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Food Security Drivers: the case of China

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Abstract

This thesis will discuss the food security of China with indicators that cover four dimensions of food security. By starting with a conceptional review of food security and an introduction to the challenge of the world's food security, factors that affect food security could be explained, as determines of aggerated food supply and demand. China is one of the biggest developing countries, who have achieved in improving national nutritional intake state while facing new food security challenges like reducing available arable land and import dependency ratio growth of particular food. This paper will analyses China's food security with an evaluation index system contains indices of main factors that impacting on food security.

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Introduction

The living cost in China was rising during 2019, and some believe it is driven up by the rocketing price of pork, in the first week of November, the producer price of the hog is equivalent to 260% of last year (Ministry of Agriculture and Rural Affairs of The People's Republic of China, 2019). This price fluctuation caused by African swine fever (ASF) raises people's concern about food security in China. As the world's biggest agriculture products consumer, the volatility of China's food security may have a worldwide impact via the international food market. For instance, as the second-largest pork producer after China and the biggest pork exporter, the European Union export 385 million tonnes of pork products in the first three quarters of 2019, 47.9% of which is exported to China, and the total volume of pork exported to China has increased 63% compared the same period in 2018, according to European Commission (2019). As a consequence, as one of the main pork producer countries in the EU, the domestic hog price of Germany has increased around 40% from January to November 2019, according to AMI.

Who will feed China? Brown (2019) raised this question in his book with the same title, where he described a pessimistic expectation that the rising food demand of China would threaten the food access of the other developing countries. Although Chinese scholars criticized the assumption, the question of food security in China is still valuable for concern. Because, as a country that did not abandon its goal of food self-sufficiency, the challenge faced by China is to fulfill the food demand of nearly one-fifth of the world's population with limit domestic natural resources.

Impressive agricultural progress has made by China since the later 1970s. Both the average annual growth rate of agriculture GDP and grain production are surpassing the population growth. The phenomenon of food deficit and malnutrition are gradually becoming a thing of the past. However, apart from the total volume of cereal supply, a sustainable system that contains developed food production, access, storage, utilization, and the capability of handling emergencies are required to maintain food security. In addition, studies on China's food security have provided some views that the drives of food demand growth have shifted from increasing of population to disposal income growth and urbanization (Huang, 2017). Relatively, the call to update the research focus of China's food security was proposed by many studies; for example, Hu (2012) and Cui (2019).

Food security normally translated as 粮食安全 in Chinese, and which literality means security of grains. In terms of the research object, grain includes rice, wheat, maize, sorghum, millet, and the other cereals (such as barley, oats, buckwheat), plus pulses and potatoes according to National Bureau of Statistics of China. This definition is relatively narrow sense compared with the food definition of FAO, and the latter includes cereals, starch tubers, sugars, beans, nuts, oils, vegetables, fruits, irritants (coffee, cocoa beans, tea), spices, wine, meat, edible protein, animal fat, milk, eggs, fish and aquatic products, a total of 18 categories (Yao, 2015). Regarding on new demand growth and dietary change, compared with traditional definition of food security used in China that emphasizes total cereals supply and 95% self-sufficiency ratio, a new target of food security that contains more content should be introduced to meet the needs of development.

The aim of the thesis is to analysis China's food security status from a board point of view that follows a proper definition of food security, and conduct an intuitive index evaluation system that shows the variance of China's food security state after 2000. Through this analysis, factors that promote and obstruct China's food security can be identified. In order to achieve the research goals, this thesis is organized as follows: Chapter 1 contains a conception review of food security and introduces the main factors that influence food security by analysis of the general case of food security in developing countries. Chapter 2 summarizes the change of food security in China according to food sufficiency and import dependency. An evaluation system on food security contains indices from different dimensions is conducted and discussed in Chapter 3.

Chapter 1: Conceptional review of Food Security and its Drivers

1.1 What is food security?

One of the most cited definitions of food security is introduced by the World Bank in 1987 as 'access by all people at all times to sufficient food for an active and healthy life'. This conceptualization is in evolution, and there is a further developed vision is developed by the World Food Summit (1996) as 'Food security, at the individual, household, national, regional and global levels when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life', which is cited by many academic writings. The above-mentioned concept is explicit but flexible and complex, a referent of food security may vary according to particle usage. There were hundreds of interpretations of the concept of food security/insecurity in the 1990s (Maxwell, 1992). To capture the board and different dimensions, food security can be break into four main components: *availability, access, utilization, and vulnerability* (Migotto et al., 2007). Since it is hard to use a single primary indicator for describing all demotions of this phenomenon, multiple indicators and measurements should be introduced and selected for different emphasis. According to FAO (2003), there are five general catalogs of indicators used to measure various aspects of food security as Undernourishment, Food Intake, Food Utilization, Food Available for Vulnerable Groups, and Vulnerability. This general catalog has been subdivision into a more detail framework, which will be presented in later chapters (Table 3.2).

Different indicators are also used based on the availability of data. One measure of FAO on food insufficient is the percentage of the population live under the energy requirement level, which is measured based on aggregate data. On the opposite, many indicators require practical inquire or practical questions in the survey. For example, in terms of 'self-assessment' indicators of food insecurity, it is crucial to let respondents identify malnutrition from the simple idea of hunger (Migotto et al., 2007). The indicators of vulnerability also require further consideration. An ideal indicator of vulnerability can hardly be captured because it used with the connection between present and future. From a stability point of view, food supply, especially in the long-term future, would be naturally unstable when facing significant negative production impacts, for example, natural hazards or economic crisis. In other words, there is the fact that everyone has the probability of risking food adequacy because of the uncertain events in the future, but some people are more vulnerable than the others (Guha-Khasnobis, Acharya and Davis, 2007). One possible approach to study vulnerability is to discuss future food adequacy status in different assumed future scenarios. Some studies use this method to analysis food security regarding climate change (see, for example, Ye et al., 2012).

Generally, all the indicators mentioned above could be used to describe food security states of both national level and individual household level, but the applied concepts among them would be slightly different. Namely, food security at national level is the overall food sufficiency condition of a country or a region, within the geographical area, the situation of some compensate individuals may be better/worse off than the average, but they would not affect the general food security level; on the opposite, the food security at individual level can be directly reflected by food acquisition condition of the respondents. Laborde (2016) describes the food and nutrition security (FNS) of individual i as a combination result of food quality and food quantity, and both quality and quantity of individual's food intake can be measured as a set of exogenous variables, shown as the following equation:

$$FNS^i = FNS(quality^i, quantity^i)$$
$$quality^i = Q(share^i, income^i, price, preferences^i, sanitary\ condition, food\ system\ quality)$$
$$quantity^i = D(share^i, income^i, price, preferences^i)$$

Where $share^i$ donate the percentage of individual's income spend on food or other nutrition intake. In this equation system, Laborde implies that quality of food is one of another components of food security apart from nutrition availability, corresponding to "food performance for an active and health life" in the definition of food security. In the other words, food safety should also be taken into consideration when food security is mentioned. Because food safety is link to the quality of food with a holistic approach that quality food should with all desirable properties such as non-toxic, nutritional value and not risk consumer into foodborne illnesses (Grunert, 2005). Since the concept of food security and food safety is sometimes easily confusing, a clear definition of Food safety should be introduced, this thesis adopts the definition of food safety generated by Australian Institute of Food Safety (2019), shown as following:

Food Safety Definition: Food Safety refers to handling, preparing and storing food in a way to best reduce the risk individuals becoming sick from foodborne illnesses. Contents: ● Properly clean and disinfect all surfaces, equipment and utensils ● Maintain a high level of personal hygiene, especially hand washing ● Store, cool and heat food properly according to temperature, environment and equipment ● Implement effective pest control ● Understanding food allergies, food poisoning and food intolerance

Source: Australian Institute of Food Safety Website (2019)

According to Unnevehr (2003), improving food safety conditions is an essential element of global food security consider the population who cannot obtain either sufficient or healthy food. There are two different views about the relationship between concerns on food safety and food security: some takes the view that emphasize food safety would help to improve food security eventually because which enhances health and nutrition conditions of food; An alternative perspective proposes that the consensus of food safety should be focus on developing countries where suffering most from foodborne illnesses, instead of developed world where food safety issues were only occasionally occurred.

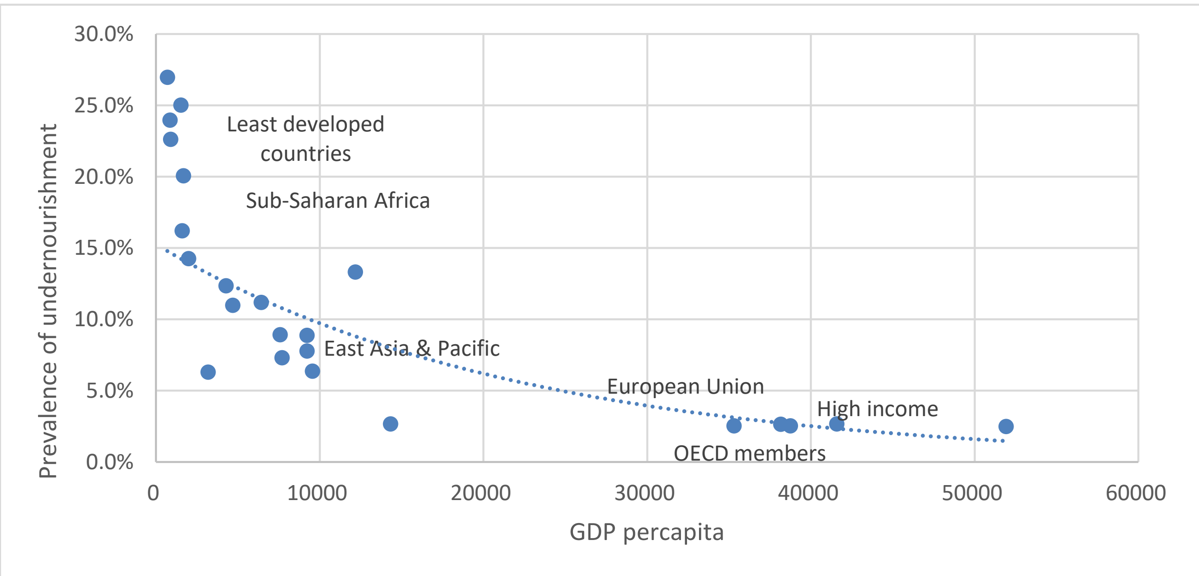
1.2 Drivers of Food Insecurity

According to FAO (2013), static and dynamic determinants can contribute to food insecurity state via market equilibrium mechanism; this feature is not only founded at household but also a macroeconomic level. For example, as quoted by Morrison (2000), the European Commission suggested that the instability of the international market can be transferred to each countries' food security dilemma mainly through cereal import prices. In terms of market equilibrium, there are two main catalogues of factors that would lead to food insecurity, as the increasing demand and restriction on supply.

1.2.1 Aggerated Food Demand

The demographic factor is one of the direct reasons that push up global food demand. World's population size has experienced a large amount of expansion after WW2, from around 3 billion in the 1960s to nearly 7.6 billion in 2018. Based on an estimation of the United Nations, the World's population will continue to grow and will reach nearly 10 billion by 2050. Food demand is increasing relatively: there are 1.62 billion more people to be feed before 2030, and this figure will rise to 2.38 billion by 2050. Another trend discovered by the World Bank is the most significant population growth happens in developing countries since the 1960s. Before 2050, countries of the Sub-Saharan Africa region would have the most considerable population growth. There will be one-fourth of the world's population living in that region. Which would challenge the international food supply and distribution system because Sub-Saharan Africa is where suffering most from the food crisis. For example, Africa South of the Sahara is a region with the highest prevalence of undernourishment and the highest Global Hunger Index as 43.5 (Figure 1.1).

Figure1.1 GDP per capita and prevalence of undernourishment (2015)



Source: Author's calculation of the World Bank Data

The negative correlation between percentage change in real gross national income per capita and the prevalence of undernourishment suggests an insight that incoming growth promotes the progress of food security (Laborde, 2016). Food inadequate is less likely to happen in the affluent area but more likely to occur in the low-income region.

The effect of economic development on the improve food security can be explained in both food supply and demand. Productivity growth is one of the supply-side benefits, specifically, which can be explained by farmers have better access to fertilizer, irrigation facility, and other industrialized agriculture production equipment. However, on the other hand, income growth also donating food demand increase for developing countries. In developed countries, people's daily average nutrition intake is about 3500 kcal, while in poor countries, people may not meet 2900kcal/day as the sufficient food intake level for adults (Carvalho, 2006). An exception suggested by Yao (2016) is that the total demand of food may decrease after the average income and calories intake reach a certain high level, for instance, per capita food consumption in Japan, France, the United Kingdom, and the United States has all experienced a development process from increase to decrease.

Besides the population volume, another demographic factor that affects aggregate food demand is age structure. Mao and Xu (2014) find people's consumption expenditure peaks at their age of 44 in China, which matches the hypothesis of the traditional neoclassical model that the youth and the elder would have a low consumption level. Xin (2018) claims that Chinese people's consumption of food has similar features. Specifically, his study shows the consumption of cereals, wine, and aquatic products peak at the age of 40- 50, which of livestock product peaks at 30 and keeps in high level until retirement age. On the aggerate level, a group with a larger share in the total population would demonstrates the food consumption feature of the whole society.

The world's urban population is expected to grow much faster than the rural population, and by 2050 more than 65 % of the population is expected to be living in urban areas. The effect of urbanization is not only the conversion of land use but also people's access to food. Said by

Huang (2004), urban consumers almost entirely depend on markets for their food consumption needs. Furthermore, dietary change associated with income growth and urbanization has changed the difficulties of food security. Vegetables and meat would take the place of grain as a staple food with economic development. For example, Historical evidence suggests that rice consumption has decreased even in Asia's traditional rice-consuming countries, for example, from 1961 to 2011, per capita rice consumption has fallen for 51%, 13% and 34% in Japan, South Korea, and Malaysia (Mottaleb et al., 2017).

1.2.2 Aggerated Food Supply

Several factors are impacting aggerated food supply, such as limited natural resources, climate change, and food access infrastructures. For example, in terms of soil and water resources available for agriculture production, according to Maggio (2015), the available cropland per person has decreased from over 0.40 ha in the 1960s to below 0.25 ha today. Where urbanization, loss of fertility caused by inappropriate water and soil utilization, salinization, and erosion are the main drivers of land degradation. Climate change is the primary topic for FAO's global food insecurity report, and there are many statistics, and analysis point out the extreme climate or temperature will affect the yield of sensitive crops (see, for example, Iqbal et al., 2009, Moriondo et al., 2011).

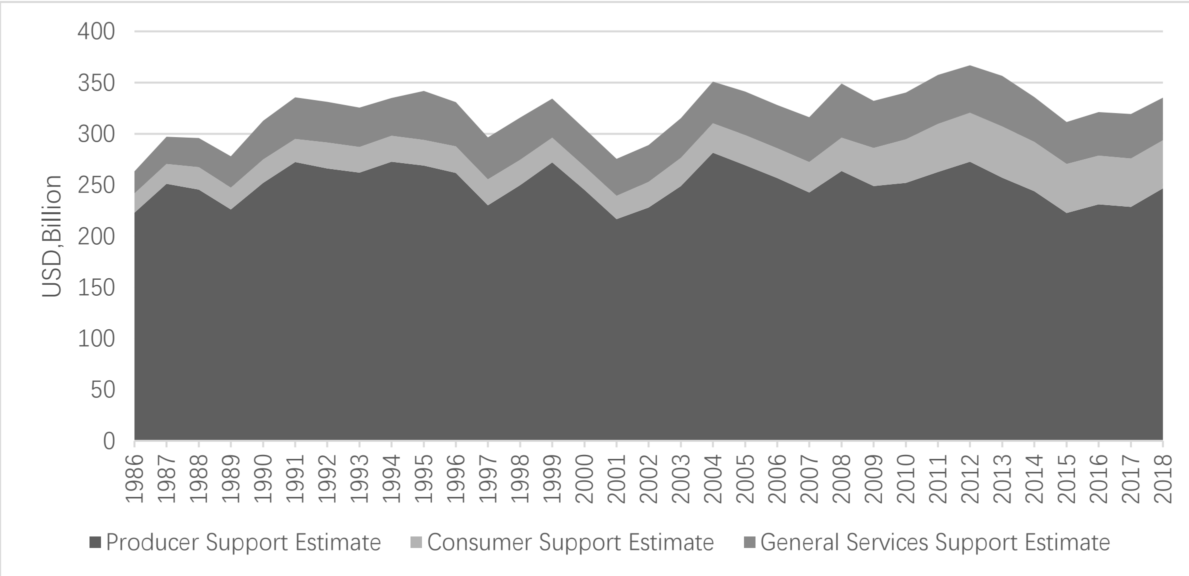
Political instability would have an impact on food security through both food supply and demand. For example, on ACAPS's analysis of food insecurity of Yemen (2019), the report shows there were 45 districts of Yemen had Catastrophic levels of food insecurity. Twenty-four areas among them are because the direct impact of violence, economic collapse, and soaring prices caused by regional conflicts are the main reasons for the other districts. The high cost of essential commodities like water and fuel limits the capability of agriculture production, the pre-existing poverty limits the access of food from the market.

1.2.3 Trade liberation and food security

There is a long-time debate about the linkage between food security and trade liberation. The benefits of free trade on food security can be generally concluded as the optimal domestic resource reallocation and its contribution to improving poverty because of the higher efficiency, which is result from the comparative advantage in international trade. On the contrary, the dissidents of liberalism criticize that open import policy would have a negative effect on food security. First, the local farmer who cannot compete with the import price would be extinct from the market; Second, the international food market is with high price volatility and varieties of monopolized market force, it would be difficult for heavy import reliance countries to have long term food security strategies in this case. In addition, most developing countries are simple price taker, in other words, they don't have enough influence on the global market price. Therefore, it could be risky when facing even increasing import prices without a solid domestic food supply. Declining terms of trade is one of the other risks associated with trade for developing countries, which means the relative price of primary commodity, trends to decrease in terms of the manufactures they import (Morrissey, 2002), while it is important to notice that primary commodity have dominant position of export in many low-income countries. There is one feature founded that import dependency grew mostly in the world's least developed regions, which could result from they failed to develop their capability of export while forced to expand food import (Hoering,2013). Moreover, following trade theory, developing ought to have a comparative advantage on agriculture production, because they are more likely to be gifted with an endowment in labor, land and other natural resources instead of capital or technological advantages (Morrissey, 2002). But this comparative advantage of the agriculture industry didn't always appear in the real food trade, as mentioned previously in this chapter. Hermann (2007) stated that the blame for market distortion should put on agriculture support from advanced exporters, especially OECD countries (Figure 1.2). The developing country's agriculture production would be affected by an advanced country's subside if open trade policy is implied, and the economy size of the advanced country is large enough to affect the world market price.

In short, trade protectionism itself can't promote the progress of food security. On the other hand, despite open import policy may reduce the agriculture production cost, the local farmer would generally be harmed because they are not affordable to compete with subsided import price. Besides that, the food insecurity risk associated with trade liberalization also includes the potential imbalance between import and export.

Figure 1.2 OECD agricultural support, 1986–2018



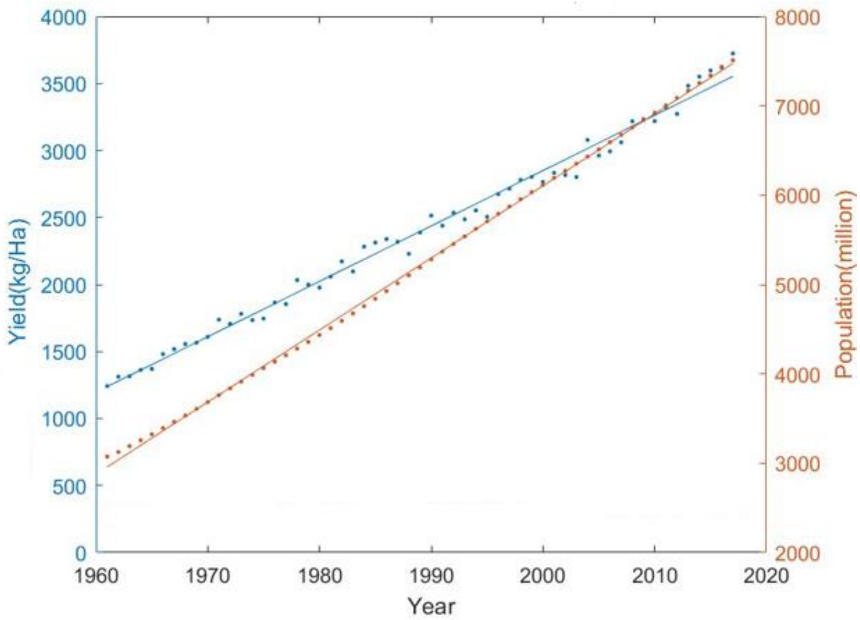
Source: Author's calculation of OECD data.

1.3 Global Food Security

Following the instruction of FAO (2003), during the past decades, people's efforts aiming at ensuring food security is mainly focusing on eliminating poverty and malnutrition by improving the availability and accessibility of food to individual consumers. However, at a more aggregate level, the growth of food production per capita is too slow to reach the Millennium Development Goal 1 (MDG1) of halving the proportion of malnutrition people by 2015. There are very few developing countries, including Angola, Bolivia, China, Costa Rica, etc., that have successfully halved the domestic malnutrition population before 2015. From an international point of view, food inadequacy exists worldwide. Despite the cereals production per capita peaked at 363kg in 2017, the highest number over the past 50 years, it is still challenging for many nations to ensure food security in the future. As reported by FAO (2009), if the global rate in yield continuously grows as the linear model established based on the past

50 years empirical, it will not be able to meet food demand. Because there will be one third more population than current to be feed in 2050 based on the United Nations' forecast, and the growth rate of per unit cereals yield is not as fast as the growth rate of population (Figure 1.3).

Figure 1.3 World's Average cereals yield per hector and population



Sources: Author's elaboration on data from *FAOSTAT* and the *World Bank*

Several other demographic factors are increasing the pressure of global food security apart from population amount. Cited from FAO (2009), future food demand increase is a comprehensive result of global population growth, urbanization, and sustained income increasing in many developing countries. First, according to UN population reports, the increase in the world population will come entirely from urban areas, which is resulted from the rise of urban areas' population is even higher than the total increase in the world population. Urbanization would change people's dietary structure and lifestyle. With the effect of income growth, food for urban residents will be foreseeably diversified: The status of cereals as the main source of calories will decline, and the proportion of fruits, vegetables, meat, and dairy will rise (FAO, 2009). Besides, there is going to be more demand for fast food and semi-finished food products in the urban area. The urban residence will rely more on the marketized food supply chain since they are less related to direct agriculture production. Secondly, most population growth will arise in developing countries, and the most considerable relative growth is expected to happen in the current least developed countries. In meanwhile, LDCs are where food dilemmas usually thought to occur. As an example, Hermann (2007) classified 24 countries, including 19 least developed countries, that appeared to have comparative advantages in agriculture production based on their natural endowments. In other words, these 24 countries ought to be net food exporter or at least be secured in the food supply field. However, there are 23 countries among them have received food aid in a short reference period. In the early 21st century, FAO (2003) estimated that there were 820 million people stuffing from undernourished, and over 96% of them were living in developing countries.

1.4 Food security in developing countries

The classification of developing countries adopted by this thesis comes from World Economic Situation and Prospects 2019 of the United Nations that classifies countries with their level of economic development, per capita gross national income (GNI) in other words. Because of the highly coincident of developed countries and high-income countries, the other countries with per capita GNI less than $12, 056 can be classified as developing countries.

Developing countries are more vulnerable in terms of food security. Political instability, natural disasters, and a high dependency ratio are three leading causes that increased the risk of food crisis in developing countries (Hermann, 2007). The concept of malnutrition, as one of the components of food insecurity, is usually associated with poverty (Maxwell, 1992). Because poorer countries generally have less distributable resources and market forces when facing negative production shock. Especially under the current circumstance that many developing countries are current food deficit and rely on imports form the global market to ensure food security (FAO,2009).

Due to the trend of globalization in the past decades, the international food trade toady is more liberalized. Consequently, many countries have turned from net food exporter to food importer (Hoering,2013). Back in 1970s, most countries appear to certain extent of food self-sufficient depending on different measurements (Clapp, 2017). For instance, cited in Clapper's paper, regarding on calories consumption, O'Hagan (1975) reported that in early 1970s, around 19 percent of countries had over 105% self-sufficient ratio and there were 19 percent of countries had below 95% self-sufficient ratio. Where the self-sufficient ratio (SSR) is defined as equation (FAO, 2012):

$$SSR = \frac{Production}{Production + Import - Export} \times 100$$

It is a hard to judge whether a country is food self-sufficient just based on SSR, besides that indicator, nutritional intake status and a standard of dietary energy production (DEP) per capita are normally required for discussing a country 's food-sufficient situation via a number of necessary steps. But from above identified figure, it is can be known that from population point of view, 80% of world population lived in a country had produced food equal or exceed domestic demand at that time. Another literature evidence is from Paarlberg (1999), who claims that there was very weak linkage between food insecure countries and world market in terms of grain import, during the world food crisis period at 1973/1974, when the real export price of wheats were doubled but overall consumption was not significantly affected.

The situation of food self-reliance was changed in the later decades, from trade liberation progress of view, the percentage of total world production food that traded in international market has increased from 15% in the 1980s to 23% in 2009. And food import has become the main food source for many countries that have natural shortages in food production (Fader, 2013). According to Valdés (2012), the number of net foods importing developing countries has increased from 74 to 89 since mid-1990s. This trend is unlikely to inverse in future, based on FAO's estimation, the total developing countries' food import will expand to twice the size of 2009 before 2050. On the supply side, certain exporting countries are trend to dominate the international food market (Clapp, 2017). For example, 53% of maize and 23% of wheat on international market is provided by exports from the United State; Thailand is another biggest supply country, where 36% of the world's export rice is produced.

This extreme division between importer and exporter can be explain as effect of comparative advantage on global food production, but policy also played essential roles in this progress: many developing countries like Bangladesh, Pakistan, India, Peru, and Turkey etc., implied loosen import restriction on agriculture products for the balance between domestic food price and demand increment caused by population growth (FAO, 2009). Import could be thought as a more direct and attractive approach for these governments to feed the expanding urban population than invest in agriculture production. On the other hand, because of the worrying of their own food security, some agriculture exporting countries applied export restrictions (Hoering,2013), which is another factor causes the distortion. The supply concentration trend and the import tariff reduction policies have combined to result in rising import dependencies in many countries, and which could lead to a further result that certain country's key crop have heavy reliance on the other countries' export (MacDonald,2013).

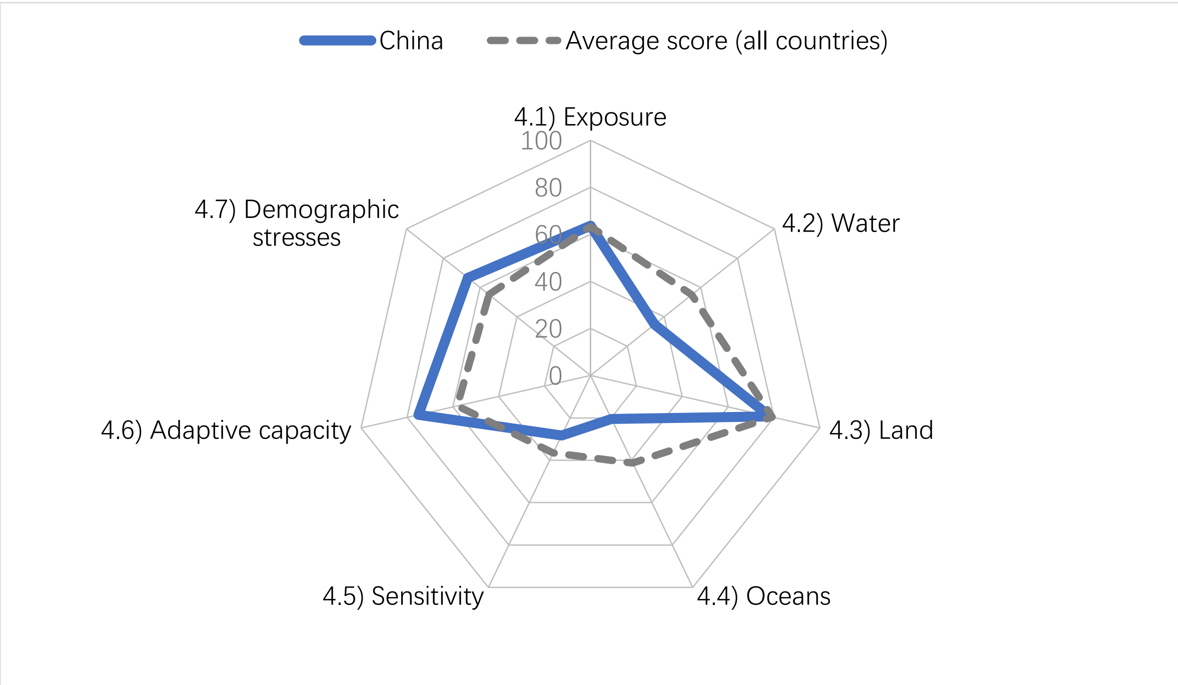
Since food security has a strong correlation with political stability, it is considerable important for countries to achieve adequate levels of food security by adopting a suitable strategy. At national scale, there are two main reasons that would result in food insecurity, the first is that domestic natural endowments are not sufficient to meet agriculture production need, the other is country's export cannot generate enough foreign currencies from international trade to support food import. And there are two strategies accordingly, as food self-sufficient and food-reliance, employed by different governments to improve their food security status. Namely, the strict food self-sufficient means a country's food consumption 100% rely on its domestic food supply while eschewing all food trade, and a broader definition refers to a country's food production capacity equal or exceed its consumption need; Food self-reliance represents a set of policies that bank food security on international trade patterns. Food self-reliance is a prevailing concept in the 1990s because of liberal global trade trend (Morrison, 2002). However, after experienced the extreme market price fluctuation during 2006-2008, there are numbers of countries improved the priority of food self-sufficiency in their policy agenda (Clapp, 2017). For instance, the food sufficiency ratio of Japan has sharply reduced from around 80% in the 1960s to 40% (Kako, 2009), but there are also studies show that Tokyo has consistently insisted on protecting its domestic farmer by excluding agriculture production from the free trade agreement negotiation (Hoering,2013).

Chapter 2 Food security in China

2.1 Measuring food security of China with food consumption adequacy

The issues of food security have plagued many developing countries for years, and China is no exception, the debate of China's food security policy has never stopped since the open economy reform in the late 1970s. As one of the biggest developing countries and the world's biggest food consumption market, China has faced a challenge of feeding twenty per cent of the world population with less than ten per cent of arable land and other limited resources (Figure 2.1).

Figure 2.1 China’s Natural Resources & Resilience of Food Security



Source: Global food security index (2019)

While China has made a great contribution to providing food security for its people since the economic reform, said by Jiang (2008). For instance, a calculation based on the food balance sheet of FAO tells that the average daily food consumption for Chinese people is only 2080 calories in 1979, as a comparison, world’s average daily food intake was 2500 calories per capita at that time. By 2013, the average daily food consumption of Chinese had increased by about 50 per cent to 3108 calories. It is above the world average over the same period as 2884 calories (see Table 2.1). In the meanwhile, nutritional intake and food quality state have also improved. This achieved progress results from improvement of agricultural production efficiency, market development and reduce the incidence of extreme poverty (Huang, 2004).

Table 2.1 Grain production, food consumption and household income in China, 1978 and 2013

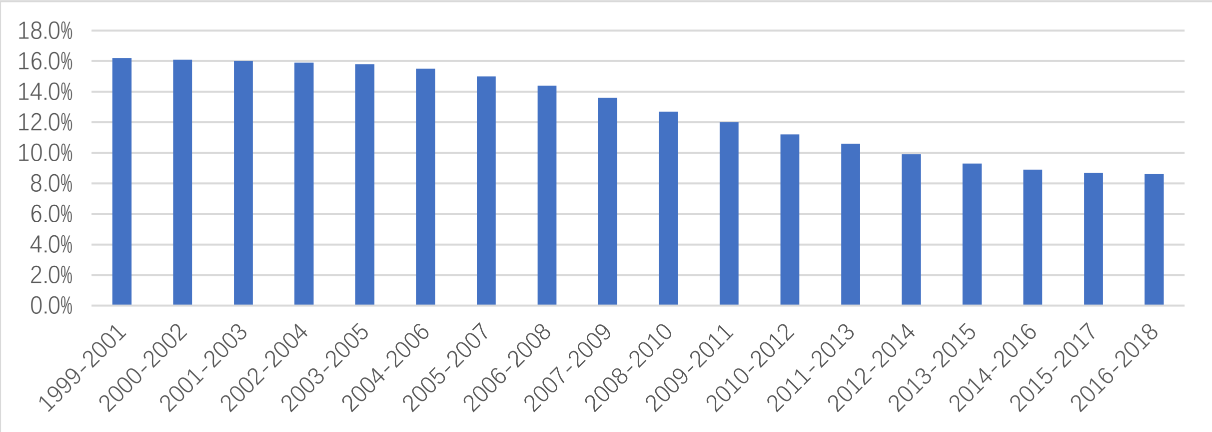
	Total grain production (million ton)	**Per capita grain production (kg)**	**Per capita daily calories**	**Per capita income of rural household (yuan)**	**Per capita disposable income of urban household (yuan)**
1978	304.8	319	2080	133.6	343.4
2013	630.5	464.48	3108	8389.3	24126.7
Average Annual growth rate (%)	2.10	1.08	1.15	12.56	12.92

Source: National Bureau of Statistics: China Statistical Yearbook (1978, 2013); FAO (2013)

In 2019 released Global Hunger Index (GHI), China ranks 25th out of 117 qualifying countries with a score of 6.5, lower than the moderate hunger level as the average of east and southeast Asia, which means China is currently suffering a very low level of hunger. Besides that, the prevalence of undernourishment and dietary energy supply adequacy are two intuitive symbols that represent China's progress on eliminating hungry, which is an essential part of food security. In the first two decades of 21st century, the percentage of undernourished population in China has continuously reduced to under 10%; according to FAO statics, up to 2018, the 3-year average dietary energy supply adequacy of Chinese people is well above the world average and close to the figure of high-income economies as 135%.

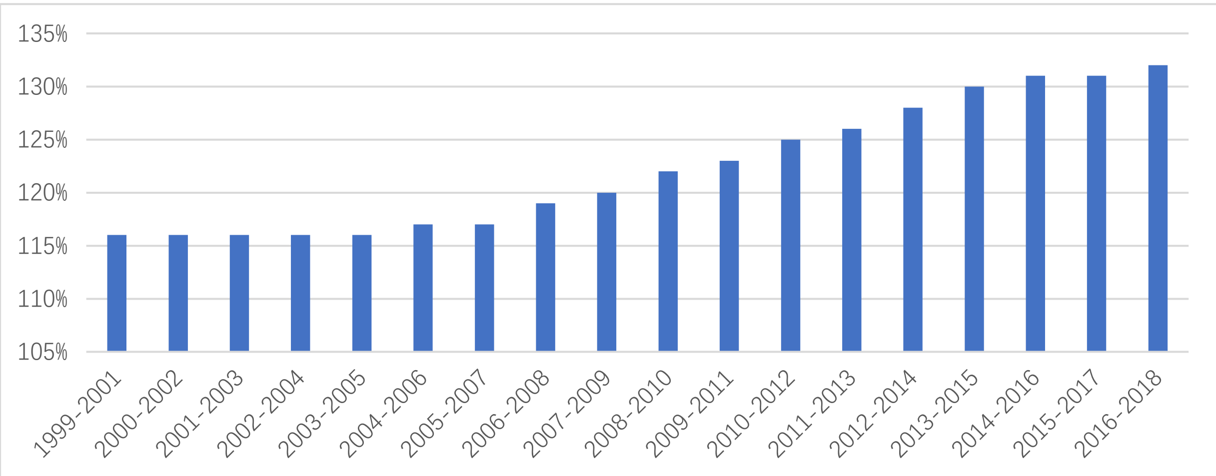
Policy change contributed a lot to this development, including but not limited to the introduction of a quota system (1955–1993), land contract reform (1981), market-oriented economy reform (1978) and the abolishing of price scissors on agriculture price (1978). These measures have incentivized farmers and promoting economic growth, which further enhanced the supply and demand for food.

Figure 2.2 Prevalence of undernourishment of China (3-year average)



Source: FAO on-line data (2019)

Figure 2.3 Average dietary energy supply adequacy of China (3-year average)



Source: FAO on-line data (2019)

Apart from calorie intake volume, the dietary change and increasing demand for diversified food also attracted many concerns (Zhou, 2012). As Zheng (2015) indicated, the significant change of food consumption pattern includes three aspects: nominal food expenditure and its proportion in total household expenditure, the proportion of away from home food consumption and food consumption structure (dietary) change. According to this study, during the period from 1990 to 2010, by using disposal income deflator with 1990 as the base year, calculated that the annual per capita real food consumption expenditure increased from 694 yuan to 1374 yuan, with an average annual growth rate of 3.7%. The change of urban residents is more prominent due to a more completed market system in the city area. Compared with the 1990s, urban residents consume less grain, more animal protein products and have more frequent away from home food consumption. For example, regarding food consumption at home, per capita consumption of grain decreased from 131 kg to 82 kg, with a decrease of 37%; per capita consumption of animal products increased from 45 kg to 76 kg, with an increase of 69%. By using cereal equivalent calculation on main food consumption data of Chinese urban residents (Table 2.2), estimated that proportion of animal products increased to around 75% of total calories intake by 2013, and which represent animal product has transformed from luxury food in traditional mindset to an essential component of Chinese people's stable food (Jiang, 2008). Meanwhile, the increasing proportion of dining out expenditure implies an alteration in food consumption pattern, which increased from 7.9% of total food expenditure in 1992 to 21.2% in 2010 according to China Statistical Yearbook.

Because of urban-rural difference, income level and food consumption expenditure of urban residences are higher than that of rural residences, and market system and infrastructure construction in urban area are generally ahead of rural area. The urban residences' food consumption pattern change implies the future change of that in rural area (Zheng, 2015). For example, in terms of nominal income, the per capita income of rural residents in 2010 is roughly equivalent to the per capita disposable income of urban residents in 2000, and the food consumption level and dietary structure of rural residents in 2010 are only equivalent to those of urban residents in 1990. Table 2.3 shows the per capita food consumption of China's rural residences from 2000 to 2017. During the past two decades, rural residences have experienced a food consumption pattern change similar to urban residences that the composition of cereals in food is relatively reduced while the proportion of meat and vegetables is increased, but the progress is relatively hystericized than urban consumer. This lag of change may be explained as inaccurate of historical data due to the low level of market development (Huang, 1998), which underestimated the food intake level of rural consumer because of the extensive self-sufficient agricultural economy in the rural area.

Table 2.2 Annual Household Food Consumption of Chinese Urban Residents, 2000-2017 (kg/person)

	*Grain**	*Vegetable*	*Oil*	*Pork*	*Beef& Mutton*	*Poultry*	*Eggs*	*Milk*	*Aquatic products*	*Fresh fruits*
2000	82.3	114.7	8.2	16.7	3.3	5.4	11.2	9.9	9.9	57.5
2001	79.7	115.9	8.1	16	3.2	7.3	10.4	11.9	10.3	59.9
2002	78.5	116.5	8.5	20.3	3.0	9.2	10.6	15.7	13.2	56.5
2003	79.5	118.3	9.2	20.4	3.3	9.2	11.2	18.6	13.4	57.8
2004	78.2	122.3	9.3	19.2	3.7	6.4	10.4	18.8	12.5	56.5
2005	77.0	118.6	9.3	20.2	3.7	9.0	10.4	17.9	12.6	56.7
2006	75.9	117.6	9.4	20	3.8	8.3	10.4	18.3	13.0	60.2
2007	78.7	117.8	9.6	18.2	3.9	9.7	10.3	17.8	14.2	59.5
2008	63.6	123.2	10.3	19.3	3.4	8.5	10.7	15.2	11.9	54.5
2009	81.3	120.5	9.7	20.5	3.7	10.5	10.6	14.9	12.2	56.6
2010	81.5	116.1	8.8	20.7	3.8	10.2	10	14	15.2	54.2
2011	80.7	114.6	9.3	20.6	4.0	10.6	10.1	13.7	14.6	52,0
2012	78.8	112.3	9.1	21.2	3.7	10.8	10.5	14.0	15.2	56.1
2013	121.3	100.1	10.5	20.4	3.3	8.1	9.4	17.1	14.0	47.6
2014	117.2	100.1	10.6	20.8	3.4	9.1	9.8	18.1	14.4	48.1
2015	112.6	100.2	10.7	20.7	3.9	9.4	10.5	17.1	14.7	49.9
2016	111.9	103.2	10.6	20.4	4.3	10.2	10.7	16.5	14.8	52.6
2017	109.7	102.5	10.3	20.6	4.2	9.7	10.9	16.5	14.8	54.3

Source: National Bureau of Statistics: China Statistical Yearbook (2001-2018)

Note*: Grain definition used in China includes all cereals (rice, wheat, maize, barley, sorghum, millet, oats, rye), plus pulses (including soybeans, beans and peas), as well as a part of edible tuber crops (sweet potatoes and potatoes are converted on a 5:1 ratio, not including cassavas). (Zhou, 2012)

Huang (2004) claimed that income growth is the main driver of China's food consumption variation, and this trend follows Engel's law that with income increase, the total expenditure of food would rise accordingly but the proportion of total household expenditure spent on food consumption would fall. Related to total expenditure on food rising, this dietary structure change also follows Bennett's law that with the rise of residents' income levels, they tend to have diversified diets: consumption of calorie-dense starchy staple foods such as grains are likely to decrease, and consumption of foods with higher economic value, such as fruits, livestock, poultry and dairy products, tends to increase (Zheng, 2015). Zhou (2012) and Zheng (2015) expected that Chinese consumers with higher disposable income would consume more meats, dairy products and especially aquatic products in future.

Table 2.2 Annual Household Food Consumption of Chinese Rural Residents, 2000-2017 (kg/person)

	Grain	*Vegetable*	*Oil*	*Pork*	*Beef& Mutton*	*Poultry*	*Eggs*	*Milk*	*Aquatic products*	*Fresh fruits*
2000	250.2	106.7	5.5	13.3	1.1	2.8	4.8	1.1	3.9	18.3
2001	238.6	109.3	5.5	13.4	1.2	2.9	4.7	1.2	4.1	20.3
2002	236.5	110.6	5.8	13.7	1.2	2.9	4.7	1.2	4.4	18.8
2003	222.4	107.4	5.3	13.8	1.3	3.2	4.8	1.7	4.7	17.5
2004	218.3	106.6	4.3	13.5	1.3	3.1	4.6	2.0	4.5	17.0
2005	208.8	102.3	4.9	15.6	1.4	3.7	4.7	2.9	4.9	17.2
2006	205.6	100.5	4.7	15.5	1.6	3.5	5	3.1	5.0	19.1
2007	199.5	99	5.1	13.4	1.5	3.9	4.7	3.5	5.4	19.4
2008	199.1	99.7	5.4	12.7	1.3	4.4	5.4	3.4	5.2	19.4
2009	189.3	98.4	5.4	14	1.4	4.3	5.3	3.6	5.3	20.5
2010	181.4	93.3	5.5	14.4	1.4	4.2	5.1	3.6	5.2	19.6
2011	170.7	89.4	6.6	14.4	1.9	4.5	5.4	5.2	5.4	21.3
2012	164.3	84.7	6.9	14.4	1.9	4.5	5.9	5.3	5.4	22.8
2013	178.5	89.2	9.3	19.1	1.5	6.2	7	5.7	6.6	27.1
2014	167.6	87.5	9	19.2	1.5	6.7	7.2	6.4	6.8	28.0
2015	159.5	88.7	9.2	19.5	1.7	7.1	8.3	6.3	7.2	29.7
2016	157.2	89.7	9.3	18.7	2.0	7.9	8.5	6.6	7.5	33.8
2017	154.6	88.5	9.2	19.5	1.9	7.9	8.9	6.9	7.4	35.1

Source: National Bureau of Statistics: China Statistical Yearbook (2001-2018)

Note: National bureau of statistics and department of household surveys applied new statistical caliber as Sample

Survey of Household's Income and Expenditure and Life Condition since the fourth quarter of 2012, the data difference of food consumption before and after 2012 may result from this rather than real consumption change.

The animal product consumption can be regarded as a measure of food consumption pattern evolution, and meat calories available per person per day is a representative indicator for measuring food nutrition value, which used by Zhang (2015) as a supply-side indicator for studying food security state of China. Where he found that in Chinese people's dietary, the proportion of calories from animal protein roughly equivalent 98% of the world's average. Consider that based on FAO data, the majority of China's food security indicators are better performance than the world's average level and some even close to high-income economies, he claims the proportion of animal protein in food consumption is one of the worst indicators that have lowest compliance level. For example, in terms of food nutrition supply, China's per capita energy supply and protein supply are 8% and 18% respectively higher than the world average, while the proportion of animal protein in total energy acquisition is only equivalent to 60% of which in developed countries.

This shortboard of China's food security could be explained by the consumption difference between income groups and regional consumption differences. For example, in the coastal area of southeast China, residences' consumption of aquatic products is significantly higher than that of inland provinces. And in inland areas, especially the northwestern regions, the amount of residences' livestock and poultry products consumption is much large than that of aquatic products. Economic and social development will reduce this difference, but this difference will not disappear in a short time (Zheng, 2015). In addition, it is also related to the widely use of vegetable protein in traditional dietary (Zhang, 2015). Gini coefficient is a measure of a nation's wealth distribution, and inequality, the World bank record shows the GINI coefficient raised from 32 in 1990 to 43.7 in 2010, which represents an increased income gap. The increase in income inequality in urban China may have resulted in a slow food demand growth and has weakened the speed of food consumption patterns transformation, particularly in terms of the demand growth of meats, poultry, and fish since the food-income elasticity of high-income residents is lower than low-income groups (Zhang and Henneberry, 2010). The difference in consumption pattern would be significant when exits large income differentials (Zhou, 2012). For instance, based on China Statistical Yearbook (2012), high-income households (64.2kg) consumed almost twice as much animal products per capita as the lowest income or poor households (33.1 kg). However, Zhang and Henneberry (2010) imply the consumption of meats, poultry and fish in urban China may be underestimated because the increase in away from home food consumption expenditure also affects at-home food consumption. Meanwhile, consider Chinese people's average demand for meats, poultry and fish is still lower than neighboring developed countries with similar traditional diets, like Japan and South Korea. Many studies believe China's total demand for animal products will continue to grow with further economic development and poverty reduction process (see, for example, Zhang and Henneberry, 2010; Zhou, 2012).

2.2 China's food import dependency

New worries about food security emerge with the food consumption structure evolution in China, particularly related to food import dependency. China is the world's largest food producer as well as the largest food consumer in volume terms, in order to meet the growing domestic demand, China has imported more food and feed ingredients from the international market since 2004, and this trend is unlikely to inverse (Zhou, 2012). However, the performance of Chinese agriculture progress during the 1980 – 2000 period is impressive and contrary to some previous expectation that China might have become a bigger food importer (Huang, 2004). One of the explanations is that China's population is too large to rely on world food market for its supply (Ye, 2012). For instance, according to USDA, the Chinese consumer consumed 55.4 million tons of pork in 2018, while the total amount of exported pork on the international market is only around 8.5 million tones. Furthermore, there are studies that believe that countries with large population would be benefited by reducing their food supply reliance from the world food market. Because if the import demand is great enough and import amount variance from year-to-year, the country's purchase of food commodity may drive the price fluctuation on the international market. On one hand, which could affect the country's foreign exchange expenditure on food purchases but also the other countries who seek for the same commodity on the world market. On the other hand, countries with higher food self-sufficient ratio would contribute to more stable domestic and import food price. Therefore, it is reasonable for a country with a large population to have cautious food import policies (Clapp, 2017). Cited from Davis (2014), food self-sufficiency ratio is in fact relatively higher in countries with a larger population like China and India.

The food self-sufficiency ratio of China can be calculated based on FAO's food balance sheet (Table 2.4). The calculation result basically matches the description in China's food security white paper published by China State Council (2019): cereals supply is basically self-sufficient (over 95%). Specifically, in 2017, three main cereal crops (Wheat, rice and maize) are self-sufficient, majority of livestock products and vegetables are also domestically produced, a relatively small proportion of import and export can be considered as a result of intra-industry trade and variety adjustment. On the contrary, soybeans and cassava are two commodities with lowest self-sufficiency rate, over 85% of soybeans and cassava consumed in China are imported. Recall that the definition of grain used in China statistics includes all cereals as well as pulses crops and converted edible tuber crops (sweet potatoes and potatoes are converted on a 5:1 ratio, not including cassavas). Under this condition, estimated the grain self-sufficiency ratio of China is around 85%, which is below the marginal self-sufficient level as 95%. Jiang (2008) recorded the grain self-sufficiency rate of China is 96.9% in 2001. Compared with nearly two decades ago, more food products are consumed in China, while the food self-sufficiency rate is reduced by about 10 per cent. The expanding soybean import is the main factor that leads to the drop of this figure. China used to produce more soybean than its domestic consumption, and the country was the world largest soybean producer until the second half of the twentieth century (Jamet, 2016). According to historical data from FAO's food balance sheet, in the 1990s, China is at the margin of soybean self-sufficient and sometimes even net exporters. However, only 12.6% of soybean consumed is produced domestically in 2017 (Figure 2.3). In volume term, China has imported 95 million tons of soybeans in 2017 (Figure 2.4), which accounts for nearly two-thirds of soybeans traded on the international market (Cui, 2018).

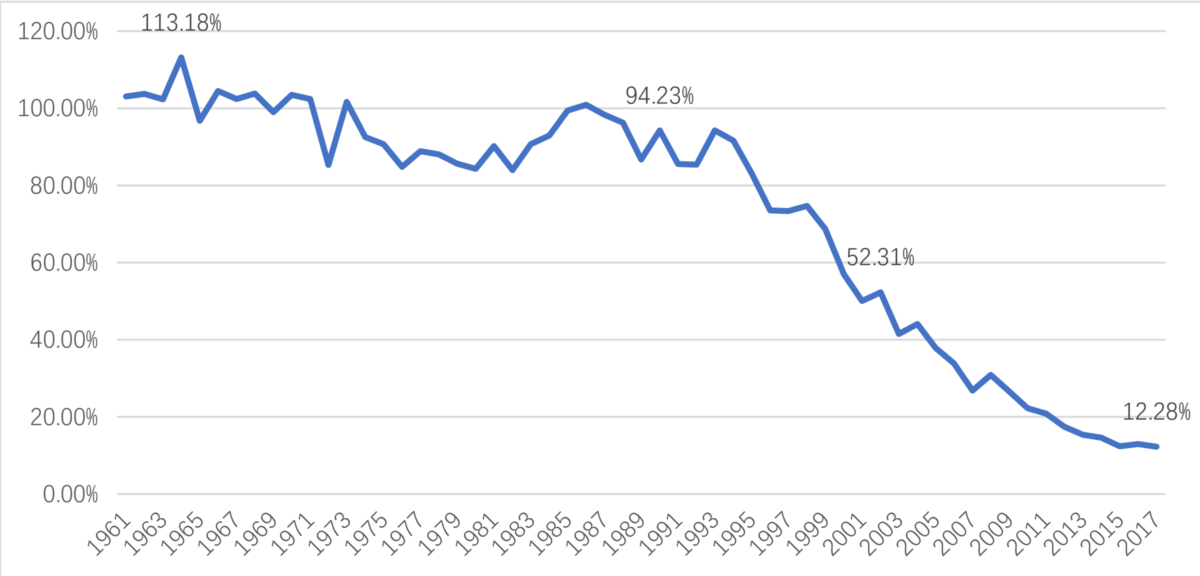
Table 2.4 Food balance and self-sufficiency in China, 2017 (1000 tons)

	Production	*Import*	*Stock change*	*Export*	*Total domestic utilization*	*Self-sufficiency ratio (%)*
Total Cereals	**618104**	**27917**	**8443**	**3524**	**634055**	**97.48**
-Wheat and products	134403	4780	1188	603	137391	97.83
-Rice (Milled Equivalent)	212676	5932	3438	1739	213432	99.65
-Maize and products	259071	2831	-2634	474	264062	98.11
Total Tuber Crops	**177845**	**36477**	**518**	**755**	**213047**	**83.48**
-Cassava and products	4847	36202	376	39	40634	11.93
-Potatoes and products	99147	271	0	559	98858	100.29
-Sweet potatoes	71797	0	0	44	71752	100.06
Sugar and sugar plants	127885	2959	-9501	2020	138324	92.45
Soybeans	**13149**	**95538**	**4000**	**150**	**104537**	**12.58**
Soybeans Oil	15390	653	396	129	15518	99.18
Pulses and products	5177	1419	318	461	5817	89.00
Nuts and products	4210	193	-105	207	4302	97.86
Oil crops	50120	7028	6020	1290	49837	100.57
Oil-Excluding Soybean Oil	8973	7930	153	112	16633	53.95
Vegetables	**650650**	**343**	**0**	**13768**	**637224**	**102.11**
Fruits	165682	4261	167	4789	164984	100.42
Coffee and products	115	136	-6	116	141	81.56
Tea	2470	32	0	367	2135	115.69
Beverages & Alcohol	58918	1574	0	529	59962	98.26
Total Livestock	**94486**	**4743**	**-412**	**906**	**98735**	**95.70**
-Bovine Meat	7261	941	-33	76	8160	88.98
-Mutton & Goat Meat	4675	249	-1	5	4920	95.02
-Pig meat	54518	1422	-301	222	56020	97.32
-Poultry Meat	18236	452	-50	576	18161	100.41
Eggs	36458	0	0	116	36342	100.32

Milk-Excluding Butter	34908	1979	0	61	36826	94.79
Aquatic Products	151350	13983	252	8451	157134	96.32
Total Grain	**670619**	**124929**	**12761**	**4256**	**778531**	**86.14**

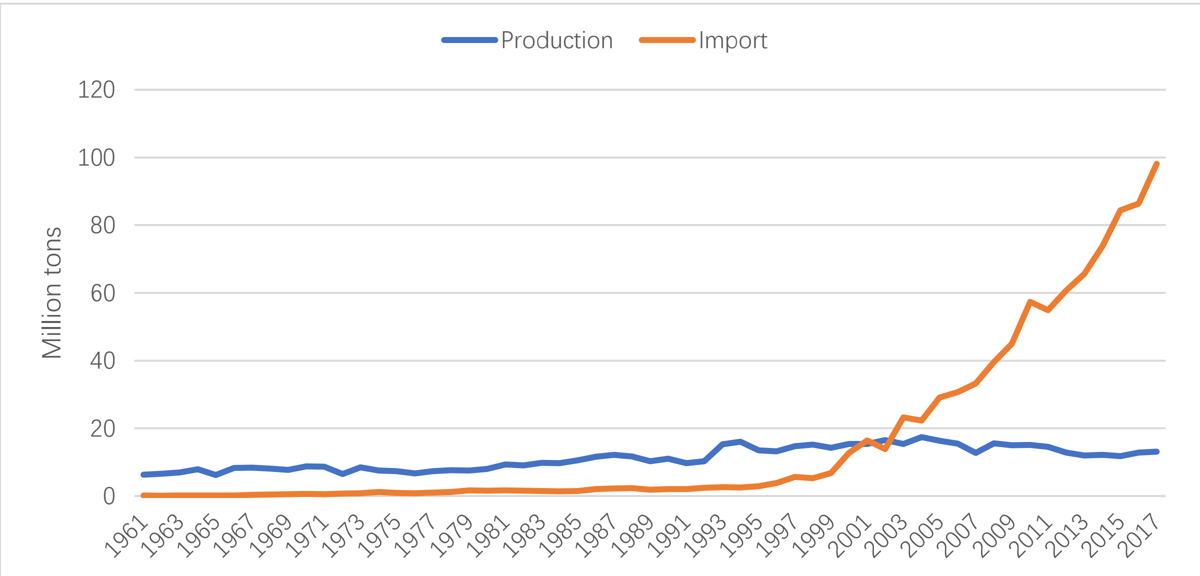
Source: Author's calculation on FAO STAT (2019).

Figure 2.4 China's soybean self-sufficient ratio



Source: Authors calculation on FAO STAT (2019).

Figure 2.5 China's soybean import and domestic production

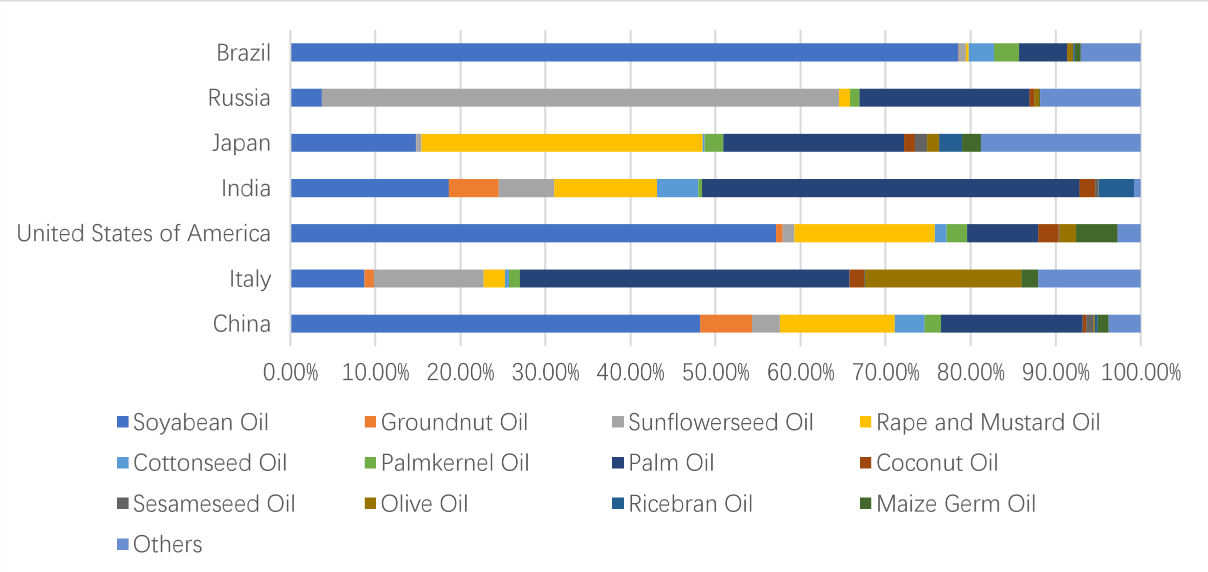


Source: Authors calculation on FAO STAT (2019).

There are several reasons that result in China's huge amount of import on soybean and its products. Starting analysis from demand side, total domestic utilization volume has increased more than five times from 1999 to 2017. According to Jamet (2016), in east Asian countries like Japan, Korea, and China, soybean and soybean products like tofu, soya sauce and miso are a common part of the diet. About 10 million tons of soybean is used directly for food. In the meanwhile, this import demand increase also results from the expansion of animal husbandry and feed need in this industry, in other words, it is because of the rising consumption of animal protein products. Compared with cereals crops, soya contains a large percentage of protein and fat ingredients, which makes soybean as one of the ideal ingredients for feed. Soybean is also an oil crop, following plum oil, soybean oil is the second largest vegetable oil used in the world, and it is especially popular in China. The demand growth of soybean oil is another factor that leads to soybean import increase. China's edible vegetable oil consumption per capita rose from less than 8 kg in 1996 to 24 kg in 2014. China's per capita consumption is lower than the US and European one but is higher than the world's average consumption (Jamet, 2016). Figure 2.5 shows the percentage structure of edible oil in several major countries. In China, around 48% oil consumed is soybean oil, which is abnormal because there are only several biggest soybean exporters like Brazil, United States of America and Argentina (nearly 90% of world's soybean was produced in these three countries) have a larger proportion of soybean oil consumption in total edible oil than China.

The domestic production of soybean didn’t have rapid growth as the amount of total demand or import. China’s soybean production peaked at 2002 while declined in the following years. One explanation is that the oil yield ratio of domestic produced soybean (10%-15%) is less than import soybean (average 18%), which can be considered as low competitiveness as an oil crop. Meanwhile, the side product of oil extracting is called soybean meal, which is the rest of soybean after extract oil, mainly protein and carbohydrates, and soybean meal is one of the components and major protein source of pannage. The rate of meal (also recalled cake) is around 78% for soybean in China. In other words, in the soybean industry, oil extracting is the upstream industry of soybean feed production, the raw martial selection of soybean oil extracting would affect soybean feed production. It is reasonable for soybean crushing company and feed producer to choose imported soybeans. In addition, Jamet (2016) states that China's oilseeds crushing industry is becoming foreign-owned despite the majority of soybean meal used in China is produced domestically.

Figure 2.6 Consumption proportion of edible oil in major countries (2017)



Source: Authors calculation on FAO STAT (2019).

Compared with the other grains, the per unit area yield of soybean is much lower than major cereals crops, according to Cui (2018), it accounts for one-third of wheat, one-fourth of rice and one-fifth of corn. In addition, soybean plants request more land resource and relatively low labor force. Which sometimes be considered as another reason for the shrink of soybean plant in China. China's 1.8 billion mu of arable land threshold policy implies the country is facing reduce of agriculture land because of urbanization, industrial pollution even environment protection project (Grain for Green Program). As one of the countries did not abandon its goal of food self-sufficiency, China shifts to import more soybeans and invest limited agriculture resource to other crops with higher yields and better match with country's production endowments. There are 50 million hectares of cropland freed up for growing the other crops, according to Cui (2018). Instead of policy guidance, the market force has played an important role in this process, Tian (2017) find that the per hector profit ratio between planting soybean and maize is about 0.43 in 2013, which means compared with soybean, maize is a more profitable crop for Chinese farmers.

There are several different models applied to forecast China's food supply and demand change in the next ten to twenty years, for example, China Agriculture Policy Simulation Model (CAPSiM) applied by Huang (2019), China Agricultural Monitoring and Early-warning System (CAMES) used by Xu (2015), Global Trade Analysis Project (GTAP) model used by Mukhopadhyay (2018), and General Equilibrium Model of China's Economy with Regional Dimension (CERD) developed by Jiang (2008) etc.

This thesis will introduce the study result of Huang (2019) and Xu (2015) as an expectation of China's food import dependency. CAPSiM employed by Huang (2019) is a partial equilibrium model, and the Almost Ideal Demand System (AIDS Model) is the core of this model in terms of the demand side determination. Huang (2019) assumes before 2030, the annual GDP growth rate will between 5% to 7%, and the growth rate of disposal income for rural residents will larger than which for urban residents. In terms of population, he assumes China's population will peak in 2030 as 14.5 billion. And the ratio of urbanization will reach 70% at that time. Under the previously mentioned assumption, CAPSiM estimated there would be a more significant imbalance between food supply and demand. Specifically, the need for feed and livestock meat will be higher than their production. Huang (2019) claims that corn was previously oversupplied due to policy interventions, as the demand for livestock products grows, the demand for corn as feed will increase significantly. If the tariff quota system is not adopted, corn imports will exceed 56 million tonnes in 2030, and the self-sufficiency rate of corn will drop to 82%. The soybean import dependency will increase as well. While the production of vegetables and fruits will continue growing steadily, and China will still be a net exporter of these two commodities.

Xu (2015) applied China Agricultural Monitoring and Early-warning System (CAMES) to forecast the future development of food industries in China. He finds a similar result as Huang (2019) that the consumption growth will be slightly faster than production growth. He estimated that grain production would slowly increase in a 0.6% annual growth rate, while meat and dairy will have a sharper growth rate as 1.7% and 2.1%. Regarding on demand side, Xu (2015) claims there will be more cereals and maize used for feed. In short, according to Huang (2019) and Xu (2015), China will import more maize and soybean for feed and industrial use in the following decades, while cereals and vegetables will remain self-sufficient.

Chapter 3 Evaluation index system on food security in China

3.1 Methodology and Data

As a compound concept with mainly four dimensions, food security should be studied through an evaluation index system that includes different aspects of the concept. For example, Coates (2013) suggested that a food security evaluation system should base on four perspectives as food adequacy (quantity), nutritional adequacy (quality), cultural acceptability and food safety, certainty and stability. The Global Food Security Index (GFSI), published and managed annually by The Economist, is a scoring system that consists a set of indices from 112 countries, where the overall score is calculated based on four sub-systems as food affordability, availability, quality& safety and natural resources resilience. China's food security has been viewed through this system since 2018, according to GFSI (2019), China ranks 39th in all selected countries and has a food security state better than the World's average level. The report of GFSI (2019) points out that the strengths of China's food security lies on food safety standard and agriculture production volatility while the weakest part is public expenditure on agricultural research. This result implies that the agriculture share of total public research and development expenditure is much lower than the share of agriculture value-added in GDP despite the fact that China has the World's second-largest R&D expenditure in volume term according to the World Bank (2017).

According to Yao (2015), there were few studies that were viewing China's food security via evaluation systems instead of using a primary weight average method of several indicators besides GFSI. FAO (2013) introduces the suite of food security indicators for measuring different dimensions of food security, contains eight major and 28 minor items (Table 3.1), while the weight of each index that used to construct a food security evaluation system is not provided.

This thesis applies entropy method for determining the weight of each index. The concept of information entropy was introduced by Claude Shannon in 1950. Namely, entropy is the mean of the amount of message contained in an event. In other words, entropy is a measure of dispersion. The greater the amount of message, the smaller the uncertainty and the smaller the entropy; In contrast, the smaller the amount of message, the greater the uncertainty and the greater the entropy. For each random variable with probability p, the amount of message contained can be calculated by the following equation:

$$f_i = \ln\left(\frac{1}{p_i}\right) = -lnp_i$$

In which f_i is the amount of message of a random variable. In this case, we assume random variables are discrete, so the expected value of an event can be calculated as

$$E = \sum p_i * f_i = -\sum p_i * lnp_i$$

And entropy in this thesis is calculated by expected value times a constant value k, for the need of set the range of entropy between 0 and 1. In information theory, redundancy represent the amount of a message that is determined by the constraints of the system and it is equivalent to one minus entropy (Comber, 2010). Therefore, the interval of redundancy is also between 0 and 1. And the determined wight is positive correlated to redundancy. This method is used by Yao (2015) in order to conduct an evaluation system of China's food security state.

In short, the algorithm of the entropy method is determining the weight of each index according to their degree of dispersion. An index will be endowed with more weight in the whole evaluation system if it is more dispersed. This method proves a scientific approach for weight determination in a compound system. While it exits some natural flaws, for instance, the correlation between each index is not considered in the calculation process. In addition, with different duration of the time interval, the determined weight could be different.

Because the measurement units of the indices are not identical, they must be standardized before they are used to calculate the comprehensive indices, in other words, the absolute values of the indices should be converted into relative values, in order to solve the problem of homogeneity of different indices. In addition, positive and negative indices have different effects on the final score, they should divide into different catalogues that for a positive indicator, the score is better with higher value, while for a negative indicator, the score is better with a lower value. In short, different algorithms are required for the positive and negative indices to standardize the data. And detail calculation steps of this method shown as below:

Table 3.1 Calculation steps of entropy weight coefficient method

1. Normalization of indices:

   For positive indices: $X_{ij}^{'} = \frac{X_{ij} - min\, X_j}{max\, X_j - min\, X_j}$

   For negative indices: $X_{ij}^{'} = \frac{max\, X_j - X_{ij}}{max\, X_j - min\, X_j}$

   Where X_{ij} is initial value, $X_{ij}^{'}$ is standardized value; j and i represents the name of indices and the number of the year, $0 \leq X_{ij}^{'} \leq 1$.

2. Calculate the proportion of the j sample value under the I year

$$p_{ij} = \frac{X_{ij}^{'}}{\sum_{i=1}^{m} X_{ij}^{'}}$$

   Where m is the total number of indices.

3. Calculate the entropy of the j indicator

$$e_j = -k \sum_{i=1}^{m} (p_{ij} \times lnp_{ij})$$

   Where $k = \frac{1}{\ln m}$, and $0 \leq e_j \leq 1$. Let $p_{ij} \times lnp_{ij} = 0$ when $p_{ij} = 0$.

4. Redundancy

$$d_j = 1 - e_j$$

5. Weight

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j}$$

   Where m is the total number of years.

6. Synthesis of Food Security Index

$$S = \sum_{i=1}^{m} \sum_{j=1}^{n} (w_j \times X_{ij}^{'})$$

7. Identify the Obstacles to the food security system

   Index deviation $D_{ij} = 1 - X_{ij}^{'}$

   Obstacle degree $H_j = \frac{D_{ij} \times w_j}{\sum_{j=1}^{n} D_{ij} \times w_j} \times 100\%$

Source: Yao (2015)

As a composite indicator system, different indicators contributed different weights to the food security evaluation score. In the above calculation process, S donates the final score produced by this evaluation system. Meanwhile, the obstacles of food security can be identified though calculation, where index deviation D_{ij} represents the gap between the indices and the largest value among the time interval, in the other words, which is the difference between 100% and the standardized value of each indicator. Obstacle degree H_{ij} represents the degree of negative influence of each indicator on the food security evaluation system at year *i*.

Table 3.2 The Suite of Food Security Indicators

FOOD SECURITY INDICATORS	DIMENSION
Average dietary energy supply adequacy Average value of food production Share of dietary energy supply derived from cereals, roots and tubers Average protein supply Average supply of protein of animal origin	AVAILABILITY
Percentage of paved roads over total roads Road density Rail lines density	PHYSICAL ACCESS
Domestic food price index	ECONOMIC ACCESS
Access to improved water sources Access to improved sanitation facilities	UTILIZATION
Cereal import dependency ratio Percentage of arable land equipped for irrigation Value of food imports over total merchandise exports	VULNERABILITY
Political stability and absence of violence/terrorism Domestic food price volatility Per capita food production variability Per capita food supply variability	SHOCKS
Prevalence of undernourishment Share of food expenditure of the poor Depth of the food deficit Prevalence of food inadequacy	ACCESS
Percentage of children under 5 years of age affected by wasting Percentage of children under 5 years of age who are stunted Percentage of children under 5 years of age who are underweight Percentage of adults who are underweight Prevalence of anaemia among children under 5 years of age Prevalence of vitamin A deficiency (forthcoming) Prevalence of iodine deficiency (forthcoming)	UTILIZATION

Source: FAO (2013), pp 16.

Indices that listed by FAO (2013) in Table 3.2 are used for conducting an evaluation system for analyses the food security state of China in this thesis. Some indices are not employed because of data unavailability or overlapping of their meaning with another index. The list of applied index and resource of data can be viewed by following Table 3.3, where part of the calculation result as Entropy, Redundancy and Weight is attached in Table 3.4.

Table 3.3 Index and data resource

Index	**Unit**	**Source**
Arable land per capita	ha	China land and resources almanac (2017)
Water resource per unit of arable land	m^3/ha	China statistical yearbook on environment (2018)
Labor force per unit of arable land	person/ha	China rural statistical yearbook (2000-2018)
Fertilizer used per unit of arable land	kg/ha	China rural statistical yearbook (2000-2018)
Government expenditure on agriculture	10^8yuan	China rural statistical yearbook (2000-2018)
Total grain production	10^4ton	National Bureau of Statistics (2019)
Grain possession per capita	kg	National Bureau of Statistics (2019)
Average supply of protein of animal origin	g/capita/day	FAO STAT (2019)
Net grain import	10^4ton	FAO STAT (2019)
Area of crops affected by natural disaster	10^4ha	China statistical yearbook (1999-2014)
Fluctuation of total grain production	%	China statistical yearbook (1998-2016)
Road density	km/100km^2	China statistical yearbook (1999-2014)
Domestic food price index	/	China statistical yearbook (1999-2014)
Per capita food energy supply	kcal/capita/day	FAO STAT (2019)
Prevalence of undernourishment	%	FAO STAT (2019)
Percentage of population using at least basic drinking water services	%	FAO STAT (2019)
Percentage of population using at least basic sanitation services	%	FAO STAT (2019)

Source: Author's elaboration of various issues

Note that the population data used in this thesis comes from the World Bank (2019), water resource referring to the total amount of water used in agriculture. Labor force stands for total rural population employed by primary industry. Government expenditure on agriculture including state financial support for agriculture production, for example, pest control and land reclamation operation etc., while not including government expenditure on forestry or water conservancy project. The total grain import is calculated based on Food Balance Sheet published by FAO with above mentioned grain statistical formula. Fluctuation of total grain production is captured according to following formula introduced by Cui (2019):

$$R_t = abs((Y_t - Y_t')/Y_t')$$

Where Y_t represents the total domestic grain production of year t, Y_t' stands for 5-year moving average of grain production.

Table 3.4 Evaluation indexes and their weight of food security system in China

Sub-system	Index	Entropy	Redundancy	Weight
Food production resources (30.86%)	Arable land per capita	0.887	0.113	0.071
	Water resource per unit of arable land	0.937	0.063	0.039
	Labor force per unit of arable land	0.938	0.062	0.039
	Fertilizer used per unit of arable land	0.895	0.105	0.065
	Government expenditure on agriculture	0.848	0.152	0.095
Food availability and stability (28.11%)	Total grain production	0.904	0.096	0.060
	Grain possession per capita	0.920	0.080	0.050
	Average supply of protein of animal origin	0.911	0.089	0.055
	Net grain import	0.933	0.067	0.041
	Area of crops affected by natural disaster	0.920	0.080	0.050
	Fluctuation of total grain production	0.960	0.040	0.025
Food access (29.38%)	Road density	0.872	0.128	0.080
	Domestic food price index	0.928	0.072	0.045
	Per capita food energy supply	0.906	0.094	0.058
	Prevalence of undernourishment	0.822	0.178	0.111
Food utilization (11.65%)	Percentage of population using at least basic drinking water services	0.909	0.091	0.057
	Percentage of population using at least basic sanitation services	0.904	0.096	0.060

Source: Author's elaboration based on data from Table 3.3

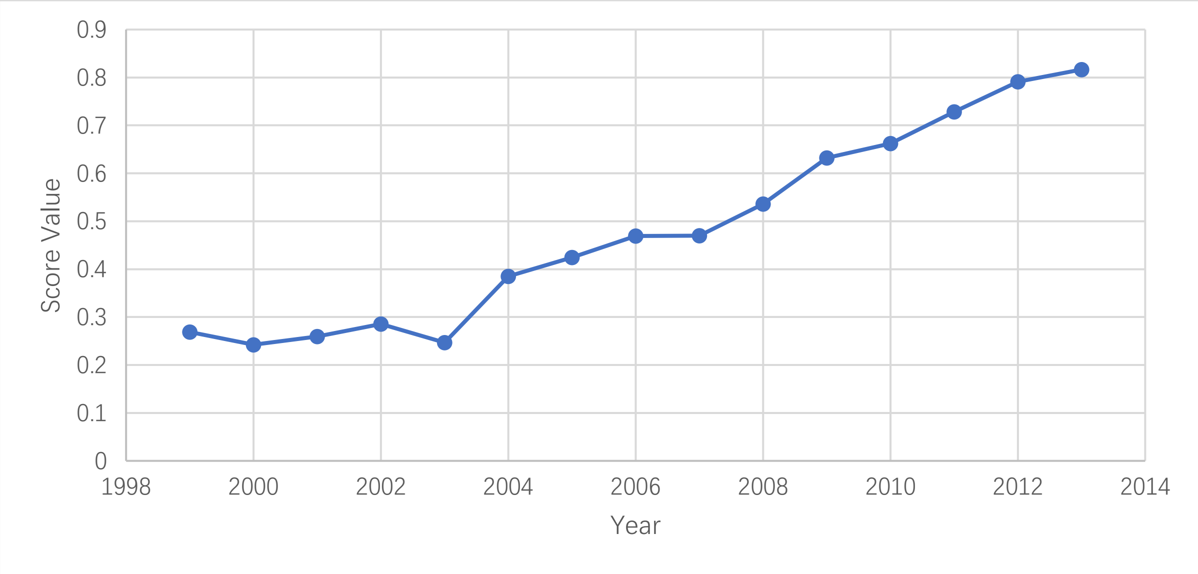
The food security evaluation system following the framework introduced by Yao (2015) that indices are classify as 4 sub-system, namely as food production resources, Food availability and stability, food access and food utilization. The effect of sub-system on final evaluation score is equal to the sum of each indices' weight under the sub-system.

3.2 Results and Analysis

Figure 3.1 shows the result of evaluation as the score of China's food security index from 1999-

2013. Yao (2015) implies the food security of China has experienced three stages during the period of 1990-2010: the score value growth steadily from 1990-1998, rapidly deteriorated during 1998-2003, and back to growth after 2004. The study of this thesis shows similar result with Yao (2015) and Ye (2012) that China had experienced the worst food security status of the last two decades at 2003, while the food security condition is generally better off in the following years.

Figure 3.1 Food security system index in China (1999- 2013)

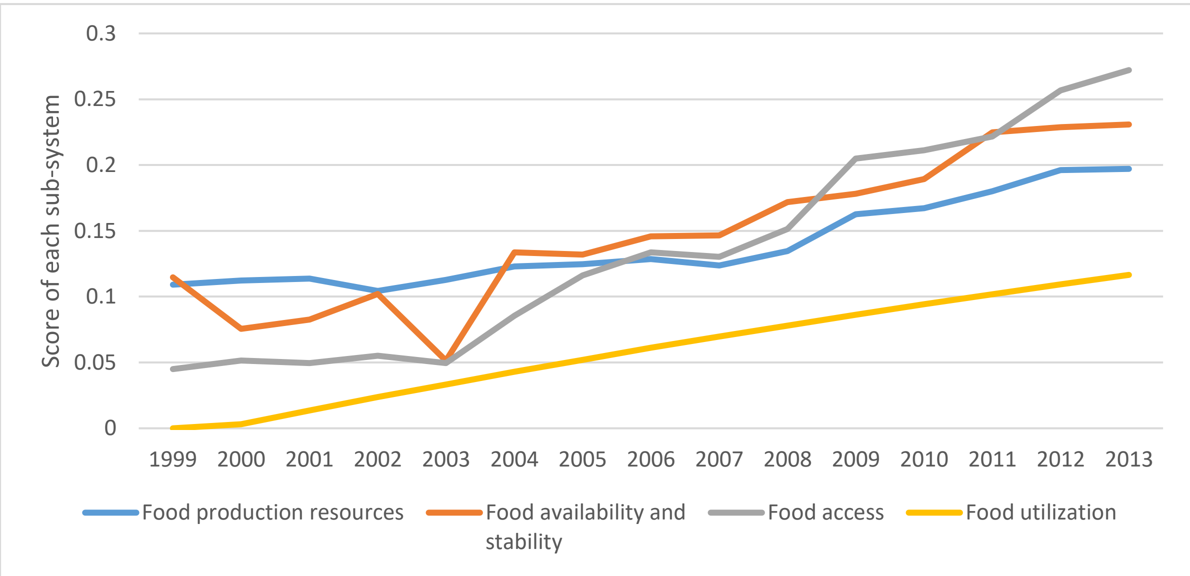


Source: Author's elaboration based on data from Table 3.3

In terms of subsystems (Figure 3.2), food production accounts for the largest proportion in the whole evaluation system, followed by food access and food availability. Which suggest in the period of 1999- 2013, food production conditions, especially crop production resources, are the key factors of China's food security. As a reference, Deng (2006) implies the limit cultivated land and other resources are restricting the potential development of China's food production.

Each sub-system score increased from 1999 to 2013, which shows China's food security state has been better off in all of the four dimensions. The Pearson's correlation coefficient between food security index score and each sub-system are all above 0.96 and passed the 5% significance testing. Specifically, the first sub-system as the factors of food production is relatively stable, which increased from 0.11 to 0.20, the average annual growth rate is 4%, food production resources system is the most weighted sub-system until 2004. Food availability and stability was fluctuation before 2004 while has similar growth path with food production resources, which show there are correlation between indices selected in these two sub-systems, for example, there is causality between the resource of production and total volume of grain production. The initial value of food access is relatively low while having the largest weight on food security after 2009. The total proportion of food utilization is relatively low because there are minimal number of indices under this catalog. Presented on Figure 3.4, the score of this system growth linearly, by use simple unary linear regression, the growth function can be shown as following function: $y = -17 + 0.0087x$, where x is year while y is the score of food utilization (R^2=0.9975). Food utilization system has nearly 30% of average annual growth rate, which is the largest average among four sub-systems, and it shows the rapid development of drinking water and sanitation services in China during last twenty years.

Figure 3.2 Changes in food security subsystems index in China



Source: Author’s elaboration based on data from Table 3.3

Regarding on individual indices, the prevalence of undernourishment (11.09%), government expenditure on agriculture (9.47%), road density (7.95%), per capita arable land (7.06%) and fertilizer use (6.55%) are five indicators that have the largest impact on the system. As an outcome of people's dietary nutrition intake, the prevalence of undernourishment is an intuitive measurement of a country's food production, distribution and utilization system. The calculation result shows government expenditure on agriculture is another important driver of China's food security. For instance, Song (2012) found that Chinese framers are incentivized by public aid on agriculture and especially growing market price. Specifically, he suggested that direct food subsidies just increased framers' expectation of revenue in the first year while subside on market price is more efficient for promoting farmer' production enthusiasm and further result in grain production growth.

According to Ni (2013), the agriculture subsidies in China mainly including direct grain plant subside, subside on purchasing means of production, farm machinery purchase subsidies, and seed subsidies. Besides, public expenditure on agriculture also contains minimum grain purchase price, temporary storage and environmental protection expenses. It is important to notice that under China's official propaganda and statistical caliber, the public expenditure on agriculture subsidies, irrigation and forestry, rural construction (such as agricultural insurance premium subsidy, financial poverty alleviation fund, and farmers training) are collectively called the expenditure on agriculture, rural, and farmers. And it is hard to distinguish which public support policy among the 'expenditure on agriculture, rural, and farmers' are the agricultural domestic support policy as defined by WTO agricultural agreement. Recalled that in the data set used by this paper, only state fiscal expenditures for agriculture that recorded by China rural statistical yearbook (2000-2018) are considered as government expenditure on agriculture. Ni (2013) claims that China's green box support level in 2008 was 591 billion yuan. The yellow box support level of non-specific products was 77.86 billion yuan, accounting for 1.5% of the total agricultural output value of the year, which didn't exceed the WTO's threshold of agricultural subsidies. In order to fulfill WTO commitments, export subsidy measures are no longer adopted in China.

However, the form of market price support as agriculture subside is controversial, for example, in WTO's dispute settlement (DS511), China's financial support on market price of wheat and rice during 2012-2015 are recognized as violation of its obligations under Agreement on

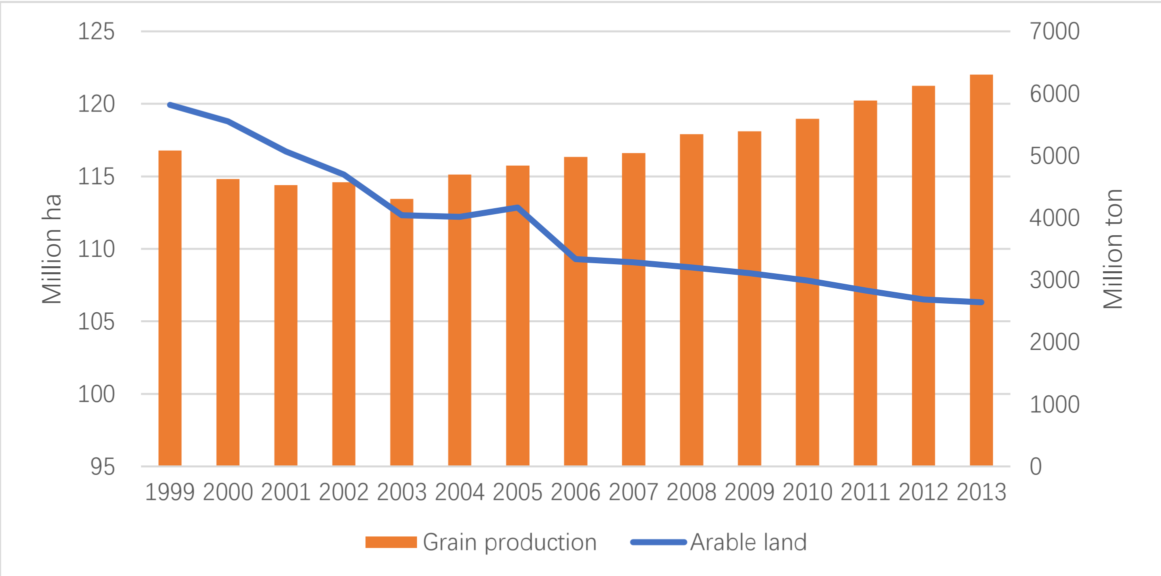
Agriculture (AoA).

One unexpected result of the weight determination is that road density has equivalent importance on food security with per capita arable land, which implies the construction of transportation facilities may have enhancement on food security development.

The score drops in 2003 can be explained as a result of grain production decline, the grain production of China has decreased from 508 million ton in 1999 to 430 million ton in 2003 when the figure of total grain production and grain possession per capita are the minimum value in the past two decades. Ye (2012) claims that the extreme weather and natural hazards are responsible for the notable production loss in the period of 2000-2003. As a consequence, in the fourth quarter of 2003, the Producer Price Index (PPI) of food was equivalent to 111% in the same period of last year, cereal prices rise 11.8%, wheat prices rise 12.1%, and corn rise 14.1%, recorded by national bureau of statistics (2004).

The decline of grain production is also due to a massive loss of quality arable land, result from the rise of rural enterprises and urbanization since the 1980s. During this period, the revenue of primary industry relatively decreased. And which effect is particularly evident in the provinces along the southeast coast of China, where is grain-producing areas in history and where is the pioneer of market economy reform. Meanwhile, the state agriculture support policy was not adjusted accordingly until 2003 when the benefiting farmer policies were officially implemented, in which grain production was directly subsidized by cash (Song, 2012). Figure 3.3 shows the change in total grain production and the total arable land in China. This figure can view that agriculture support is a practical approach to slow down arable land decline and promote agriculture production. For instance, the average rate of arable land reduce is 4.2% from 1999 to 2003, while it is 0.8% for the period of 2004-2008. The total amount of grain production is continuous growth after 2003, which suggests the growth of output is a result of productivity increase, for example, the development of irrigation facility, the use of agricultural machinery and fertilizer, etc., instead of expansion of arable land. According to Yao (2015), China’s agriculture supporting policy has contributed a lot during this process, for example, the policies of exempt agricultural taxes, direct grain production subsidies, and subsidies for agricultural machinery purchase are implied by the Chinese government after the food production decline during 2000- 2003.

Figure 3.3 Total Grain Production and Arable Land Change in China (1999-2013)



Source: Author's elaboration based on FAO STAT (2019) and National Bureau of Statistics (2019)

The obstacles identity process analysis of subsystem analysis supports the above conclusion: food security index falls from 1999-2003 is result from total production decline and a relatively slow increase of public expenditure on agriculture support (Table 3.5). Followed by the prevalence of undernourishment, government expenditure is the second-largest obstacle that affects the food security index in 2000 and 2003. Besides, other significant obstacles that occurred in this time period, like the percentage of the population using at least basic sanitation services, fertilizer used per unit of arable land, and road density, are related to the state's financial support on infrastructure in the rural area. Which in other words, are also government expenditure related factor improvements in agricultural production. Hu (2001) implies that the lack of agriculture support and related infrastructure before 2000 is because of the low development of China's economy, and which restricted the state's measure of subsiding food production. As a result, the food production volume was prone to fluctuations.

Table 3.5 Five major obstacles and their obstacle degree on food security index of China (2000-2013)

	2000	2003	2005	2008	2010	2013
ARABLE LAND PER CAPITA				11.5%	17.8%	38.5%
LABOR FORCE PER UNIT OF ARABLE LAND						21.0%
FERTILIZER USED PER UNIT OF ARABLE LAND	9.0%	6.7%				
GOVERNMENT EXPENDITURE ON AGRICULTURE	12.9%	11.4%	12.7%	13.8%	9.2%	
TOTAL GRAIN PRODUCTION		7.9%	7.6%	6.2%		
GRAIN POSSESSION PER CAPITA			6.2%			
NET GRAIN IMPORT					9.4%	22.6%
AREA OF CROPS AFFECTED BY NATURAL DISASTER						3.4%
ROAD DENSITY	10.9%	9.8%				
DOMESTIC FOOD PRICE INDEX				9.7%	8.2%	11.8%
PER CAPITA FOOD ENERGY SUPPLY			6.7%			
PREVALENCE OF UNDERNOURISHMENT	15.2%	13.9%	16.2%	12.3%	9.7%	
ACCESS TO AT LEAST BASIC SANITATION SERVICES	8.2%					
TOTAL OBSTACLE DEGREE OF 5 MAIN OBSTACLES	56.1%	49.7%	49.4%	53.5%	54.3%	97.2%

Source: Author's elaboration based on data from Table 3.3

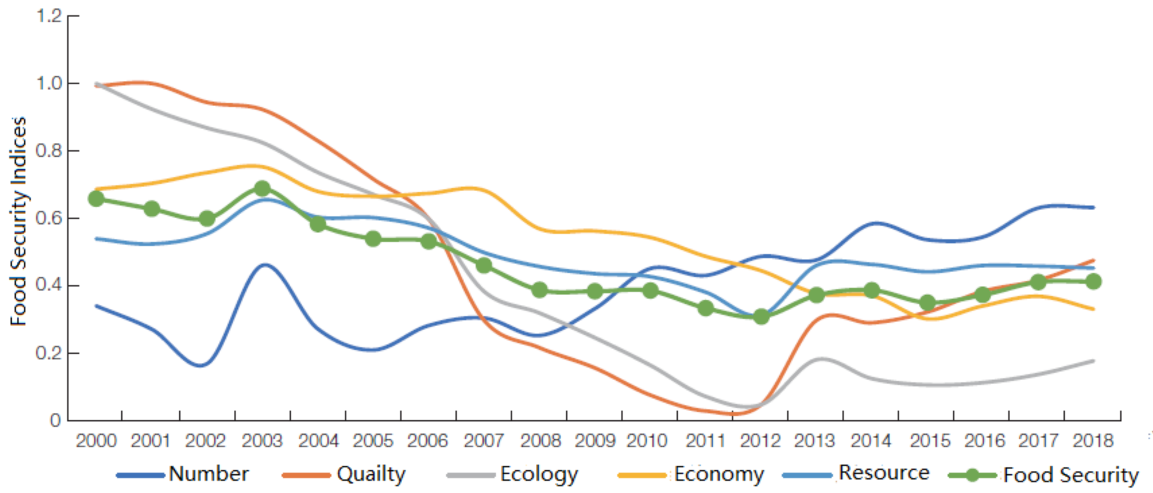
Since 2008, the negative effect of insufficient public support on food security is generally decreased. Similarly, fertilizer use, road density and grain production are no longer major obstacles for China's food security. Because of the expansion of public expenditure on improving infrastructure, sanitation facilities, and agricultural investment, while the limit land resource and rising import dependency have become new obstacles to China's food security. Apart from the emerging soybean import, China's cereal import dependency ratio also increased from -0.6% in 2000 to 3.4%. Yao (2015) claims the reason lies on the rapid urbanization. For instance, from 2000-2010, the total urban area in China has increased around 18,377 square kilometers, and there are approximately 70% of the urban area are comes from arable land. As a comparison, only 53% of land used for city construction were transformed from arable land during 1990- 2000.

In short, the food security system employed by this thesis finds that the food security state of China is generally better off between 2000 and 2013. Before 2003, the score is relatively low because of grain production decline and price increase derived by total demand growth, while due to expansion of public expenditure on agriculture in the following decades, the facilities of agriculture production, transportation, and public sanitary is primarily improved. The prevalence of undernourishment or food deficit is no longer the major obstacle of food security in China. However, the new challenge emerges as there are less land and labor invested in agriculture production and rising import dependency.

There are several limitations regarding the research method applied in this thesis. First, the developed food security system in Figure 3.1 focuses on the score changes over time rather than obtaining a convincing conclusion that weather food security in China is achieved. From a methodology point of view, it is because in the data standardization process, for each index, maximum value among the time series be transformed into 1, and minimum value is set as 0 in the standardized sequences. In this case, it is impossible to have the maximum grade of the whole system as 1 unless every value in the time series is identical. One possible solution is to introduce a widely accepted criterion as a qualified level instead of the maximum value in the time series. For example, in the above food security evaluation system, in terms of daily food energy supply per capita, we adopted the figure of China in 2013 as 3112 kcal/day as the standard of 1, a better criterion could be the average daily energy requirement figure suggested by FAO. According to FAO (2001), the average daily energy requirement for 18 to 30 years old female population is 2410 kcal/day, and the average daily energy requirement for 18 to 30 years old male population is 3100 kcal/day. Since the ratio of male to female in China is 1.2, in this case, 2790 kcal/day can be treated as a benchmark of the per capita energy supply in China (consider the age structure, an ideal criterion should be lower than this value). However, for the majority of indices used in this food security evaluation system, such as food price index and road density, it is hard to find a standard value as guaranteed food security level.

Another shortage is that some factors may have an ambiguous effect on food security. However, in the model assumption, an index is either have positive or negative on the final evaluation score. Depends on different defines, the same indicator could have a very different effect on the whole system. For example, the use of fertilizer has been considered as one of agriculture input and a positive factor for food security; however, Cui (2019) defined that the use of fertilizer and pesticide are burdens for natural resources and threats to food safety. Therefore, his research shows the opposite result that China's food security situation has deteriorated since 2003. This thesis didn't try to repeat the research process of Cui because the publish time of his work is very close to the presenting of this thesis, in this case, it is difficult to find appropriate data for updating the research model. The main research result of Cui (2019) is quoted in Figure 3.4.

Figure 3.4 Food Security Index of China from 2000 to 2018 (Cui, 2019)



Source: Cui (2019), pp 914.

There are some impressive research results of Cui (2019) that can be introduced as a supplement to this thesis. First, in terms of the economic aspect of food security, per hector profit of grain production was adopted as an indicator of farmer's income. This study suggested that the low income of farmers and the cost of high-level storage are obstacles to food security. Another shortage of China's food security indicated by this paper is the mismatch of food supply and demand. For instance, the total supply of maize, rice and wheat was exceeding the estimated consumption demand in 2015 while the protein crops like soybean are import-dependent.

Chapter 4 Concluding Remarks

The research aim of this thesis is to assess China's food security situation and analyses its determinants. Food security has been a central goal of China's agriculture policy, cited from Huang (2004). The definition of food security is the very first question to answer because it is a broad concept with multiple dimensions. The traditional concept of food security adopted in China as a relatively narrow idea that emphasizes food production and grain self-sufficiency. However, a formal approach to discuss the food security state of a country should involve different aspects, as food availability, access, utilization, and vulnerability.

From a worldwide perspective, food insecurity is widely existing and unlikely to be eliminated without successful technological development and popularize in the agriculture industry. Developing countries with lower incomes are generally more vulnerable to food deflect for various reasons. For example, food demand expansion results from population growth, dietary change, and limited food supply because of urbanization and market distortion in international trade. As one of the largest developing countries, China's food security also faces similar challenges despite significant progress in agriculture has made since the market-oriented economy reform.

This paper first follows the traditional food security concept by reviewing food consumption adequacy and import dependency in China. Then conduct a food security evaluation system with broader content by compositing 17 indicators that represent different aspects of food security. Regarding food consumption adequacy, this study shows that after experienced decades of rapid economic growth, the total food consumption volume and nutrition intake condition of Chinese people is gradually improved. Changes in food consumption pattern is a common trend, which embodies as dietary change with less consumed grain and vegetables but more consumption of animal protein. There exist urban-rural and regional differences during the dietary modification process, residents in urban and affluent areas are leading the trend of food consumption pattern change, and this change will also happen to rural residents in the foreseeable future. In terms of food import dependency, China is at the margin of self-sufficiency for most of the traded food commodities; in other words, the self-sufficient ratio is equal or above 95%. Soybean and cassava are two exceptional food that mainly dependent on imports, and imported soybean is mainly used for feed ingredients. Other studies suggested that current agricultural resource allocation in China may not be enough to fulfill the developing food demand in future. Increasing import is inevitable is this case. Maize, soybeans, and meat products are foods that could have significant import increases.

This thesis adopted the entropy method to determine the weight of each index. The weight determination result shows the prevalence of undernourishment should account for the most substantial proportion in food security evaluation systems, followed by public support on agriculture, road density, and per capita arable land. This sequence proves the rationality of FAO to set the first Millennium Development Goal as eradicate extreme poverty and hunger. Besides, this thesis suggests the government expenditure on agriculture support and food access promote programs should be given adequate attention in order to improve food security. The obstacles identity process finds food demand growth derived by urbanization and on the rise of food import dependency are two emerging factors that stress food insecurity in China. In 2010-2013, reduced arable land, limited labor force for agriculture, and declining food self-sufficiency were deficiencies in China's food security. Consider the limited arable land and water resource, it is unlikely that the expansion of arable land area will be implemented in China. Meanwhile, compared with net agricultural exporters, China's unit crop yields are still relatively low. Therefore, increasing yields may be an effective way to reduce import dependence and increase food self-sufficiency. Because the level of chemical fertilizers and pesticides used in China is already higher than the world average, farmers in China should focus on the other approaches, such as the promotion of agricultural machinery and improved seeds in the process of increasing yield.

The final evaluation score shows from 1999 to 2013, the food security state of China first worse off until 2003, and gradually improves after 2004. This research result is consistent with Ye (2012) and Yao (2015), while contrary to the findings of Cui (2019) and Zou (2015). The inconsistent implies the model limitation; for example, the correlation between each index is not considered by the analysis model. In addition, the same index may have various explanations and opposite effects in different models. Cui (2019) suggests food safety is also an essential component of food security. Food safety could have a significant impact on food security levels. Which is not emphasized in this thesis but should be considered in further studies.

The conceptional idea of food security is widely accepted, but there is only a few clear standard value or threshold for food insecurity at the national level. This thesis calls for the establishment of evaluation standards for each food security indicators so that the achievement of food security in countries can be intuitively reflected. Without a specific certificate of food security, the thesis study believes an appropriate evaluation of China's food security status should be based on particular analysis objects. For example, this thesis believes food security in China is generally guaranteed since malnutrition level is low, and most staple foods are self-sufficient. However, animal feed in China is highly import dependent, and this import dependency may expand in the future because of demand growth. Which is a hidden danger of China's food security. In conclusion, in the case of China, infrastructure that promotes food accessibility, policy support on agriculture, and adequate supply of food are positive drivers of food security, while reducing agricultural land and labor, rising food import dependency, and food safety hazards are obstacles of food security.

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