Imbalance and Polarization of Spatial Distribution of China's Swine Production

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Abstract Based on annual pork yield of each province in 1996 – 2014, using Gini coefficient and spatial polarization index model, empirical analysis was carried out for spatial imbalance and polarization degree of swine production distribution. Results indicate that there is high imbalance in spatial distribution of swine production. The imbalance takes on first rise then declines with fluctuation, largely because of inter-group gap. From the perspective of regions, the regions with balanced grain production have the highest imbalance in swine production, followed by main sales regions, and the main grain production regions have the lowest imbalance. The polarization index indicates that the overall polarization degree of the spatial distribution of swine production takes on a growing trend, and that of each functional region of grain production is also growing.

Key words Swine production, Spatial imbalance, Polarization index, Grain functional region

1 Introduction

Swine industry is a sector of animal husbandry with great national support. Pork yield is an aggregative indicator for measuring the development of swine industry. In meat production of China, pork yield is the largest. In 2014, China's total pork yield was 567.139 million t, accounting for 65.14% of meat production. Pork is also the primary source of meat consumption of urban and rural residents. In 2014, per capita pork consumption of national residents was 20 kg, accounting for 78.13% of meat consumption. By comparison, the per capita beef and mutton consumption was 2.5 kg, only 12.5% of pork consumption (data source: National Bureau of Statistics of the People's Republic of China). Therefore, safe swine production greatly influences living standards of residents.

In 1996 – 2014, except Shanghai, the pork yield of other provinces and cities showed positive growth trend. The growth rate was greatly varied. Xinjiang and Hainan had high annual growth rate of pork yield, respectively 7.38% and 6.08%, while Ningxia and Beijing had annual growth rate lower than 1%. For this reason, changes have taken place in distribution of swine production. At present, literature about distribution of swine production can be divided into two types: (i) studies about characteristics of changes in distribution of swine production. Due to influence of natural resource factors, traditional swine production is mainly distributed in Sichuan Basin, Huang-Huai-Hai Plain (North China Plain) and plains in the middle and lower reaches of Changjiang River. However, with social development, influenced by market economy, farmers' income, and breeding infrastructure, the swine production gradually spreads from south to north and from east to west[1,2]. Yu Hui *et al.*[3] analyzed changes in distribution of swine production from the perspective of environmental protection. With gradual improvement in market economy and constant improvement of people's living standards, they believed that requirements of residents will also increasingly rise, and China's swine production also moves from regions with strict regulations to regions with less strict regulations. According to calculation of comprehensive comparative environmental advantages, Zhang Hui and Yu Hui[4] pointed out that comprehensive comparative environmental advantages of southern regions are significantly better than northern regions, and they proposed strengthening swine production in southwestern regions and slowing down swine production in northeastern regions. (ii) Studies about factors influencing distribution of swine production. For example, Hu Hao *et al.*, Huang Yanjun, Zhang Zhen, Qiao Juan, Lei Xianyun *et al.*[5-8] analyzed factors influencing distribution of swine production from natural conditions, market, policies, and ecology. They concluded that the distribution of swine production is influenced to a certain extent by endowment of feed resources, feeding scale, non-agricultural employment opportunity, consumption demands, breeding technology, traffic, and environmental limitation.

In sum, most existing researches are qualitative studies about characteristics of spatial distribution of swine production. In this situation, we analyzed imbalance and polarization of spatial distribution of swine production from the quantitative perspective. Besides, feed is great support of swine industry and feed cost accounts for approximately 55% of total costs of swine production[9], and grain is the main source of feed for swine production. Therefore, we compared spatial distribution of swine production between functional regions of grain production. This, to a certain extent, is favorable for further understanding characteristics and changes of regional distribution of swine production in China.

2 Analysis method and data source

2.1 Spatial Gini coefficient In this study, we applied Gini coefficient and its decomposition method developed by Mookherjee

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and Shor-rocks. The spatial Gini coefficient for distribution of swine production will be:

$$G = \frac{1}{2n^2\mu}\sum_i \sum_j |y_i - y_j| \quad (1)$$

Its decomposition is:

$$G = \sum_k v_k^2 \lambda_k G^k + \frac{1}{2}\sum_k \sum_h v_k v_h |\lambda_k - \lambda_h| + R \quad (2)$$

where y_i denotes the pork yield in province i, v_k signifies the volume of number of group K provinces to total number of provinces, λ_k signifies average pork yield of group K provinces to average pork yield of all provinces. λ^k denotes Gini coefficient for spatial distribution of swine production in group G^K provinces, and R is the residual term. In equation (2), the first term in the right side reflects intra-group difference, the second term reflects inter-group difference, the third term is residual term and reflects alternative degree of the swine production level.

2.2 Spatial polarization index

2.2.1 ER index. Esteban and Ray introduced a method for measuring the polarization degree on the basis of defining the sense of identity and sense of alienation. According to this, we built the following ER index for measuring the polarization degree of swine production distribution:

$$ER = K\sum_i \sum_j v_i v_j v_i^a |\mu_i - \mu_j| \quad (3)$$

where v_i and v_j denote the volume of number of samples in group i and group j to total samples, μ_i and μ_j denote the average pork yield of group i samples and group j samples. Parameter $K>0$ and plays the role of standardization, and ER index remains in the range of 0 – 1; α is arbitrary value in (0, 1.6). The closer to 1.6, the greater difference there will be between ER index and standard Gini coefficient. To reflect the polarization trend, α is generally 1.5[11].

2.2.2 EGR index. In view of certain limitation of ER index, Esteban *et al.* improved the ER index and put forward EGR index[10]. According to the EGR index, we built EGR polarization index for distribution of swine production:

$$EGR = K\sum_i^n \sum_j^n v_i v_j v_i^a |\mu_i - \mu_j| - \beta [G_1 - G_2] \quad (4)$$

In equation (4), the first term in the right side is ER index, G_1 denotes Gini coefficient, G_2 denotes inter-group gap, parameter $\beta>0$. In actual calculation, it is necessary to adjust K and β, to make the EGR index remain in (0, 1).

2.2.3 *LU* index. When there is overlap between pork yield of each group, the second term in the *EGR* index will not well reflect the imbalance degree of distribution of intra-group swine production. For this, Lasso and Urrutia introduced a new index, *i.e.* *LU* index for measuring the polarization degree in 2006[10,11]. On the basis of this index, we build following *LU* polarization index for distribution of swine production:

$$LU = K\sum_i^n \sum_j^n v_i v_j v_i^a (1 - G_i)^\beta |\mu_i - \mu_j| \quad (5)$$

where G_i denotes Gini coefficient for spatial distribution of swine production of group i samples. Similar to *ER* index and *EGR* index, parameter $K>0$ and plays the role of standardization, $\beta>0$, β is the parameter for sensitivity of intra-group aggregation degree. In actual calculation, it is necessary to adjust K and β, to make the *LU* index remain in (0, 1).

2.3 Data source and parameter setting In this study, we selected annual pork yield data of provinces in 1996 – 2014 from database of National Bureau of Statistics of the People's Republic of China. When calculating the polarization index for spatial distribution of swine production, to make the *ER*, *EGR*, and *LU* remain (0, 1), we adjusted parameter K and β. The results are as follows: take $K = 0.03$, $\beta=0.5$, and $\alpha=1.5$ when calculating the polarization index for spatial distribution of swine production of the whole country; take $K = 0.02$, $\beta = 0.5$, and $\alpha = 1.5$ when calculating the polarization index for spatial distribution of swine production of functional regions of grain production.

3 Analysis on spatial imbalance of swine production distribution

3.1 Distribution of swine production in China For a long term, China's swine production is influenced from natural resources, so the swine production is relatively concentrated in main grain production regions. As shown in Table 1, in 1996 – 2014, the pork yield of main grain production regions accounted for 67.28% of total pork yield of the whole country, the pork yield of grain balanced regions took up 19.80%, and main sales regions accounted only for 12.92% of total pork yield of the whole country. According to trend of changes, before 2008, changes were basically consistent in swine production between main sales regions and balanced regions, the pork yield first declined then rose, and it fluctuated in a V shape, while the situation was opposite in main grain production regions, taking on an inverted V shape; after 2008, the pork yield of main grain production regions and balanced regions took on a growing trend, while it declined in main sales regions. The above analysis indicates that the swine production is still mainly distributed in main grain production regions, and there is a trend of aggregating towards balanced regions.

Table 1 Swine production distribution of functional regions of grain production in 1996 – 2014

Year	Main sales regions // %	Main production regions // %	Balanced regions // %
1996	12.32	67.01	20.66
1998	11.97	69.01	19.02
2000	12.56	67.59	19.85
2002	13.58	66.73	19.70
2004	13.56	66.73	19.72
2006	12.81	67.66	19.53
2008	13.36	66.82	19.82
2010	13.12	67.16	19.72
2012	12.95	67.20	19.85
2014	12.03	67.78	20.19
Average value	12.92	67.28	19.80

3.2 Imbalance degree and its decomposition for spatial distribution of swine production in the whole country To further analyze the imbalance degree and trend of changes in spatial distribution of swine production, we calculated and decomposed Gini coefficient for spatial distribution of swine production in China. The results are listed in Table 2. The Gini coefficient was higher than 0.4, indicating extreme imbalance in spatial distribution of swine production. According to trend of changes, Gini coefficient for spatial distribution of swine production firstly rose then declined with fluctuation in 1996 – 2014, and changes can be divided into two stages:

In 1996 – 2004, spatial Gini coefficient showed a growing trend, from 0.4574 in 1996 to 0.4715 in 2004, increasing by 3.08%, indicating increase in imbalance of spatial distribution of swine production.

In 2004 – 2014, spatial Gini coefficient declined with fluctuation, from 0.4715 in 2004 to 0.4522 in 2014, dropping by 2.99%, which was lower than the level in 1996, indicating a decline trend in imbalance of spatial distribution of swine production.

According to decomposition of Gini coefficient, the intra-group difference is smaller than inter-group difference. The contribution rate of intra-group difference to overall difference is below 30%, while the contribution rate of inter-group difference to overall difference is above 55%, indicating that regional difference is the major reason for imbalance of distribution of swine production. The residual term reflects alternative degree of pork yield between functional regions of grain production, which is opposite to trend of changes in intra-group difference, and its contribution rate to overall difference is about 15%.

Table 2 Gini coefficient and its decomposition for swine production distribution in 1996 – 2014

Year	The whole country	Main sales regions	Balanced regions	Main production regions	Intra-group difference	Inter-group difference	*R*	Contribution rate		
								Intra-group	Inter-group	*R*
1996	0.4574	0.4699	0.5159	0.2790	0.1293	0.2537	0.0744	0.2827	0.5546	0.1627
1998	0.4576	0.4652	0.5110	0.2642	0.1235	0.2712	0.0629	0.2699	0.5926	0.1375
2000	0.4655	0.4589	0.5250	0.2865	0.1310	0.2621	0.0724	0.2815	0.5630	0.1555
2002	0.4720	0.4451	0.5103	0.3042	0.1341	0.2601	0.0778	0.2841	0.5510	0.1649
2004	0.4715	0.4730	0.4984	0.2921	0.1304	0.2701	0.0709	0.2766	0.5729	0.1505
2006	0.4616	0.4955	0.5264	0.2725	0.1281	0.2559	0.0775	0.2776	0.5544	0.1680
2008	0.4490	0.4821	0.5128	0.2585	0.1230	0.2462	0.0798	0.2740	0.5483	0.1777
2010	0.4505	0.5094	0.5157	0.2590	0.1241	0.2502	0.0761	0.2755	0.5555	0.1690
2012	0.4462	0.4872	0.5158	0.2517	0.1215	0.2516	0.0731	0.2723	0.5638	0.1638
2014	0.4522	0.4935	0.5149	0.2568	0.1233	0.2614	0.0675	0.2727	0.5781	0.1492

Table 3 Polarization index of spatial distribution of swine production in 1996 – 2014

	G	Division of groups according to pork yield			Division according to functional regions of grain production
		ER	*EGR*	*LU*	*LU*
1996	0.4574	0.4748	0.3896	0.3323	0.3606
1998	0.4576	0.5837	0.4986	0.4089	0.4803
2000	0.4655	0.6180	0.5297	0.4378	0.4757
2002	0.4720	0.6679	0.5757	0.4765	0.5176
2004	0.4715	0.7282	0.6368	0.5165	0.5866
2006	0.4616	0.7037	0.6195	0.4870	0.5428
2008	0.4490	0.6848	0.6059	0.4838	0.5296
2010	0.4505	0.7516	0.6717	0.5273	0.5861
2012	0.4462	0.7867	0.7085	0.5536	0.6200
2014	0.4522	0.8450	0.7642	0.5947	0.6729

3.3 Analysis on imbalance in spatial distribution of swine production in functional regions of grain production According to Gini coefficient for spatial distribution of swine production of main grain production regions, main sales regions, and balanced regions, Gini coefficient of main grain production regions is the lowest and is always lower than the average Gini coefficient of the whole country in the sample survey period, the average value is 0.2726, indicating main grain production regions have the lowest imbalance of spatial distribution of swine production, followed by main sales regions, and balanced regions have the highest imbalance of spatial distribution of swine production and the average Gini coefficient of balanced regions reaches 0.5138, higher than the imbalance of spatial distribution of swine production in the whole country in the sample survey period.

From the trend of changes, in the sample survey period, the Gini coefficient for spatial distribution of swine production takes on an inverted W shape in balanced regions, but it becomes stable in recent years; the Gini coefficient fluctuates more frequently in main sales regions of grain, but it takes a significant growing trend; changes of Gini coefficient for spatial distribution of swine production in main grain production regions are similar to the whole country, and the overall changes take on an inverted V shape. Changes of Gini coefficient for main grain production regions are gentler. In 2002, it reached the highest value, later, it declined slowly, indicating that the imbalance degree of swine production distribution in main grain production regions is slowly declining.

4 Analysis on polarization degree and variation trend of spatial distribution of swine production

In order to reveal polarization degree and variation trend of swine production distribution in China, we firstly divided samples into 3 groups according to pork yield, measured the spatial polarization index of swine production. Secondly, we divided swine production regions into 3 regions according to functional regions of grain production, and calculated spatial polarization index of swine production, to find out the difference in swine production between 3 regions. Since *LU* index is modification of *ER* index and *EGR* index, we just listed corresponding *LU* index. Finally, we calculated the spatial polarization index of swine production in functional regions of grain production, to find out polarization degree and variation trend of swine production in respective functional regions of grain production.

4.1 Polarization degree and variation trend of spatial distribution of swine production in the whole country We divided groups according to the pork yield and calculated the polarization degree of China's swine production distribution. From Table 3, it can be seen that the polarization index of China's swine production distribution grew with fluctuation, from 0.4431 in 1996 to 0.7929 in 2014. During this period, the polarization index of China's swine production declined greatly only in 2007. From 2008, the polarization index grew again.

Next, we divided groups according to functional regions of grain production, and calculated the polarization index of China's swine production. According to Table 3, the polarization index was basically the same as variation trend of polarization index of groups divided by pork yield. It greatly declined only in 2007, but the overall trend was growing, indicating a widening gap of swine production between functional regions of grain production.

In sum, the polarization index of spatial distribution of China's swine production is growing, which is not consistent with variation trend of Gini coefficient of China's swine production distribution. However, these are not contradictory, because their meanings are different. Gini coefficient stresses the average deviation of all individuals from the overall situation, while it neglects aggregation of individual in local areas. By comparison, the polarization mainly emphasizes aggregation of individuals in local areas. When the polarization of a certain distribution is serious, the corresponding imbalance may be not high. Similarly, when the imbalance is high, the corresponding polarization may be not serious[12]. According to variation trend of Gini coefficient and its decomposition and polarization index, changes of China's swine production distribution can be divided into following 4 stages:

In 1996 – 2004, the variation of Gini coefficient and polarization index was consistent with each other, showing that the growing imbalance of spatial distribution of swine production is also a process of increasing polarization. In this period, both intra-group difference and inter-group difference showed increase, intra-group difference increased by 0.85%, and inter-group difference increased by 0.65%.

In 2005 – 2008, Gini coefficient and polarization index showed consistent variation trend, but it was different from previous stage and it took on a decline trend. In this period, both intra-group and inter-group difference declined, indicating that both the imbalance degree and polarization degree of China's swine production distribution declined in this period.

In 2009 – 2012, the variation trend of spatial Gini coefficient and polarization index was different. The spatial Gini coefficient declined, while the polarization index grew, showing the imbalance degree of China's swine production declined but the polarization degree deteriorated. In this period, intra-group difference slightly declined, while inter-group difference slightly grew, indicating intra-group aggregation degree increased, while inter-group difference deteriorated. This leads to increase in polarization degree of distribution of China's swine production.

In 2013 – 2014, variation of Gini coefficient was basically consistent with polarization index. Similar to the stage of 1996 – 2004, both showed a growing trend. Besides, both intra-group difference and inter-group difference deteriorated, indicating an increasing trend of spatial imbalance and polarization degree of swine production.

4.2 Polarization degree and variation trend of spatial distribution of swine production in functional regions of grain production In main grain production regions, main sales regions and balanced regions, the polarization index of distribution of swine production basically showed a growing trend. Since the *LU* polarization index is the modification of *ER* and *EGR* index, we mainly analyzed *LU* polarization index for distribution of swine production in functional regions of grain production. The variation trend is illustrated in Fig. 1.

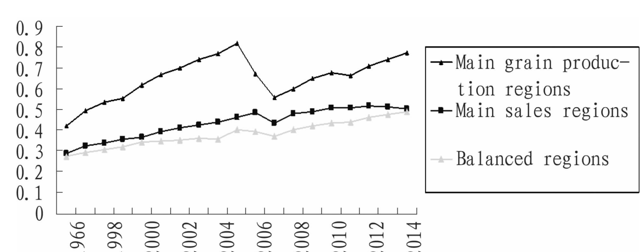

Fig. 1 LU polarization index for distribution of pork yield in functional regions of grain production

According to Fig. 1, the fluctuation amplitude of polarization index is smaller in main grain production regions than in main sales regions and balanced regions. In 1996 – 2014, the *LU* index of main grain production regions increased by 74.17% and 78.06% respectively, with annual growth of 3.13% and 3.26%, indicating that the polarization degree in both main sales regions and balanced regions was growing. For balanced regions of grain production, swine production was mainly distributed in Guangxi, Chongqing, Yunnan, and Guizhou. In recent 3 years, the pork yield of these regions was higher than 1.5 million t. Except Shaanxi whose pork yield was 0.9 million t approximately, the pork yield of other provinces was below 0.65 million t, showing a high polarization degree. For main sales regions of grain, swine production was mainly distributed in Fujian, Guangdong and Hainan. From the new century, the pork yield of these regions was higher than 1 million t, annual growth rate of total yield of these three provinces was 2.1%, while the pork yield of Beijing, Tianjin, Shanghai, and Zhejiang was below 0.5 million with average annual growth of 1.3%, lower than Fujian, Guangdong and Hainan, showing deterioration of polarization trend.

As to main grain production regions, the polarization index of distribution of swine production was also increasing. In 1996 – 2005, the polarization index increased by 95.12% with average annual growth rate of 7.71%. However, the decline rate in 2006 and 2007 was relatively high, dropping from 0.82 in 2005 to 0.56 in 2007. After 2007, the polarization index slowly grew with annual growth rate of 4.78%, but it still did not reach the level in 2005, indicating that the polarization degree of main grain production regions firstly rapidly grew, then declined by a large margin, finally slowly grew, which are basically consistent with polarization degree of the swine production in the whole country. The pork yield of main grain production regions was relatively high. In 2014, except Inner Mongolia with pork yield lower than 1 million t, other provinces had pork yield above 1 million t. The pork yield of Shandong, Henan, Hunan, and Sichuan was higher than 4 million t. Specifically, the pork yield of Hubei and Hebei was 3.396 million t and 2.812 million t, while other provinces had pork yield below 2.65 million t, showing obvious polarization.

5 Conclusions

Based on annual pork production of each province in 1996 – 2014, using Gini coefficient and spatial polarization index model, we made an empirical analysis on spatial imbalance and polarization degree of swine production distribution and arrived at following conclusions:

(i) The Gini coefficient of China's swine production is higher than 0.4 all the time, indicating extreme imbalance in spatial distribution of swine production and the imbalance degree firstly grows and then declines. The inter-difference is major reason for imbalance in spatial distribution of swine production, indicating that grain is still an essential factor influencing the distribution of swine production. (ii) From the perspective of regions, the imbalance degree of distribution of swine production is the lowest, next is main sales regions, and balanced regions of grain production had the highest imbalance degree. As to the variation trend, the Gini coefficient for spatial distribution of swine production in main grain production regions takes on an inverted V shape, and the distribution imbalance slightly declines, while the imbalance of distribution in main sales regions and balanced regions of grain production fluctuates more frequently. (iii) On the whole, the spatial polarization index of China's swine production is growing, indicating deteriorating polarization of the distribution of swine production. This is mainly resulted from opposite effect of intra-group difference and inter-group difference. When intra-group difference declines, inter-group difference will increase, accordingly it will lead to deterioration of polarization. The spatial polarization index is growing for China's swine production in functional regions of grain production, indicating deteriorating polarization of the distribution of swine production in functional regions of grain production,

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