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Evolvement Characteristics of Population and Economic Gravity Centers in Tarim River Basin, Uygur Autonomous Region of Xinjiang, China

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Abstract: Using the data at the county level and the regional gravity center model, we calculated six key socio-economic gravity centers, namely population, GDP, output values of primary, secondary and tertiary industries, and arable land area in the Tarim River Basin for each year from 1980 to 2009. We inspected the spatial dynamics of these centers and found that the gravity centers of population and economy evolved simultaneously. The disproportional growth between the population and the economy is also analyzed. The results show that: 1) The gravity centers of the GDP, the output values of the main three industries and arable land area show migration trending from southwest to northeast, while the population gravity center shows an excessive growth in the southwest during the same time period. The migration amplitude of the GDP and output values of primary industry, secondary industry, tertiary industry are measurably higher than that of the population. 2) The population gravity center has a negative correlation with the gravity centers of secondary and tertiary industries output values in both longitudinal and latitudinal directions, and a positive correlation with that of primary industry output value in the longitudinal direction. Based on the analysis of correlation coefficient and offset distance, the imbalance between the population and the economy has increased since the 1980s, with regional economic differences now exceeding the international cordon.
Keywords: regional gravity center model; population gravity center; economic gravity center; Tarim River Basin

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1 Introduction

Regional differences in economically underdeveloped areas have recently become a hot topic of interest for domestic and foreign researchers (Chen, 2010; Fleisher *et al.*, 2010; Li and Wei, 2010; Fan *et al.*, 2011). In delineating the key characteristics of these differences, numerous indicators emerge (Li and Qin, 2004; Wang, 2004), the main ones being the economy and spatial changes in population. In unified market information symmetry, the convergence of economic and population distribution indicates well-coordinated regional development, while the separation of these two factors reflects unbalanced development (Duan, 2008). American scholars initiated research into social, economic, and resource gravity centers some time ago, and the fruits of their research have had a profound impact on changes in the population and economy of the United States (Smarzynska, 2001; Aboufadel and Austin, 2006; Klein, 2009; Grether and Mathys, 2010). Since the 1970s, China has also begun research into social, economic, and resource gravity centers at the national (Xu and Yue, 2001; Qiao and Li, 2005; Xu and Li, 2005; Fan *et al.*, 2010), provincial (Bi *et al.*, 2007; Shen *et al.*, 2009; Qin

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et al., 2009; Xu and Yu, 2009) and river basin levels (Zhong and Lu, 2011), using the regional gravity center model to explore the correlation between population and the economy.

In recent years, with the implementation of China′s Western Development Program, both academics and policy-making departments have focused on regional economic differences in the Uygur Autonomous Region of Xinjiang, which is located in the arid region of Northwest China (Liu *et al.*, 2009; Han *et al.*, 2010; Lu *et al.*, 2010; Li *et al.*, 2011). However, a knowledge gap still exists in the systemic analysis of the gravity center′s evolvement characteristics in the hyper-arid region. The Tarim River Basin, which covers the entire southern part of Xinjiang, has the distinctive features of uneven population distribution and a fragile ecological environment (Chen *et al.*, 2008; 2011; Xu *et al.*, 2008; Tao *et al.*, 2011).

In this paper, we analyze the spatial-temporal evolution and the correlation of population and economic gravity centers over the past 30 years based on the regional gravity center model. The purpose of this paper is to reveal the characteristics of population and economic development on the ecological environment.

2 Materials and Methods

2.1 Study area

The Tarim River Basin, with an area of 1 157 800 km^2, lies between the Tianshan Mountains and Kunlun Mountains and covers the entire southern part of Xinjiang. The basin spans five prefectures and autonomous prefectures including Aksu Prefecture, Kashi (Kaxgar) Prefecture, Hotan Prefecture, Kirgiz Autonomous Prefecture of Kizilsu, Mongolian Autonomous Prefecture of Bayingolin, and includes 42 county-level administrative divisions (counties, autonomous counties and coungty-level cities). The total population of the Tarim River Basin region is 1.05 × 10^7, which accounts for about 48% of Xinjiang (Fig. 1). Throughout the basin, oasis agriculture has developed ′white agriculture′ (cotton production) as a result of long-term land reclamation. As of 2009, the GDP of the Tarim River Basin was 1.235 × 10^{11} yuan (RMB), accounting for 29% of Xinjiang′s GDP.

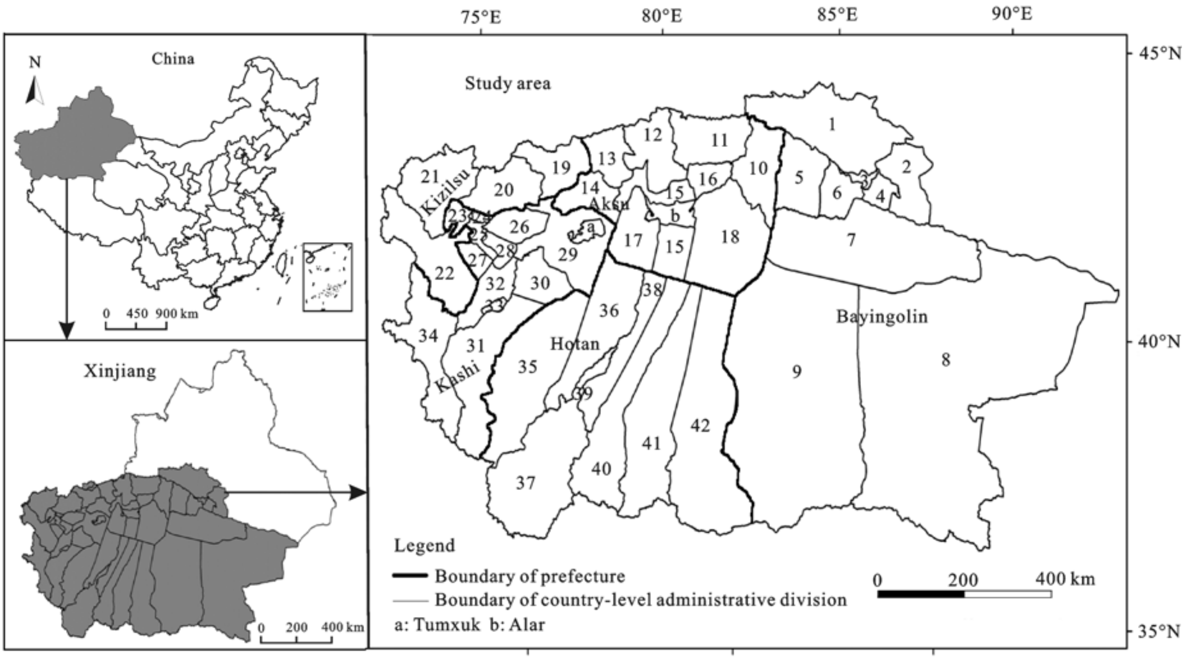

Fig. 1 Location of study area. 1. Hejing County; 2. Hoxud County; 3. Hui Autonomous County of Yanqi; 4. Bohu (Bagrax) County; 5. Luntai (Bügür) County; 6. Korla City; 7. Yuli (Lopnur) County; 8. Ruoqiang (Qarkilik) County; 9. Qiemo County; 10. Kuqa County; 11. Baicheng (Bay) County; 12. Wensu County; 13. Wushi (Uqturpan) County; 14. Kalpin County; 15. Aksu City; 16. Xinhe (Toksu) County; 17. Awat County; 18. Xayar County; 19. Akqi County; 20. Artux City; 21. Wuqia (Ulugqat) County; 22. Akto County; 23 Shufu County; 24. Kashi (Kaxgar) City; 25. Shule County; 26. Jiashi County; 27. Yengisar County; 28. Yopurga County; 29. Bachu (Maralwexi) County; 30. Markit County; 31. Yecheng County; 32. Shache County; 33. Zepu (Poskan) County; 34. Tajik Autonomous County of Taxkorgan; 35. Pishan (Guma) County; 36. Moyu (Karakax) County; 37. Hotan County; 38. Lop County; 39. Hotan City; 40. Qira County; 41. Yutian County; 42. Minfeng County). The study area does not include the territory country-level cities: a and b

2.2 Data

The data are mainly composed of spatial and attribute data. Spatial data were obtained from 1∶4 000 000 national fundamental geographic data, and attribute data were collected from *50 Glorious Years of Xinjiang* (People's Government Office of Xinjiang Uygur Autonomous Region, 1999) and *Xinjiang Statistical Yearbook 1989–2011* (Statistical Bureau of Xinjiang Uygur Autonomous Region, 1989–2011). The data include the population, GDP, arable land area, and the output values of primary, secondary and tertiary industries in 1980–2009. In this paper, the GDP, arable land area, and the output values of primary, secondary and tertiary industries are collectively called economic gravity centers.

2.3 Methods

2.3.1 Regional gravity center model

We use the regional gravity center model derived from the concept of mechanics to express the regional center of gravity coordinates as ($\overline{X}, \overline{Y}$) (Li, 1999):

$$\overline{X}=\sum_{i=1}^{n}\mathrm{M}_i X_i \Big/ \sum_{i=1}^{n}\mathrm{M}_i$$
$$\overline{Y}=\sum_{i=1}^{n}\mathrm{M}_i Y_i \Big/ \sum_{i=1}^{n}\mathrm{M}_i \qquad (1)$$

where X_i, Y_i are the longitude and latitude of unit i, meaning the geometric center of the region (X_i, Y_i); and M_i is the 'gravity' of unit i. If a certain element's spatial average ($\overline{X}, \overline{Y}$) is significantly different from the regional geometric center (X_i, Y_i), this means the uneven distribution of one phenomenon, i.e., a 'gravity center deviation'. The deviation direction indicates the 'high density' part of the space phenomenon, while the deviation distance indicates the disequilibrium level (Li, 1999).

2.3.2 Gini coefficient

The Gini coefficient (G) is a measurement index of income differences (Li and Xiu, 2008). We measure the evolution of regional economic differences based on the following equation:

$$G=\frac{1}{2n^2u}\sum_{j=1}^{n}\sum_{i=1}^{n}\left|Y_j - Y_i\right| \qquad (2)$$

where $|Y_j–Y_i|$ is the absolute value of any pair's (j and i samples) revenue difference; n is the number of samples; and u is the mean of income.

2.3.3 Tsui-Wang (TW) index

Wang and Tsui (2000) developed the Wolfson index, also referred to as the Tsui-Wang index. It is used to reflect the agglomeration characteristics of regional differences. The equation is as follows:

$$TW=\frac{\theta}{\mathrm{N}}\sum_{i=1}^{k}\pi_i\left|\frac{y_i-m}{m}\right|^{\gamma} \qquad (3)$$

where N is the total population in the study region; π_i is the population in the geographical unit i; k is the number of regional units; y_i is the per capita GDP in the geographical unit i; m is the center value of per capita GDP in total geographical units ($\theta = 0.5$, $r = 0.5$); and θ and r are polarization indexes (0–1), with a greater tendency to 1 indicating more prominent regional polarization.

3 Results and Discussion

3.1 Changing characteristics of gravity centers

3.1.1 Changing characteristics of population gravity center

Figure 2 illustrates that the population gravity center showed a trend from the northeast to southwest in 1980–2009. It indicates that population growth rapidly in the southwest. The gravity center moved west about 0.072° and south about 0.0629° (gravity center in 2009 compares with that in 1980), marking a slightly larger movement westward (in the longitude direction) than southward (in the latitude direction) and accumulating a movement distance of about 70.07 km.

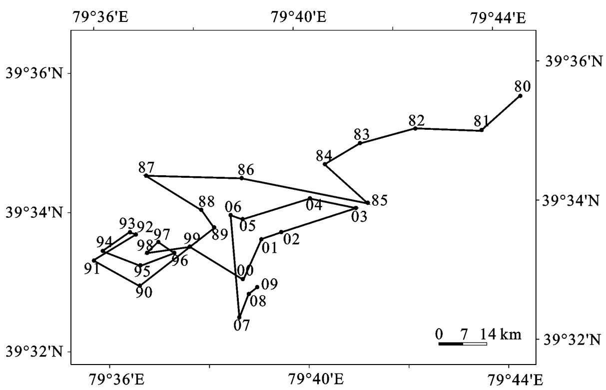

Fig. 2 Changing characteristics of population gravity center in Tarim River Basin. 80: 1980; 81: 1981; 82: 1982; 83: 1983; 84: 1984; 85: 1985; 86: 1986; 87: 1987; 88: 1988; 89: 1989; 90: 1990; 91: 1991; 92: 1992; 93: 1993; 94: 1994; 95: 1995; 96: 1996; 97: 1997; 98: 1998; 99: 1999; 00: 2000; 01: 2001; 02: 2002; 03: 2003; 04: 2004; 05: 2005; 06: 2006; 07: 2007; 08: 2008; 09: 2009. Below is the same

The better socio-economic development in the northeastern region made the population there hold a more scientific concept of family planning. As a result, the population growth rate declined in the northeastern region. Meanwhile, in the Kashi Prefecture, Hotan Prefecture and Kirgiz Autonomous Prefecture of Kizilsu (an area which is home mainly to minority population), a fast rate of population growth emerged due to relatively poor family planning, which caused poor socio-economic development.

3.1.2 Changing characteristics of economic elements' gravity centers

We analyzed the evolution of economic gravity centers in the Tarim River Basin and found that the gravity centers of GDP, along with those of output values of primary, secondary and tertiary industries, all revealed a southwest-to-northeast migration trend from 1980 to 2009 (Fig. 3). The GDP gravity center had deviated to the northeast compared to the geometric center and had a contrary movement direction in relation to the population (Fig. 3a). This indicates that the northeastern region formed the economic high-density area of the Tarim River Basin, and the relationship of economic development and population had been in a state of imbalance. Specifically, from 1980 to 2009, the primary industry gravity center moved from 80.13°E, 39.80°N to 80.79°E, 40.07°N (Fig. 3b), and the secondary industry gravity center moved from 81.11°E, 40.37°N to 83.64°E, 41.05°N (Fig. 3c). During the same time period, the tertiary industry gravity center moved from 80.12°E, 40.09°N to 80.87°E, 40.27°N (gravity center in 2009 compares with that in 1980) (Fig. 3d).

It is noteworthy that Aksu formed the GDP gravity center from 1993, and directly towards northeast direction. The same geographic area had formed the secondary industry gravity center, spreading rapidly towards Bayingolin (with Korla, the largest city in the southern Xinjiang) direction. The economy developed rapidly in Mongolian Autonomous Prefecture of Bayingolin because of their rich resources of heat, water, soil, oil, gas and minerals, and the region then dominated the economic zone of the Tarim River Basin. The industrial base in Korla City expanded rapidly, and so the secondary industry likewise emerged rapidly. Although the

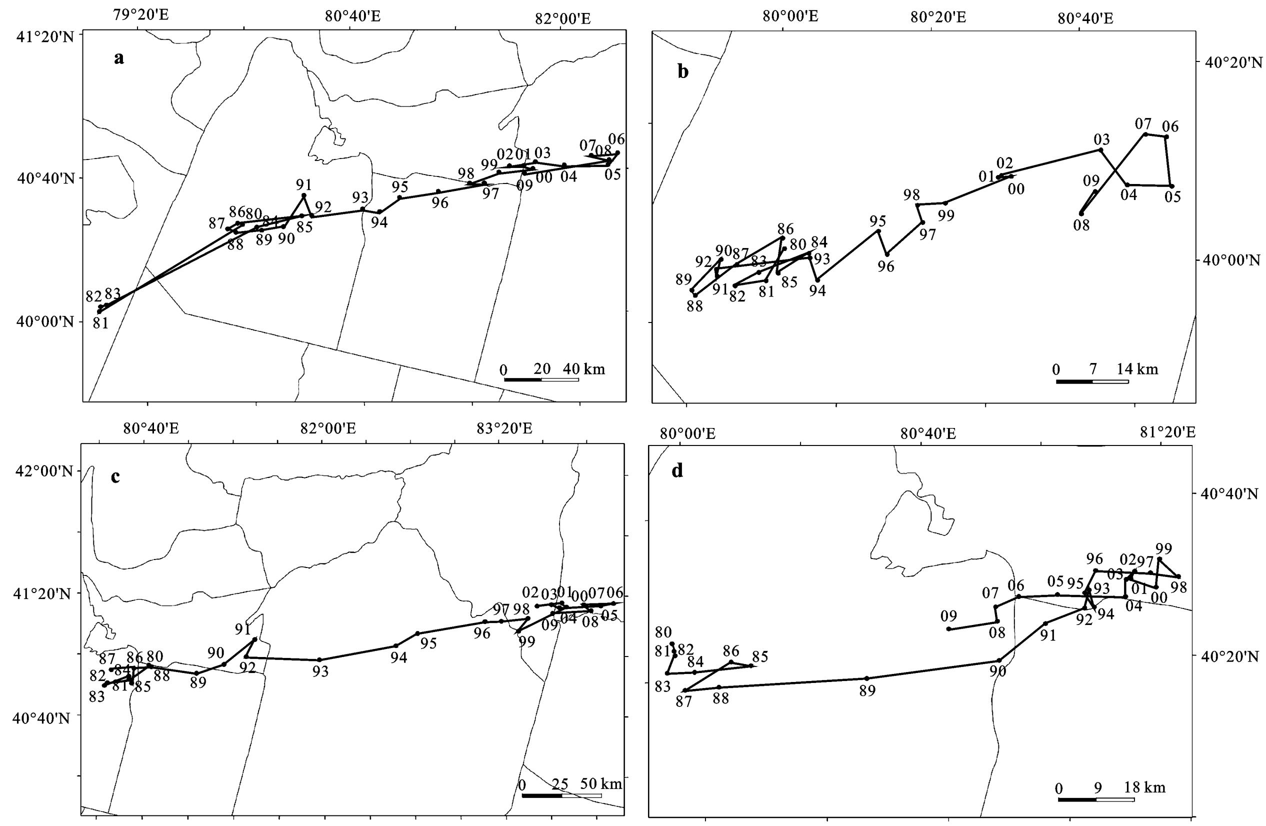

Fig. 3 Changing characteristics of economic elements′ gravity centers in Tarim River Basin. a. GDP; b. Primary industry; c. Secondary industry; d. Tertiary industry

primary industry remained in the Awat County, these became increasingly disorganized due to the overall low level of agricultural development and production tools, the rudimentary knowledge of workers, and the fragile environmental conditions. In contrast, Bayingolin Mongol Autonomous Prefecture, with its rich oil resources, quickly became highly industrialized and urbanized, and its strong industrial and transportation foundations made way for the development of tertiary industry in the Tarim River Basin. The weak economic and industrial bases in the Aksu Prefecture, Kash Prefecture, Hotan Prefecture and Kirgiz Autonomous Prefecture of Kizilsu, led to sizeable migration trajectory changes in tertiary industry since 1998, especially in 2000.

The gravity center migration of the three industries resulted in significant changes in the industrial structure. Primary industry decreased from 57.13% in 1980 to 25.91% in 2009, while secondary and tertiary industry increased from 17.86% and 25% to 42.28% and 31.81% respectively during the same time period. A summary of the foregoing is as follows: 1) The proportion of agriculture-led development in the Tarim River Basin has gradually declined over the past 30 years. 2) Secondary industry has grown to become leading industry due to the acceleration process of large-scale development in the western region; tertiary industry has gradually expanded; the secondary and tertiary industries have become more important.

3.1.3 Changing characteristics of arable land area gravity center

Arable land, as an important carrier of the primary industrial development in the Tarim River Basin, has shown obvious stage changes in its gravity center tracks (Fig. 4). From 1980 to 1985, the evolution of its gravity center followed no apparent course and showed little migration in latitudinal or longitudinal direction, which may have been due to the balanced development of land and water during this time period. Instead of artificially-imposed economic interventions, natural conditions and socio-economic activities endemic to the region determined the migration of arable land area gravity center. The following were the main aspects: In the late 1990s, in order to rapidly improve the scale of fruit planting, Aksu Prefecture and Mongolian Autonomous Prefecture of Bayingolin began growing specialty fruits such as pears, apricots, apples, jujubes, which caused a excessive reclamation of arable land in the northeast. And the arable land in Bayingolin has the fastest growing speed (Zhu *et al.*, 2011). The arable land area of the eastern, central and western regions in the Tarim River Basin showed a significant imbalance in distribution.

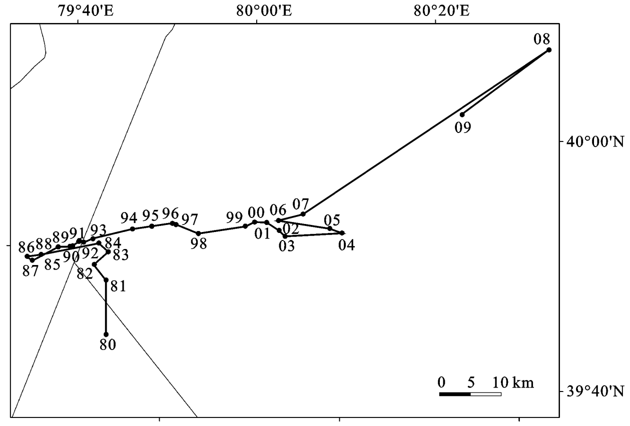

Fig. 4 Changing characteristics of arable land area gravity center in Tarim River Basin

3.2 Correlation of population gravity center and economic gravity centers

3.2.1 Correlation in longitudinal and latitudinal directions

There was little consistency in either longitudinal or latitudinal gravity center movements among the six main categories of population, GDP, output values of primary, secondary and tertiary industries, and arable land area. In the longitudinal direction, the movements of the GDP, output values of primary, secondary and tertiary industries were all larger than those of the population, while the secondary industry gravity center moved markedly towards the eastern region and had the farthest deviation of population gravity center (Fig. 5). Figure 5 also illustrated that the population of the study area showed steady development in the longitudinal direction, while the economic gravity center′s showed eastward migration trend. Since 2005, the development of the economy and arable land approached the population gravity center, which implied that the GDP, output values of primary, secondary and tertiary industries and arable land area were gradually moving towards balanced development.

In analyzing correlations in longitude and latitude directions among the gravity centers of population, GDP, primary industry, secondary industry, tertiary industry and arable land area, we found that, based on Table 1, there were negative correlations between the gravity

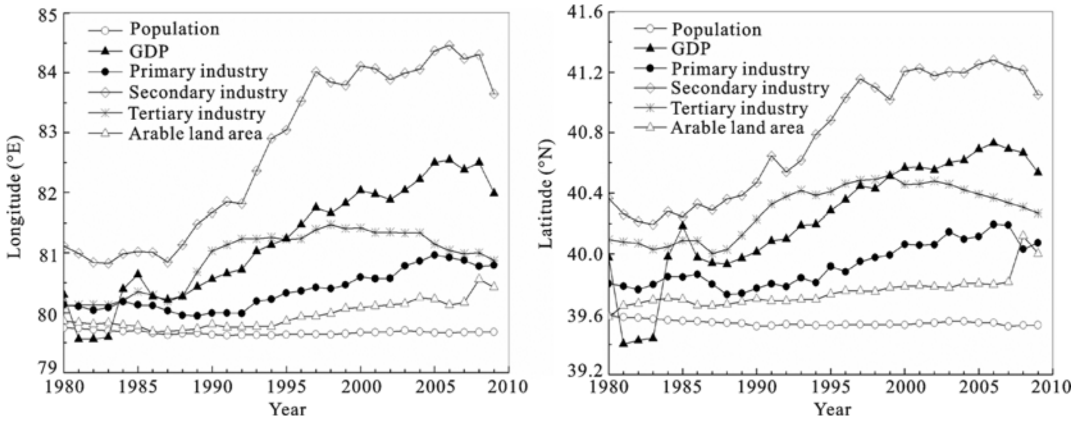

Fig. 5 Contrast of population and economic gravity centers′ movement in Tarim River Basin

Table 1 Correlation coefficient of population and economic gravity centers′ movement

		GDP	Primary industry	Secondary industry	Tertiary industry	Arable land area
Population	Longitude	–0.209	0.113	–0.207	–0.530*	0.408*
	Latitude	–0.587**	–0.284	–0.542**	–0.604**	0.561**

Note: * and ** indicate significant level at 0.05 and 0.01 , respectively

centers of population and the GDP, secondary and tertiary industries. Both in longitude and latitude directions, the population gravity center and arable land area showed positive correlations, which indicated the importance of the agricultural economy in the Tarim River Basin.

3.2.2 Offset distance of economic gravity centers relative to population gravity center

From Fig. 6, we found that: 1) The offset distance of the GDP gravity center and secondary industry output value gravity center relative to the population gravity center had increased during the 1980–2009 time period, and that the degree of deviation of the secondary industry output value was higher than that of the GDP. This indicated an imbalance in the GDP and secondary industry output value with population, due to the effect of the secondary industry, which were then no longer subjected to labor restrictions. 2) The offset distance of the tertiary industry output value relative to the population gravity center increased until 1998 and then decreased, while the primary industry output value underwent complex but subtle changes. 3) The offset distance of arable land area had not obviously change, and the stability between the arable land area and population grew increasingly.

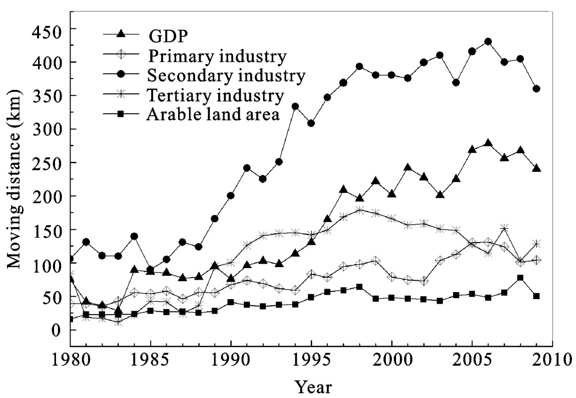

Fig. 6 Offset distance of economic gravity centers relative to population gravity center in Tarim Basin (1980–2009)

3.2.3 Disproportion between population and economic gravity centers

The disproportion between the population and the economy in the Tarim River Basin revealed strong regional economic differences. In combination with Gini coefficient and TW index trends, we analyzed these differences (Fig. 7). The results showed that the Gini coefficient and TW index trends increased, which indicated that regional economical differences were expanding.

Since 1990, the regional economic difference index (Gini coefficient) has risen quickly and, as of 2005, exceeded the international cordon (0.40). This trend may lead to a large gap between the rich and the poor, which will have negative social impacts. The distance between the population and economic gravity centers was insignificant in the early years of our study period, but as time passed, the coordination gradually weakened and

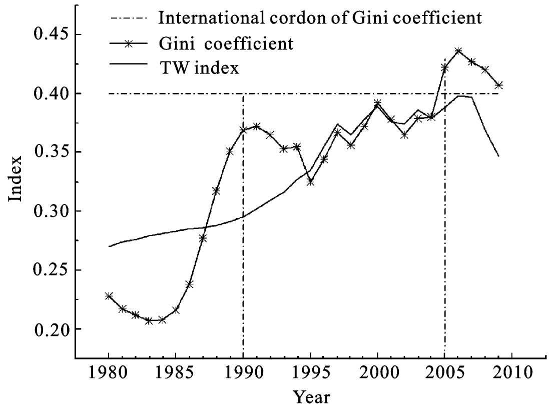

Fig. 7 Gini coefficient and Tsui-Wang (TW) index trends in Tarim River Basin (1980–2009)

moved disproportionately in a southwest-northeast direction. Overall, the population gravity center matched well with the economic gravity centers in the early years of economic reform, but the imbalance gradually increased due to inconsistent development directions.

4 Conclusions

(1) The gravity centers of GDP, output values of primary, secondary and tertiary industries, and arable land area in the Tarim River Basin all showed southwest to northeast migration trends from 1980 to 2009, while the population gravity center showed an excessive growth in the southwest during the same time period. The migration amplitude of the GDP and output values of primary, secondary and tertiary industries were measurably higher than that of the population, and the offset distance of economic gravity centers relative to population gravity center increased. This indicated that the imbalance of economic development and population distribution was intensifying, and that economy in the eastern region was rapidly developing.

(2) The industrial structure changed visibly from 1980 to 2009. Specifically, primary industry significantly decreased, tertiary industry gradually increased, and secondary industry surged to the forefront.

(3) The disproportion between population and the economy increased steadily from 1980 to 1990, after which regional economic differences rose quickly, surpassing the international cordon in 2005. The population grown rapidly in the Kashi Prefecture, Hotan Prefecture and Kirgiz Autonomous Prefecture of Kizilsu, which were in the west region of the southern Xinjiang; while the economic gravity centers indicated a migration towards Mongolian Autonomous Prefecture of Bayingolin, which was in the northeast region of the southern Xinjiang. This phenomenon resulted in a disproportion between population and the economy, and led to poverty in Kashi Prefecture, Hotan Prefecture and Kirgiz Autonomous Prefecture of Kizilsu; while Mongolian Autonomous Prefecture of Bayingolin, especially Korla City, became an important economic polarization center in the southern Xinjiang.

References

Aboufadel E, Austin D, 2006. A new method for computing the mean center of population of the United States. *The Professional Geographer*, 58(1): 65–69. doi: 10.1111/j.1467-9272.2006.00521.x

Bi Qige, Bao Yin, Li Baisui, 2007. Relevancy analysis of the coupling between population structure and regional economy in Inner Mongolia. *Geographical Research*, 26(5): 995–1004. (in Chinese)

Chen A P, 2010. Reducing China's regional disparities: Is there a growth cost? *China Economic Review*, 21(1): 2–13. doi: 10.1016/j.chieco.2009.11.005

Chen Y N, Pang Z H, Chen Y P *et al.*, 2008. Response of riparian vegetation to water-table changes in the lower reaches of Tarim River, Xinjiang Uygur, China. *Hydrogeology Journal*, 16(7): 1371–1379. doi: 10.1007/s10040-008-0306-1

Chen Y N, Ye Z X, Shen Y J, 2011. Desiccation of the Tarim River, Xinjiang, China, and mitigation strategy. *Quaternary International*, 244(2): 1–8. doi: 10.1016/j.quaint.2011.01.039

Duan P Z, 2008. Influence of China's population mobility on the change of regional disparity since 1978. *China Population, Resources and Environment*, 18(5): 027–033. doi: 10.1016/S1872-583X(09)60018-8

Fan Jie, Tao Anjun, Lu Chen, 2010. The coupling mechanism of the centroids of economic gravity and population gravity and its effect on the regional gap in China. *Progress in Geography*, 29(1): 87–95. (in Chinese)

Fan S G, Kanbur R, Zhang X B, 2011. China's regional disparities: Experience and policy. *Review of Development Finance*, 1: 47–56. doi: 10.1016/j.rdf.2010.10.001

Fleisher B, Li H, Zhao M, 2010. Human capital, economic growth, and regional inequality in China. *Journal of Development Economics*, 92: 215–231. doi: 10.1016/j.jdeveco.2009.01.010

Grether G M, Mathys A, 2010. Is the world's economic center of gravity already in Asia? *General and Introductory Geography*, 42(1): 47–50. doi: 10.1111/j.1475-4762.2009.00895.x

Han Chunxian, Ma Yaofeng, Luo Hui, 2010. Economic spatial evolution and its mechanism in Xinjiang. *Arid Land Geography*, 33(3): 449–455. (in Chinese)

Klein L R, 2009. Measurement of a shift in the world′s center of economic gravity. *Journal of Policy Modeling*, 31: 489–492. doi: 10.1016/j.jpolmod.2009.05.005

Li Jizhi, Qin Qiming, 2004. Research on the regional economic difference and regional development of Liaoning Province. *China Population Resources and Environment*, 14(2): 77–80. (in Chinese)

Li X B, 1999. Visulizing spatial equality of development. *Scientia Graphica Sinica*, 19(3): 254–257.

Li Xuemei, Zhang Xiaolei, Du Hongru, 2011. Selection of leading industry and appraisal system of urban in arid area. *Arid Land Geography*, 34(4): 693–699. (in Chinese)

Li Xiuwei, Xiu Chunliang, 2008. New pattern of regional economic polarization in the three provinces of northeast China. *Scientia Geographica Sinica*, 28(6): 722–728. (in Chinese)

Li Y, Wei Y H, 2010. The spatial-temporal hierarchy of regional inequality of China. *Applied Geography*, 30(3): 303–316. doi: 10.1016/j.apgeog.2009.11.001

Liu Yaxuan, Zhang Xiaolei, Lei Jun *et al.*, 2009. Moving route of economic gravity center of Xinjiang in recent thirty years. *Arid Land Geography*, 32(3): 471–477. (in Chinese)

Lu Sijia, Zhang Xiaolei, Lei Jun *et al.*, 2010. Division of urban economic region and its influence scope in Xinjiang. *Arid Land Geography*, 33(2): 300–305. (in Chinese)

People′s Government Office of Xinjiang Uygur Autonomous Region, 1999. *50 Glorious Years of Xinjiang*. Xinjiang: People′s Press. (in Chinese)

Qiao Jiajun, Li Xiaojian, 2005. The shift route of Chinese economic gravity center in recent 50 years. *Areal Research and Development*, 24(1): 12–16. (in Chinese)

Qin Zhenxia, Li Hanlin, Su Chaoyang, 2009. Evolvement and comparative analysis of population gravity center and economy gravity center from 1987 to 2006 in Henan. *Research of Agricultural Modernization*, 30(1): 16–19. (in Chinese)

Shen Xulei, Wang Guixin, Kong Chao, 2009. Comparative study on the spatial disequilibrium between China′s population distribution and economic development. *Population and Development*, 15(6): 69–73. (in Chinese)

Smarzynska B, 2001. Does Relative Location Matter for Bilateral Trade Flows? An extension of the gravity model. *Journal of Economic Integration*, 16(3): 379–398.

Statistical Bureau of Xinjiang Uygur Autonomous Region, 1989–2011. *Xinjiang Statistical Yearbook*. Beijing: China Statistics Press. (in Chinese)

Tao H, Gemmer M, Bai Y G *et al.*, 2011. Trends of streamflow in the Tarim River Basin during the past 50 years: Human impact or climate change. *Journal of Hydrology*, 400(1–2): 1–9. doi: 10.1016/j.jhydrol.2011.01.016

Wang Qifang, 2004. Case study of regional economic disparity in Jiangsu Province during the period of economic conversion. *China Population Resources and Environment*, 14(3): 75–79. (in Chinese)

Wang Y Q, Tsui K Y, 2000. Polarization ordering and new classes of polarization indices. *Journal of Public Economic Theory*, 3(2): 349–363. doi: 10.1111/1097-3923.00042

Xu H L, Ye M, Li J M, 2008. The water transfer effects on agricultural development in the lower Tarim River, Xinjiang of China. *Agricultural Water Management*, 95(1): 59–68. doi: 10.1016/j.agwat.2007.09.004

Xu Jianhua, Yue Wenze, 2001. Evolvement and comparative analysis of the population center gravity and the economy gravity center in recent twenty years in China. *Scientia Geographica Sinica*, 21(5): 385–389. (in Chinese)

Xu Yueqing, Li Shuangcheng, 2005. Dynamic evolvement of the population and the social economy gravity center in China. *Human Geography*, (1): 117–120. (in Chinese)

Xu Yanyan, Yu Yang, 2009. Comparative analysis of the dynamic evolvement procedure of population and economy in Gansu Province. *China Forestry Economy*, (2): 41–44. (in Chinese)

Zhong Yexi, Lu Yuqi, 2011. The coupling relationship between population and economic in Poyang Lake ecological economic zone. *Economic Geography*, 31(2): 195–200. (in Chinese)

Zhu Hui, Jiao Guanghui, Wang Zhe *et al.*, 2011. Research on spatial change process of the cultivated farm land and dynamic evolution in Xinjiang During 1978–2008. *Agricultural Research in the Arid Areas*, 29(2): 185–197. (in Chinese)