Research on Early Warning of Chinese Food Safety Based on Social Physics

Yonghuan Ma[1,2], Wenyuan Niu[1,2], and Qianqian Li[1,2]

[1] Institute of policy and Management, CAS
[2] Center for Interdisciplinary Study of Natural and Social Sciences, CAS
Zhong Guancun East Road.55, 100190, Beijing, China
mayonghuan@casipm.ac.cn

Abstract. Based on social physics, this paper designs the index system of food safety, builds early warning model of food safety, calculates the degree of food safety, and assesses the state of early warning of 2007 in China. The result shows the degree of food safety is near 0.7 in securer state, belonging to slight emergency. It is much lower in eastern areas of developed regions, belonging to insecure state in the mass. That the food safety is ensured in major grain producing areas, Inner Mongolia, Ningxia and Xinjiang is the prerequisite of realizing the food safety of China. The result also shows four significant indices, grain production capacity, grain circulation order, grain demand and grain supply, which are important indicatio to control food safety.

Keywords: social physics, food safety, early warning.

1 Introduction

Grain production and consumption are undergoing profound changes in the world. As far as the tense situation between grain supply and demand is concerned, the international community has attached great importance to it. Influenced by the relationship of grain supply and demand, in addition with the price increase of oil in the international market, the grain prices rose so fast. As a result, it led to grain shortage, social unrest, political and economic turmoil in many areas, especially in Africa, Asia and Latin America.

However, there are 22 provinces, 5 autonomous regions and 4 municipalities directly under the central government of China with huge regional differences. It shows not only the climatic conditions, productivity of farmland and cropping system, but also population density and the level of economic development. Under such conditions, it is important that there is a direct relation between food safety and social stability or national security. Therefore, the implementation of grain early warning is an issue of the utmost importance. Academic circles have attached great importance to this issue. Up till to now, the one designed the index system to evaluate food safety [1, 2, 3, 4, 5, 6], such as per capita output of grain, cultivated land, self-sufficiency rate and grain reserves, others calculated the factor of food safety using part of selected indices[3, 7]. These researches could provide some guidance to early warning of grain

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security. However, there are inevitably some limitations. Firstly, although they have researched national food safety situation macroscopically, there are not researches on regional difference of China. Secondly, the index system they have established is too simple to evaluate food safety, and the early warning system of food safety is not based on grain production capacity, grain circulation order, grain demand and grain supply. Thirdly, in the past two years, it is self-evident that the grain shortage of public opinion affected grain prices and security, which should be considered as the more important index. This paper designs the index system of food safety from the social physical point of view, forms the early warning model of food safety. Based on statistical data and Network Data in 2007, the early warning of food safety is researched in China.

2 Social Physics and Early Warning of Food Safety

2.1 Social Physics

Since the birth of social physics, it brought about extensive and profound influences on the theoretical application of coordinating the man-land relationship, sustainable development and social early warning, and so on. This will be a new direction to probe into issues of China. The social physics carried through reasonable analogy between social events and combustion phenomenon of nature [12, 13], and thought if there were necessary conditions, i.e. 'burned substance', 'burning-rate accelerator' and 'firing temperature', social disorder, unstability and chaos will take place. 1) The basic reasons for social disorder, i.e. the uncoordinated relationship of man-land, and the disharmonious relationship of man-man, are deemed as 'burned substance' of social unstability. 2) The accelerating factors of social unrest, i.e. misled and exaggerated information of media, a trivial situation grossly magnified, the spreading of gossip and rumors, a wanton attack of hostile forces, irrational conclusion, are equivalent to 'burning-rate accelerator' of social unrest. 3) Accidents with a certain scale and effects, are usually signal for social unrest or considered as 'firing temperature'. This will become the theoretical basis to design index system on early warning of food safety.

2.2 Influence of Food Safety on Social Stability

Grain is not only the basic products that is related to national existence and development, but also a public product that stabilizes social order. Food safety is the most important and essential part of social security in any country or region. As grain is the base of national economy and the people's livelihood, higher grain prices will induce an increase in meat, eggs, milk prices and many other grain-related commodities prices. Since the second half of 2006, influenced by high international grain prices and excess liquidity, the consumer price of poultry, egg, oil and flour food rose in a row in China. As a result, there has been a strange phenomenon that the consumer price index (CPI) rises at a rapid pace. Researches have shown that CPI and CPI of grain have a strong correlation from July 2005 to August 2008 (Fig. 1.), and this will be called "combustion substance" which impacts economic security and social instability.

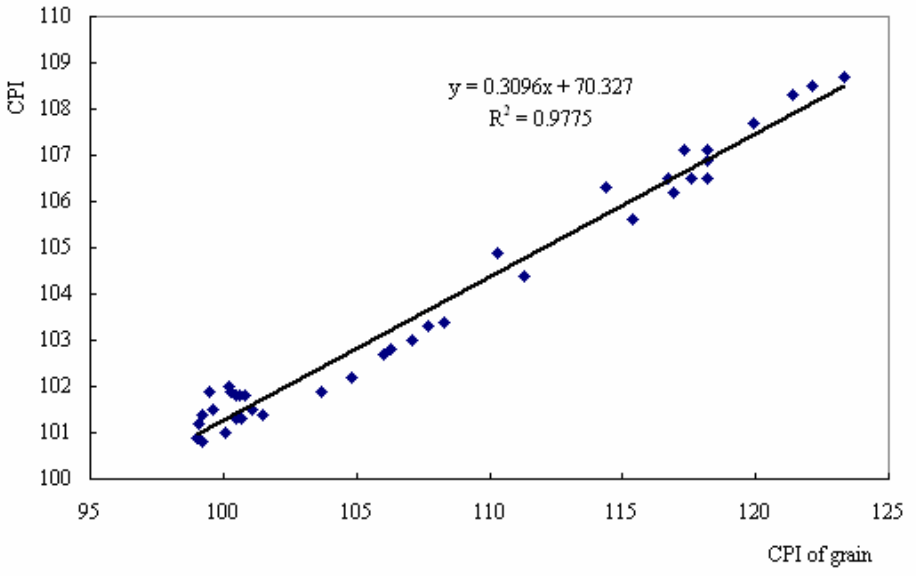

Fig. 1. The trendline between CPI and CPI of grain (*July, 2005 –August, 2008*)

The conduction and magnification effects of the increase in grain prices disturb the normal consumer-style, and cause residents take drastic reserve action such as scare buying. In addition, influenced by spreading public opinion about grain shortage, illegal traders take this opportunity to hoard, collude and drive up prices, and some even take this opportunity to sell contaminated and water-injected pork, and this will be called 'burning-rate accelerator' effecting on the rising prices and social instability. By studying on the relation between the number of scare buying coverage and the change of CPI over time, we discover that there are higher consistency and relevance between public opinion events and CPI with two-month lag (Fig. 2., Fig. 3.). To a large extent, the public opinion about grain shortage plays an important role in stimulating the rising consumer prices.

Food shortage could also lead to social unrest and even political crisis, so it is a major threat to social stability. Although there are specific and objective reasons for any peasant uprising in Chinese history, land annexation, natural and man-made calamities and feudal tyranny are the three main factors. From the view of social combustion theory, peasant revolt is the 'firing temperature' to cause social disintegration and collapse. Influenced by 'grain tsunami', global staple food prices have risen by 80 percent, while the international price of rice rose to a 19-year high and the real price of wheat has hit a 28-year high. Scarcity of grain staples has led food shortage in many countries. Because of higher food prices, Egypt, Haiti and several African countries would face social unrest, even political turmoil and bloodshed [16, 17]. International food experts have warned that if the short-term grain shortages around the world could not be resolved effectively, more unrest is bound to occur.

On the sense of social-biology, human beings are actually an existence system with sociality in nature [14, 15]. Only when there is an effective protection of grain

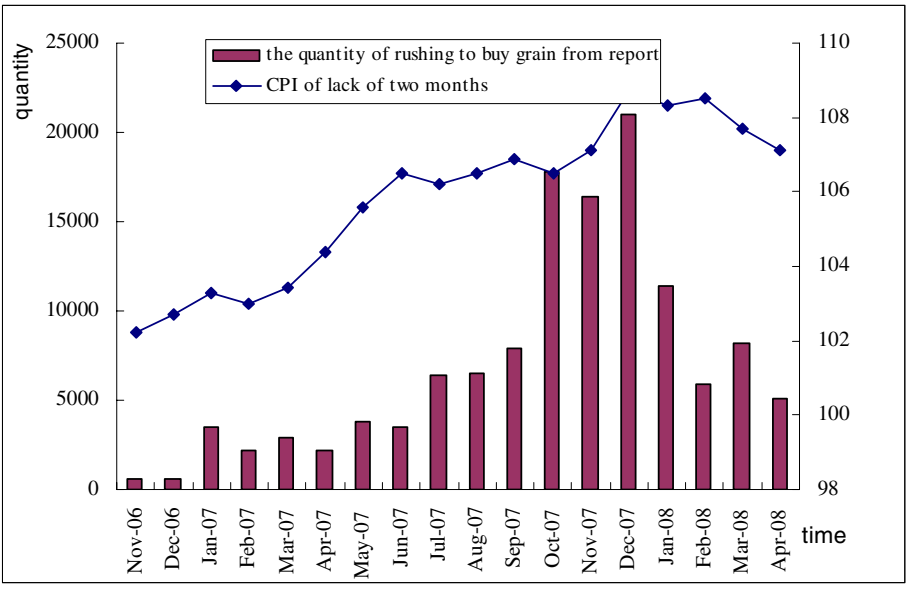

Fig. 2. The change of time series of CPI and public opinion

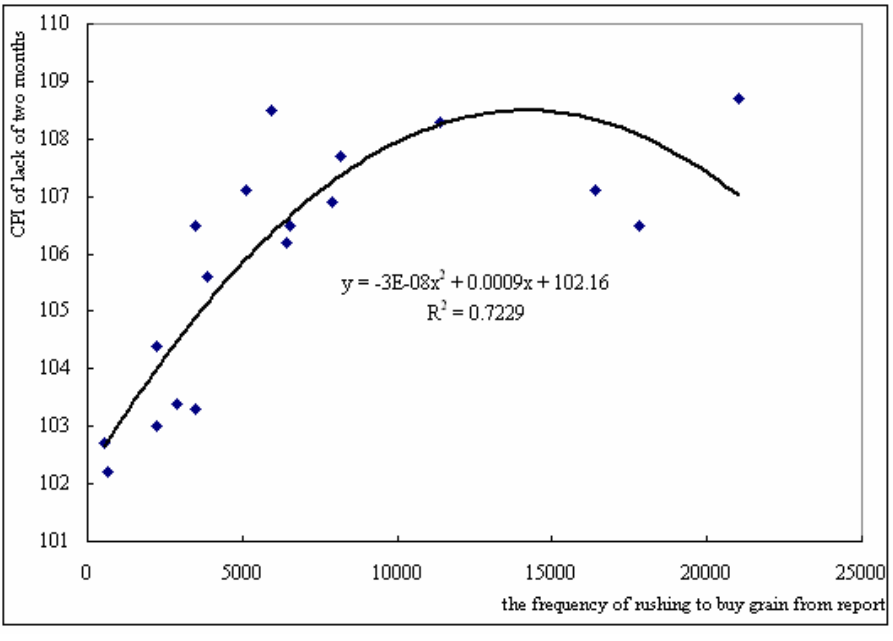

Fig. 3. The relationship between CPI and public opinion

supply, society could develop stably. Therefore, food safety is the kernel problem of social stability.

3 Constructing Early Warning System of Food Safety

The early warning of food safety is to constructing grain production, consumption, circulation, reserve, and other aspects of the elements of the warning signs, from the angle of realizing human existence, sending out warning signals with warning levels and providing theoretical basis for decision-makers taking initiative in defense strategy. Because grain shortage is not only the most direct and basic factor in food safety, but also is the fundamental factor impacting social stability, the basic idea about constructing indices system of food safety is social combustion theory.

According to our knowledge and understanding regarding social physics and social stability theory, our grasp of food safety problem and supervision of public opinion, we start with the basic factors, repeat screening process of pre-selecting elements, make analysis and eventually select 30 elements to form an element layer. Clustering is progressed on this basis, and related elements are classified to the corresponding variable layer, variable layer is clustered into state layer with the same method. Through the convergence of layer by layer and the superposition of three layers, finally we form four state layers, nine variable layers and 30 elements layers, which construct early warning indices system of food safety (Table 1.).

Table 1. The early-warning indices system of food safety

system layer	State layer	Variable layer	element layer
degree of grain security	grain production capacity (GPC)	indices of agricultural input (AI)	the ratio of effectively irrigated farmland
			the contribution rate of science and technology to agriculture
			material input
		indices of productive potentiality (PP)	per unit area yield of grain
			multiple-crop index
			the proportion of sown area of grain
			per capita amount of arable land
		indices of farmland resisting natural disaster (FRND)	fluctuant coefficient of per unit area yield of grain
			percentage of farmland covered by natural disaster
			percentage of farmland affected by natural

Table 1. (*continued*)

system layer	State layer	Variable layer	element layer
	grain circulation order (GCO)	indices of market stability (MS)	ratio of dependence on foreign trade
			event probability of scare buying
			safety factor of total grain output
		indices of prices security (PS)	price indices of agricultural production
			price indices of grain
			percentage of domestic grain prices to external price
	grain demand (GD)	indices of demand scale (DS)	per capita grain expenses
			rate of natural increase of population
			urbanization level
			per capita of gap between demand and production
		indices of potential demand (PD)	the number of poverty-stricken people
			gini coefficient
			the coefficient of dual structure in urban and rural economy
			the proportion of breadless household
	grain supply (GS)	indices of provisionment (P)	per capita output of grain
			self-sufficiency rate of grain
			grain support of residents with low incomes
		indices of grain stock (GS)	grain stock level of government
			grain stock per farmers

On the basis of the data in 2007, elements layer adopts measurable, comparable indices to measure directly the number of variable layer, intensity behavior and velocity, including per capita share of grain. Variable layers substantially reflect and reveal the state behavior, relation between states, reasons and drive for variations [18], including grain demand index and grain supply index. State layers are the major

section and key components for deciding food safety situation. They include the state on a certain time section and changes in a certain time series, including grain production capability, grain circulation order, grain demand and grain supply. The degree of food safety forming by the state layers is the most fundamental trend and variation characteristics reflecting the early warning system of food safety.

4 Calculation and Analysis

4.1 Data Processing

The early warning system of food safety is made up of a lot of elements, expressed by X_i, which set a clear-cut development goal in a given period of time, and could be quantified. According to the difference of target orientation, these elements are divided into two types. One pursues satisfying value of object. The other pursues maximal or minimum value of object. The results acquired by transforming actual value and target value (F 1, 2, 3), reflect actions and efficacies of elements in the system, called efficacy coefficient (EC). Usually, EC_i is between o and 1 ($i = 1, 2, \ldots n$). When the target values of elements tend to be the most satisfying, EC_i is equal to 1, when they tend to be the most worst, EC_i is set to 0. The relationship is named as efficacy function. Because EC with individual element does not yet explain general developing trend and state of food safety, the relational expression that takes overall efficacy coefficients as independent variable should be built so as to describe the comprehensive influences or efficacies [8]. In general, it is called early warning function of food safety, and its function value is called degree of security (DS). Values of range from 0 to 1, the larger DS, the completeness of the system is better. Conversely, the less DS, the completeness of the system is worse.

The actual value of X_i is the x_i ($i = 1, 2, \ldots n$), and α_i is upper limit of X_i, β_i is lower limit of X_i, i.e. $\beta_i \le x_i \le \alpha_i$. According to synergy science theory, when the system is under stable conditions, the extremal points of state function are the critical points of elements [9]. At the same time, order parameters act two efficacies to the system. One is positive, i.e. following the increasing of order parameters; the order degree tends to increase. The other is negative, i.e. following the increasing of order parameters; the order degree tends to decrease. So EC can be represented as follows:

if X_i is the positive, then

$$EC(X_i) = (x_i - \beta_i) / (\alpha_i - \beta_i), \quad (\beta_i \le x \le \alpha_i) \tag{F 1}$$

if X_i is the negative, then

$$EC(X_i) = (\alpha_i - x_i) / (\alpha_i - \beta_i), \quad (\beta_i \le x \le \alpha_i) \tag{F 2}$$

if X_i is modest, then

$$EC(X_i)=\begin{cases}1,(x_i=X^{'})\\ \dfrac{\left|x_i-X^{'}\right|}{Max(\alpha_i-X^{'},X^{'}-\beta_i)}(x_i\neq X^{'}),\\ 0,(x_i\leq\beta_i\ ,\ x_i\geq\alpha_i)\end{cases} \tag{F 3}$$

Among (F 3), $X^{'}$ is satisfying value of X_i.

4.2 Definitive Weight

Owing to the differences of contribution degree for elements in element layer, state layer and variable layer of the system, the definitive weight of elements need to be determinated. By analytic hierarchy process [10], the research builds mathematical model to calculate the weights of factors in each layer.

4.3 Building Early Warning Model

The early warning model of food safety is usually formed with weighted sum, i.e. the product of efficacy coefficient of each elements and corresponding weight. The model as follows:

$$\begin{aligned}DS&=EC(X_1)\times F_1+EC(X_2)\times F_2+\cdots+EC(X_i)\times F_i\\&=\sum_{i=1}^{n}EC(X_i)\times F_i\end{aligned} \tag{M 1}$$

$$\sum_{i=1}^{n}F_i=1,$$

The grain shortage of public opinion led to panic buying, would increase the prices of grain and other goods (Fig. 2., Fig. 3.). From social physics point of view, it is 'burning-rate accelerator' of social unrest[19]. In order to emphasize influences of the grain shortage of public opinion on food safety, DS is modified as follow:

$$DS^{'}=[\sum_{i=1}^{n}EC(X_i)\times F_i]^{\frac{1}{1-\delta}}, \tag{M 2}$$

Where δ as modified parameter of DS, stands for the probability of the grain shortage of public opinion. When $DS^{'}\geq 0.8$, the state of food safety is highly secure; when $0.7\leq DS^{'}<0.8$, the state of food safety is secure. There is no emergency in two situations. When $0.6\leq DS^{'}<0.7$, the state of food safety is securer in light

emergency; when $0.5 \leq DS' < 0.6$, it is more insecure in medium emergency; when $DS' < 0.5$, it is insecure in serious emergency.

4.4 Results and Analysis

4.4.1 General Assessment before Modifying DS

According to M 1, China is in a grain secure situation as the total score of DS is 0.697. But it is various in different regions of China (Fig. 4.). DS of Henan, Jilin, Heilongjiang and Inner Mongolia, is more than 0.8 and in high secure state. It is between 0.700 and 0.767 in Hebei, Jiangsu, Anhui, Jiangxi, Shandong, Ningxia and Xinjiang, in secure state. There is no emergency in these 8 provinces and 3 autonomous regions. DS of some regions, Liaoning, Hubei, Hunan, Sichuan, Tibet and Gansu, is between 0.607 and 0.649 in securer state, belongs to light emergency. However, it is between 0.502 and 0.584 in Shanxi, Zhejiang, Fujian, Guangxi, Chongqing, Guizhou, Yunnan and Shaanxi, belongs to more insecure state and medium emergency regions. Especially, DS of some regions, in Beijing, Tianjin,

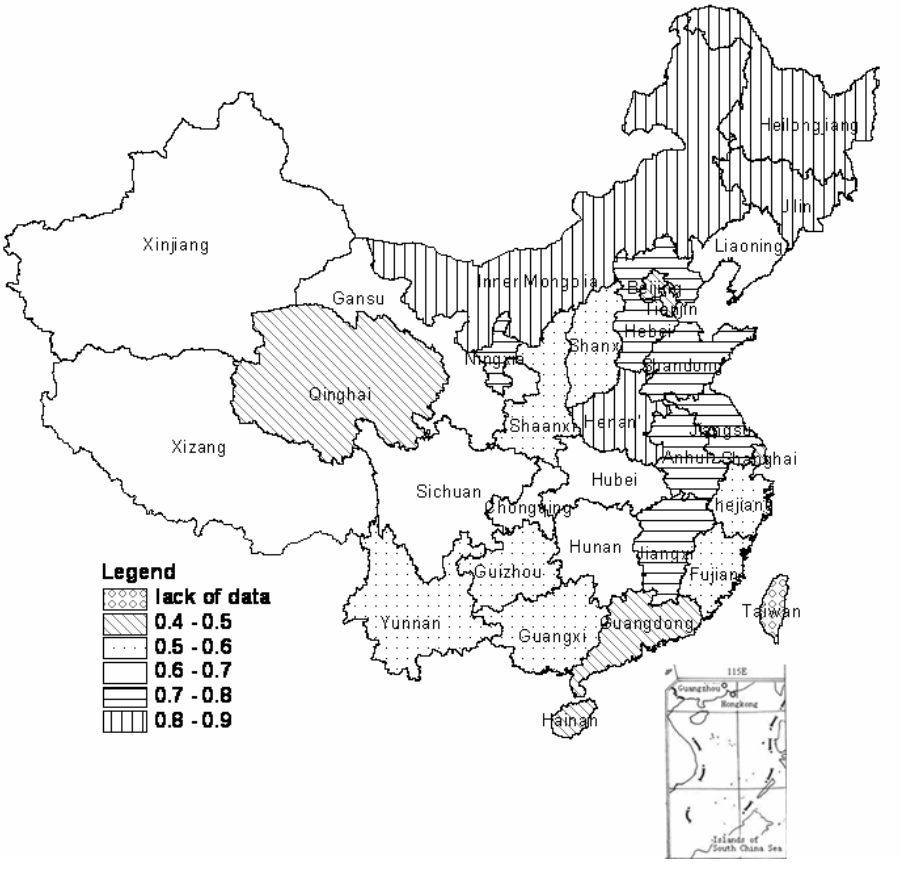

Fig. 4. The spacial distribution map of early warning on food safety

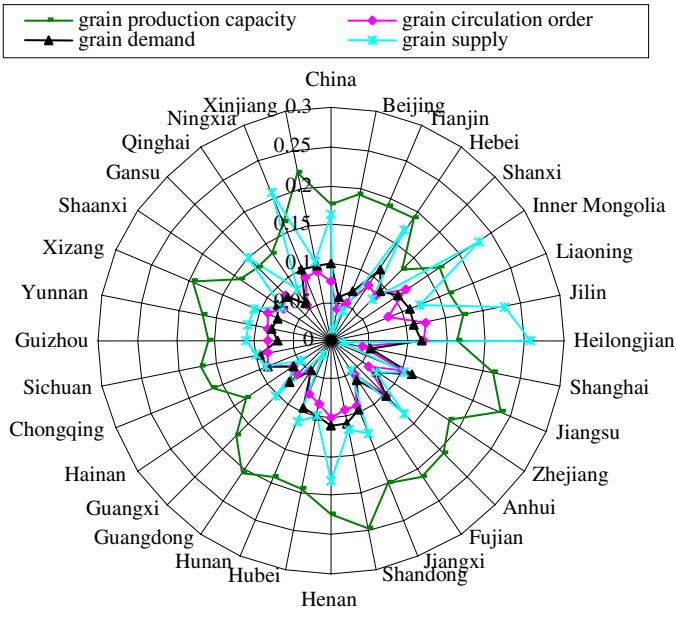

Fig. 5. The spacial distribution map of indexes in state layer

Shanghai, Guangdong, Hainan and Qinghai, is between 0.404 and 0.522, in insecure state, belongs to serious emergency regions.

There are four important indices in state layer of the early warning system. Similar to DS, they are also various in different regions (Fig. 5.). In the eyes of grain production capacity, the score is 0.175 in China, it contributes more than 25 per cent to food safety. Though DS is less than 0.522, the contribution of grain production capacity exceeds 39 per cent in Beijing, Tianjin, Shanghai, Zhejiang, Fujian and Guangdong. Obviously, these regions belong to economically developed areas, there are many advantages, e.g., better basic conditions for agricultural production, high overall production capacity of farmland, and so on. Eight provinces in major grain producing areas, Hebei, Jiangsu, Shandong, Anhui, Jiangxi, Henan, Hubei and Hunan, the average score of grain production capacity is more than 0.19, higher than average score of China. This indicates the grain production capacity of major grain producing areas is fairly high. Jilin and Heilongjiang belongs to the areas, and their DS is highly secure, but the contribution of grain production capacity to food safety is less 5.8 per cent than general level of China. So the position of agriculture as the foundation should be strengthen and production conditions should be improved, they are important conditions to improve grain production capacity of the two provinces.

In the eyes of grain circulation order, the score of China is 0.077, contributes 11 per cent to food safety. The spacial variety is unconspicuous in different regions. With regard to Beijing, Shanghai, Fujian and Guangdong, the scores are lower 1 per cent than average score of China, others are equal to average score of China. This shows that grain circulation order is worse in major grain purchasing areas of developed regions. Some actions from government, such as shocking profiteer, preventing prices

Table 2. The regional comparison of indexes in variable layer

region	AI	PP	FRND	MS	PS	DS	PD	P	GS
China	0.033	0.104	0.038	0.048	0.029	0.075	0.024	0.080	0.082
Beijing	0.057	0.090	0.044	0.002	0.040	0.013	0.043	0.003	0.014
Tianjin	0.054	0.085	0.048	0.012	0.042	0.030	0.038	0.020	0.021
Hebei	0.047	0.107	0.038	0.049	0.038	0.076	0.036	0.087	0.083
Shanxi	0.017	0.087	0.025	0.036	0.044	0.060	0.031	0.060	0.014
Inner Mongolia	0.019	0.131	0.018	0.067	0.050	0.075	0.030	0.171	0.058
Liaoling	0.024	0.122	0.018	0.050	0.028	0.075	0.035	0.092	0.032
Jilin	0.019	0.148	0.006	0.075	0.049	0.076	0.033	0.207	0.023
Heilongjiang	0.010	0.142	0.011	0.075	0.044	0.076	0.041	0.209	0.047
Shanghai	0.060	0.100	0.055	0.001	0.038	0.012	0.040	0.002	0.014
Jiangsu	0.063	0.128	0.046	0.049	0.051	0.077	0.034	0.088	0.014
Zhejiang	0.050	0.096	0.036	0.014	0.045	0.033	0.039	0.022	0.048
Anhui	0.043	0.113	0.047	0.053	0.045	0.076	0.025	0.103	0.030
Fujian	0.069	0.101	0.040	0.019	0.034	0.036	0.026	0.031	0.014
Jiangxi	0.043	0.127	0.029	0.051	0.041	0.074	0.022	0.094	0.037
Shandong	0.053	0.123	0.070	0.051	0.040	0.075	0.034	0.096	0.022
Haian	0.054	0.131	0.039	0.057	0.041	0.077	0.033	0.124	0.056
Hubei	0.043	0.112	0.039	0.048	0.037	0.076	0.023	0.081	0.018
Hunan	0.051	0.133	0.008	0.050	0.025	0.075	0.019	0.091	0.021
Guangdong	0.051	0.095	0.059	0.013	0.034	0.026	0.019	0.021	0.000
Guangxi	0.033	0.092	0.049	0.036	0.025	0.060	0.013	0.059	0.042
Hainan	0.030	0.077	0.025	0.024	0.036	0.044	0.015	0.039	0.007
Chongqing	0.023	0.110	0.032	0.048	0.038	0.077	0.010	0.082	0.010
Sichuan	0.030	0.109	0.030	0.047	0.036	0.078	0.017	0.078	0.020
Guizhou	0.008	0.084	0.066	0.036	0.046	0.063	0.005	0.059	0.050
Yunnan	0.015	0.087	0.066	0.040	0.044	0.067	0.012	0.066	0.042
Tibet	0.016	0.107	0.071	0.041	0.049	0.060	0.013	0.068	0.039
Shaanxi	0.025	0.084	0.032	0.035	0.039	0.061	0.024	0.057	0.018
Gansu	0.010	0.085	0.040	0.039	0.043	0.066	0.012	0.064	0.088
Qinghai	0.013	0.067	0.054	0.021	0.036	0.040	0.019	0.034	0.044
Ningxia	0.025	0.107	0.034	0.056	0.034	0.072	0.027	0.117	0.089
Xinjiang	0.044	0.119	0.058	0.050	0.042	0.071	0.028	0.088	0.015

of agricultural materials from frequently rising, insuring the balance between the supply and demand of grain, are key measures to control grain circulation order.

With regard to grain demand, the score of China is 0.099, contributing 14.3 per cent to food safety. Eight provinces, Hebei, Liaoning, Jilin, Heilongjiang, Jiangsu,

Anhui, Shandong and Henan in major grain producing areas, are slightly higher 0.002 than average score of China, and it is lower than average of China in other regions.

The grain supply capacity is an important index to measure food safety to a great extent. According to calculated results, the score of China is 0.162, contributes 23.2 per cent to food safety. The diversity among different regions is rather large. The score is between 0.170 and 0.256 in Hebei, Jilin, Heilongjiang and Henan of major grain producing areas. Though Inner Mongolia and Ningxia do not belong to the areas, their scores of grain supply capacity are 0.300 and 0.206 respectively, accordingly, contribute 27.3 and 27.1 per cent to food safety. These six regions play an important role in insuring food safety of China. The grain supply capacity is lower in developed eastern areas of China, especially, Beijing, Shanghai, Fujian and Guangdong, it is less than 0.014. These regions are important grain purchasing areas of eastern China.

The diversity of indices in variable layer is similar to those in state layer (Table 2.).

4.4.2 General Assessment after Modifying DS

In order to emphasize the influence of the grain shortage of public opinion, DS is modified, i.e. $DS^{'}$. According to model (2), the result indicates $DS^{'}$ is 0.688, decreasing 0.009 than DS, a decline of 1.2 per cent. Comparing with DS, the decreasing range of $DS^{'}$ is around 2 per cent in Beijing, Tianjin, Shanghai, Zhejiang, Fujian, Guangdong, Hainan and Qinghai. Most of them belong to developed areas and major grain purchasing areas. The influence of the grain shortage of public opinion exceeds average degree of China on DS. Hence, information of food safety must be impersonally disseminated through authoritative media, well and truly reported grain demand and supply. It will help to realize the security of grain market.

5 Conclusions and Discussion

5.1 General Situation of Food Safety

The score of DS is 0.697, and the score of $DS^{'}$ is 0.688 in China. This indicates that the influence of δ as modifying parameter on DS is not more than 2 per cent. In a word, the degree of food safety is near 0.7, and belongs to slight emergency in a securer state. There are 11 provinces in major grain producing areas of China. It is above 0.7 and secure in Jilin, Heilongjiang, Hebei, Jiangsu, Anhui, Shandong, Henan and Jiangxi. It is about 0.64 in securer state in Liaoning, Hubei and Hunan. This result shows the grain is secure in major gain producing areas. Although three autonomous regions, Inner Mongolia, Ningxia and Xinjiang do not belong to these areas, their degrees of food safety are higher than average degree of China, and in securer state. Moreover, the degree of food safety in developed eastern region of China, Beijing, Tianjin, Shanghai, Zhejiang, Fujian, Gudong and Hainan, is below 0.522 in insecure state. The analysis mentioned above indicates ensuring the food safety of major grain producing areas and three autonomous regions is the prerequisite of realizing the national food safety of China.

5.2 Aspects of Insuring Food Safety

The early warning system of food safety is made up of grain production capacity, grain circulation order, grain demand and grain supply, which are important indicatio to control food safety. To further improve the degree of food safety of China, the work needs strengthening as follow: (1) Grain production capacity should be further improved in major grain producing areas, especially, the three provinces in northeast China, Heilongjiang, Jilin and Liaoning, effectively irrigated farmland should be considerably extended, per-unit grain yield should be steadily raised. (2) Effective regulation of grain prices should be strengthened, profiteer must be cracked down, and the so called demagoguery of grain shortage must be forbidden so as to realize the ordered circulation of grain. (3) The population growth must be strictly controlled so that grain supply could meet grain demand. (4) Grain supply is the base line of food safety. Grain reserve is important to ensure food safety in grain purchasing areas.

5.3 Discussion

This is an attempt to research the degree of food safety in different regions of China. Restricted by collecting data, the indix system does not involve the nutritious factors and quality of food safety. Index system of food safety should be improved in the further research.

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