commerce technology to reduce transaction costs.

References

Benjamin P T, Lawrence C B, 2010. Use of system dynamics as a decision-making tool in building design and operation. *Building and Environment*, 45(4): 1006–1015. doi:10.1016/j.buildenv.2009.10.008

Chen Jianjun, Ge Baoqin, 2008. Theoretical study of inner-mechanism in regional coordinated development. *Journal of China University of Mining & Technology* (*Social Science*), (4): 59–66. (in Chinese)

Duran-encalada J A, Paucar-caceres A, 2012. A system dynamics sustainable business model for Petroleos Mexicanos (Pemex): Case based on the global reporting initiative. *The Journal of the Operational Research Society*, 63(8): 1065–1078. doi: 10.1057/ jors. 2011.115

Fong W, Hiroshi M, Lun Y, 2009. Application of system dynamics model as decision making tool in urban planning process toward stabilizing carbon dioxide emission from cities. *Building and Environment*, 44(7): 1528–1537. doi: 10.1016/j.buildenv.2008.07.010.

He Renwei, Liu Shaoquan, Liu Yunwei, 2011. Application of system dynamics in analyzing the carrying capacity of water resources in Karst region of Southwest China. *Scientia Geographica Sinica*, 31(11): 1376–1382. (in Chinese)

John D. Sterman, 2001. System dynamics modeling: Tools for learning in a complex world. *California Management Review*, 43(4): 8–25.

Lin Liang, 2003. *Interregional Economic Relationship and Industry Migration*: *Taking Zhejiang and Shanghai as an Example*. Hangzhou: Zhejiang University. (in Chinese)

Liu Li, 2009. Study of the regional linkage mechanism for industrial relocation and upgrade: Discussion on Guangdong′s regional harmonious development model. *International Economics and Trade Research*, 25(12): 9–13. (in Chinese)

Liu Yaobin, Li Rendong, Li Chunhua, 2005. Scenarios simulation of coupling system between urbanization and eco-environment in Jiangsu Province based on system dynamics model. *Chinese Geographical Science*, 15(3): 219–226.

Lu Wanhe, Liu Jisheng, Na Wei, 2012. Industry conversion simulation analysis of resource-exhausted mining city based on the system dynamics: Taking Liaoyuan City of Jilin Province as example. *Scientia Geographica Sinica*, 32(5): 577–583. (in Chinese)

Luan Weixin, Chen Hang, Wang Yuewei, 2010. Simulating mechanism of interaction between ports and cities based on system dynamics: A case of Dalian, China. *Chinese Geographical Science*, 20(5): 398–405. doi: 10.1007/s11769-010-0413-5

Mohamed S, Rogelio O, Christian E K *et al*., 2010. A comprehensive analytical approach for policy analysis of system dynamics models. *European Journal of Operational Research*, 203(3): 673–683. doi: 10.1016/j.ejor.2009.09.016

NBSC (National Bureau of Statistics of China), 2001–2011. *China Statistical Yearbooks*. Beijing: China Statistics Press. (in Chinese)

Nie Hualin, Zhao Chao, 2000. Impact of inter-regional economic transition on the economic development of West China. *Journal of Lanzhou University*, 28(5): 11–15. (in Chinese)

Peng Wenbin, Liu Youjin, 2010. Research on space-time evolution characteristics of China′s regional economic disparity. *Economic Geography*, 30(4): 574–578. (in Chinese)

Quan Chun, 2005. Industrial relocation and central region′s industry structure evolution. *Truth Seeking*, (4): 45–47. (in Chinese)

Saysel A K, Yaman Barlas, Orhan Yenigun, 2002. Environmental sustainability in an agricultural development project: A system dynamics approach. *Journal of Environmental Management*, 64(3): 247–260. doi: 10.1006/jema.2001.0488

Tang Qing, Yuan Huiming, 2010. Impact of international polluting industries transfer on Guangdong′s environment. *Resources & Industries*, 12(4): 133–137. (in Chinese)

Wan Yongkun, 2011. Sustaining effects of the industrial transmission in the under-developed western areas. *Journal of Lanzhou University* (*Social Sciences*), 39(3): 104–108. (in Chinese)

Wang Jun, 2008. *The Transfer of Industrial Property in Beijing and Economic Development Research of Jing JinJi*. Beijing: Capital University of Economics and Business. (in Chinese)

Wang Siwen, Qi Jipeng, 2012. Flowing difference of elements and inter-regional industrial shift. *Journal of Lanzhou University* (*Social Sciences*), 40(2): 105–110. (in Chinese)

Wang Qifan, 1994. *System Dynamics*. Beijing: Tsinghua University Press: 1–25. (in Chinese)

Wei Houkai, 2003. Development trends and their impact on the competitiveness of industrial relocation. *Fujian Tribune*, (4): 11–15. (in Chinese)

Wei Houkai, Liu Changquan, 2006. Negative effects of foreign funds utilization in China and the direction of strategic adjustment. *Henan Social Sciences*, 14(5): 21–25. (in Chinese)

Wu D D, Xie K, Liu H *et al*., 2010. Modeling technological innovation risks of an entrepreneurial team using system dynamics: An agent-based perspective. *Technological Forecasting & Social Change*, 77(6): 857–869. doi: 10.1016/j.techfore.2010.01.015

Wu Xiaojun, Zhao Haidong, 2004. Industrial relocation and less-developed region economic development. *Contemporary Finance & Economics*, (6): 96–99. (in Chinese)

Xu Guangqing, Zhou Ji, 2006. The method of system dynamics: Principle, characteristics and new development. *Journal of Harbin Institute of Technology* (*Social Sciences Edition*), 8(4): 72–77. (in Chinese)

Xu Zhaoyuan, Li Shantong, 2008. The effect of inter-regional migration on economic growth and regional disparity. *The Journal of Quantitative & Technical Economics*, (2): 38–42. (in Chinese)

Yang Kaizhong, 2003. The western should overcome uneconomical spatial development pattern. *Economic Daily*, 09-19. (in Chinese)

Yang Kaizhong, 1989. *Chinese Regional Development*. Beijing: Maritime Press: 90–102. (in Chinese)

Zhang Keyun, 2001. *Regional War and Regional Economic Relations*. Beijing: Democracy and Construction Press, 241–282. (in Chinese)

Zhang Qin, 2010. Research on international industry transfer and industrial structure optimization: An empirical analysis based on Zhejiang Province. *Journal of International Trade*, (2): 60–67. (in Chinese)

Zhang Tingting, 2009. *The Innovative Research of Regional Policy Based on the Industrial Relocation*. Lanzhou: Lanzhou University. (in Chinese)

Zhao Hongchao, 1992. A survey of researches and developments of system dynamics. *Journal of East China Institute of Technology*, (2): 90–93. (in Chinese)

Zhao Zhangyao, Wang Bin, 2005. Studies on modes of international network-like industrial relocation. *China Industrial Economy*, (11): 68–71. (in Chinese)

Zhu Gang, 2006. Analysis on the negative effect of international industry transfer. *Science Technology and Industry*, 6(7): 17–20. (in Chinese)