

The Impacts of Food Security Policies in China at 2030

—A Global CGE Analysis

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April 2015

A thesis submitted to McGill University in partial fulfillment of the
requirement for the degree of Masters of Science in Agricultural Economics
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Abstract

In recent years, there has been a growing interest in China's food security issue. China faces multiple challenges to achieve food security in the near future. On the supply side, current urban expansion trend continuously cause the rapid land diminution. In addition, the agricultural productivity of China is lower than the world average. On the food demand side, large population base and rapid income growth drive China's domestic food demand considerably. The unbalanced development of food demand and supply in China raise concern if China is able to feed itself in next decades. Unfortunately, existing studies have yet to arrive at a consensus in this debate. This thesis provides further discourse in this area.

In this study, the GTAP framework and database is used to construct a multiregional CGE model to estimate impacts of different policy interventions in China's food security. The model contained 36 sectors and 16 regions. A recursive process is used to project the model to the 2030 and 2050 under BAU (business as usual). The study attempts ten scenarios to investigate implications of tariff adjustments, agricultural total factor productivity, agricultural subsidies and mandated grain growth rates. The effects of those policy interventions on the food security are then measured by nine indicators, including agricultural outputs, agricultural import and export, grain self-sufficiency rate, food price, private household food consumption, as well as China's economic growth, national welfare change, poverty implication and factor returns to unskilled labor.

Projection of the China's food security status to the year 2030 and 2050 in BAU suggests that China is expected to just above 90% grain self-sufficiency in 2030, but it couldn't achieve 90% grain self-sufficiency in 2050. The current arable land protection—"Red Line" arable land policy (1,800 million mu) is not sufficient to produce enough grain in 2030 to meet 95% self-sufficiency rate; moreover, it is not enough to meet 90% (2,727.495 million mu) and 95% (2,879.022 million mu) self-sufficiency rates in 2050. The results suggest that agricultural TFP improvement is greatly helpful to achieve food security. Regarding to agricultural trade policy, meat import tariff reduction is likely to have more benefits in food security than grain tariff adjustments. The free meat trade agreement with Australia is expected to improve China's food

security. Mandated grain growth rate is also a favorable policy option, when government attempts to improve poor people's food accessibility and ensures high rice and wheat self-sufficiency rate. Compared those policies, fertilizer and machinery subsidies, grain tariff adjustments, and free meat trade with Korea are expected to have detrimental effects on China's food security. In conclusion, the study suggests that (1) China must strictly protect arable land (2) Reducing meat tariff is helpful to achieve higher food security status. Free meat trade agreement with Australia is expected to have long-term benefits to food security. (3) The government should promote investment on agricultural research and technology development to improve agricultural productivity (TFP), which is considered to have profound and lasting benefits to national food security.

Résumé

Au cours des dernières années, il y a eu un intérêt croissant pour la question de la sécurité alimentaire de la Chine. La Chine fait face à de multiples défis pour atteindre la sécurité alimentaire dans un avenir proche. Sur le côté de l'offre, tendance actuelle de l'expansion urbaine continue à provoquer la diminution rapide des terres. En outre, la productivité agricole de la Chine est inférieure à la moyenne mondiale. Du côté de la demande alimentaire, la grande base de la population et la croissance rapide des revenus sont des facteurs importants pour la croissance rapide de la demande alimentaire. Le développement déséquilibré de la demande et de l'offre alimentaire en Chine suscitent des craintes, si la Chine est capable de se nourrir dans les prochaines décennies. Malheureusement, les études existantes n'avaient pas encore parvenir à un consensus dans ce débat. Cette étude prévoit en outre le discours dans ce domaine.

Dans cette étude, le cadre et la base de données du modèle GTAP est utilisé pour construire un modèle CGE multirégional pour estimer les impacts de différentes interventions politiques dans la sécurité alimentaire de la Chine. Le modèle contenait 36 secteurs et 16 régions. Un processus récursif est utilisé pour projeter le modèle pour l'année 2030 et l'année 2050 en vertu de BAU (business as usual). L'étude y compris dix scénarios pour étudier les implications d'ajustements tarifaires, la productivité totale des facteurs agricoles, les subventions agricoles et les taux de croissance de grains mandatés. Les effets de ces interventions politiques sur la sécurité alimentaire sont ensuite mesurés par neuf indicateurs, y compris les produits agricoles, l'importation et aux exportations agricoles, taux d'autosuffisance céréalière, prix des denrées alimentaires, la consommation alimentaire des ménages privés, ainsi que la croissance économique de la Chine, le changement de bien-être national, l'implication de la pauvreté et des facteurs rémunération du travail non qualifié.

Projection de l'état de la sécurité alimentaire de la Chine pour l'année 2030 et 2050 dans BAU suggère que la Chine s'attend à juste au-dessus autosuffisance céréalière de 90% en 2030, mais il ne pourrait pas atteindre l'autosuffisance en céréales de 90% en 2050.

La politique de la protection de terres arables actuelle "Ligne rouge" (1,800 millions de mu) n'est pas suffisante pour produire suffisamment de céréales en 2030 pour répondre à taux d'autosuffisance de 95%; en outre, il n'est pas suffisant pour répondre à

taux d'autosuffisance de 90% (2,727.495 millions de mu) et de 95% (2,879.022 millions de mu) en 2050. Les résultats suggèrent que l'amélioration de la PTF agricole est grandement utile pour atteindre la sécurité alimentaire. En ce qui concerne la politique commerciale agricole, la réduction tarifaire d'importation de la viande est susceptible d'avoir plus d'avantages en matière de la sécurité alimentaire que les ajustements tarifaires de grain. L'accord de libre commerce de la viande avec l'Australie s'attend à améliorer la sécurité alimentaire de la Chine. Taux de croissance mandaté des grains est également une option favorable, lorsque le gouvernement tente d'améliorer l'accessibilité alimentaire des populations pauvres et assurer un taux d'autosuffisance haut du riz et du blé. En comparant avec ces politiques, les subventions aux engrais et de machines, les ajustements tarifaires des grains, et le commerce de la viande avec la Corée sont censés avoir des effets néfastes sur la sécurité alimentaire de la Chine. En conclusion, l'étude suggère que (1) la Chine doit strictement protéger les terres arables (2) La réduction tarifaire de la viande est utile pour atteindre un statut plus élevé de la sécurité alimentaire. Accord de commerce libre de la viande avec l'Australie devrait avoir des avantages à long terme pour la sécurité alimentaire. (3) Le gouvernement devrait promouvoir l'investissement dans la recherche agricole et le développement de la technologie pour améliorer la productivité agricole (PTF), qui est considérée comme un des avantages profonds et durables pour la sécurité alimentaire nationale.

Acknowledgements

In completing this research work, I would like to recognize the contribution of people who have made all this possible. I take this opportunity to express my gratitude to Professor John Henning (Ex-Chair, Department of Agricultural Economics) for his help and support during the course work.

I wish to express my sincere thanks to my thesis supervisor, Professor Paul J. Thomassin. I would like to express my extreme gratefulness to my Co-Supervisor, Dr. Kakali Mukhopadhyay for her guidance and advice throughout my thesis work. Her patience in working with me is greatly appreciated. I have been extremely lucky to have a co-advisor who cared so much about my work, and who responded to my questions and queries so promptly.

I would also like to extend my special thanks to Prof. Laurie Baker for his careful editing contributed enormously to the production of this thesis.

I would also like to express my deepest gratitude to my family, especially my parents, for the unconditional support they have provided me in pursuing my graduate studies. Furthermore, I would like to extend my special thanks to Yining Jia, Xi Chen, Weina Zhao, Miao Nie, Mengjie Lu, Qiming Zhang, Haihao Jiang, Jing Zhang, those close friends who have been an invaluable moral support. They provided me with a listening ear and encouragement through all this time.

Not the least, I would like to thank the rest of the professors and my friends in the Department of Agricultural Economic at McGill University.

Chapter 1 Introduction

1. Background and overview

Food security is said to exist when all people at all times have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary and food preferences for an active and healthy life (FAO 2009). At present, the world faces multiple challenges to strengthen food security ranging from rapid transition of diet consumption patterns and continuously increasing population to constantly decreasing cultivated land and insufficient production practices (Beddington et al. 2012). The world population was 6.4 billion in 2004 and increased further to 7.04 billion in 2012, and it is expected to reach 9.4 billion in 2050 (World Bank 2014c). In addition, the global average food consumption has increased from 2,250 calories per capita per day in 1961 to 2,750 calories per capita per day in 2007. This figure is projected to rise to 3,070 calories per person per day by 2050 (Alexandratos and Bruinsma 2012). On the food supply side, the technological advances, such as the green revolution in wheat and rice production, have greatly contributed to adding per capita food production level during the 20th century. However, agricultural activities largely depend on the natural resource endowments, such as water, weather and land. The per capita availability of the world's farmland are decreasing at a rate of 0.8% per year during the twentieth century (Ramankutty et al. 2008). This tendency is expected to continue into the foreseeable future (Ye et al. 2014). Lack of water, climate change and soil degradation are major restrictions on agricultural production expansion. In addition, concern about global food security has emerged in tandem with more volatile price and this is expected to continue into the future (Beddington et al. 2012). According to the World Bank's food price index, the increasing food price in 2011 was close to its peak in 2008. For example, the price of corn, wheat and soybeans has increased by 75%, 69% and 36% in 2011, respectively. Rice price did not change significantly (World Bank 2011). Therefore, food insecurity is still a serious global issue. Approximately, 870 million out of the 7.1 billion people still experience transitory hunger. Moreover, over 98% of the hungry people live in developing countries (FAO; WFP and IFAD 2012).

Strengthening food security is a focus for many countries and it is a significant development strategy for the People's Republic of China. Food security in China can promote economic development, maintain social stability, and achieve national self-sufficiency (Zhou 2011). China is a large agricultural country, as well as one of the largest and most rapidly developing countries. The role of China in the world food market is expected to expand with an increasing in the demand for food and feed. For the last two decades, China's food security has attracted great attention due to its growing population, improving purchasing power and soaring demand on animal feed and bio-fuel. On the other hand, agricultural production is a critical component of China's economy and people's life. In addition, agricultural development lags behind industrial development.

The following facts support this contention

- China's agricultural production provides 1.3 billion people with food;
- 737 million rural people's income are from agricultural production
- 42.6% of the labor force is in agricultural sector
- Agricultural production only accounts for 10% of GDP
- 35.4 billion dollars of exports are from the agricultural sector
- 66% of the light industry outputs are based on agricultural products

(China 2008; National Bureau of Statistics of China (NBSC) 2010; World Bank 2014b)

From 2006 to 2008, soaring grain prices on international markets decreased the stability of developing countries. Under this situation, China was able to provide enough grain because of the grain came from domestic production. In addition, recently, rural incomes have risen greatly, resulting in millions of people being lifted out of poverty permanently, with the increase in agricultural productivity (Ye and Van Ranst 2009). The experience and lessons of China in avoiding world food price fluctuations serve as an example for other emerging economies, as well as for China's future agricultural policies. It has experience with grain security, as well as having to face future challenges. The grain sufficiency rate of China is in danger of becoming lower than the target rate; 95% self-sufficiency rate, which is considered a key national food security indicator from the Chinese government's perspective. China's population has increased over 30% since 1980 and is predicted to reach 1.3406 billion by 2050 (World Bank 2014c) . At present, China's total GDP ranks second in the world and its annual

GDP growth rate is approximately 8.6% (World Bank 2014b). The rising people's income has tripled food demand in the past 30 years (Liao 2010). More arable land is changing to other uses in the past years, as a result of rapid urbanization and industrialization. Limited arable land has attracted more attention by government.

To feed approximately 22% of the world's population on less than 9% of the world's cropland is a difficult problem. As a result, food security is a fundamental issue for policy makers (Zhou 2011). To feed its population with per capita cropland far below the world's average is difficult problem, which requires immediate attention. The next section will discuss the problems of arable land resources, agricultural trade and agricultural productivity.

I. Limited arable land resources

Land is a critical endowment factor for agricultural production. Per capita land resources in China are only equivalent to 0.38% of the world average (World Bank 2014a). Urbanization and industrialization have shifted limited arable land from the agricultural sector to non-agricultural sectors. The potential growth of food production depends entirely on crop yield per unit of land, but this yield has already obtained at a relative high level (Liao 2010). From 2000 to 2007, on average 0.17 million hectares of cultivated land was removed to non-agricultural sectors every year on average. Even though government has applied strict regulations to protect farmlands, arable land loss is still anticipated (Liao 2010). If the current urban expansion trend continues, resulting in rapid decreasing in arable land, it will make the task of producing sufficient food in the next half century more difficult. Several major factors cause cultivated land to shrink, such as converting agricultural land to residential on industrial areas, forest and grassland replanting programs. It is crucial to limit the loss of arable land to ensure food security. China has rigidly restricted the conversion of arable land to other non-agricultural purpose, but the continuous urbanization and construction of highways has decreased the country's limited arable land. The Ministry of Land and Resources (MLR) reports (2004), total arable land decreased by 2.01% and total arable was approximately 123.4 million hectares in 2003 (The Ministry of Land and Resources of China 2004). At present, only 12.8% of the total national land area is available for agricultural production (Chen 2007a). In addition, China's increased agricultural

harvest in the past years to some extent can be attributed to the over-use of fertilizer and pesticide (Huang et al. 2012). This is not a sustainable approach for a country that aims to maintain a stable grain supplies in the long term. To strengthen food security, the Chinese government has unveiled a series of new regulations and standards to safeguard sufficient arable land. China's government has set a "red line" to guarantee the amount of arable land never goes below 120 million hectares (1,800 million mu). However, whether this red line is enough for the population in 2030 and 2050 is still a concern.

Another means of obtaining food is through international market. Some scholars believe that producers in foreign country will be able to meet China's future increasing food demand. Directly importing food products from other countries is helpful to release pressure on domestic arable land demand and food demand.

II. Agricultural trade

Many scholars project that China is likely to encounter large grain deficit in the coming decades (Brown 1994; Chen 2004). These projections indicate that China has to expand grain imports to overcome grain shortages. In fact, according to China's trade data, China's grain imports have increased over ten folds from 2002 to 2013. On the other hand, grain exports have decreased by 16% over the same period (UN Comtrade 2014). Since 2010, China has changed its position in the world grain market from net exporter to net importer. The total grain trade deficit was \$420 million in 2010. In addition, this trade deficit has increased significantly to \$4 billion in 2013. Since joining the WTO, China has undertaken a series of tariff reductions. The majority of tariffs on agricultural products have been gradually reduced. Major grain products; i.e. rice and wheat, are in the tariff reduction exception list, which triggers heated discussion, on trade liberalization and food security. Many countries apply border interventions, including China, particularly on sensitive goods. The government is committed to protecting domestic food and agricultural industries and rural income by imposing tariff on grain products. China's agricultural production is based on a small-peasant economy, which is not strong enough to compete with large farm production in developed countries. Another concern is more political imperative. The amount of grain in the overall food basket of the population is relative large. Grain as a staple food is an important calorie

provider. Grain is the main staple food for the Chinese diet. The government does not want to depend on international market to satisfy domestic grain demand. Therefore, China's government has identified a 95% self-sufficiency goal as an objective of government policy for recent years. Holding the rice bowl firmly in one's own hands is one of a fundamental policy of the China's government (The CCCPC and The State Council 2014).

III. Agricultural productivity

In 2008, the agricultural productivity of China was 47% of the world average and only 2% of that of high-income countries (Wang 2012). A huge disparity in agricultural productivity is observed. Some modern agricultural industries produce agricultural commodities efficiently and export their commodities overseas. On the other hand, some peasants still use traditional method in agricultural production. Recently, the government of China has introduced policies to encourage farmers to buy agricultural machinery. In addition, some provinces have developed insurance systems to help farmers during the time of natural disasters and help them maintain productivity. Nevertheless, in 2012, Shandong, Yunnan and Guizhou encounter frequent droughts, causing considerable outputs loss. Aging irrigation system has become a serious constraint for agricultural production (Wang 2012). Poor irrigation systems have become major production limitation in dry areas. Furthermore, hybrid rice has been the greatest achievement in China's modern agricultural research. It has played an important role in food security. Unfortunately, in recent years, there has been substantial agricultural scientific research breakthrough to improve agricultural productivity. Another important driver for enhancing agricultural total factor productivity is agricultural mechanization. Agricultural machinery application effectively reduces production cost and improves output per unit of land (Liu 2013). Moreover, agricultural machinery is helpful to conserve natural resources, such as land and soil (Liu 2013). Therefore, the use of agricultural machinery is needed to improve overall agricultural productivity. However, the degree of agricultural mechanization is very low in China, even though China's government has subsidized agricultural machinery in recent years. Even though extensive agricultural machinery application is believed to improve productivity, this issue still needs further study further in the case of China. China's agricultural production is characterized by small-peasant scale farms.

Each rural household only has a small piece of land. Large-scale agricultural machinery is difficult to promote in rural areas. Low rural income and the high price of machinery is another reason for the low application rate of large-scale agricultural machinery. The application of agricultural machinery largely depends on government subsidy. To continue to subsidize machinery purchase will be a large financial burden for government. The final possible reason for why machinery has not been adopted is the large amount of surplus labor in rural regions; as a result, low labor cost leads to weak demand for machinery (Liu 2013).

Given present conditions in China's agriculture China is on the front line of the global food security crises. Effective research on food security is required to ensure the national stability and to improve the well being in China. Several key questions need to be addressed. How much the cultivated land is required for feeding the Chinese population in 2030 and 2050? What are the implications of meat and grain tariff reductions on China's food security in the future? What are the impacts of agricultural productivity improvements on food security? Answers to the above questions are significant for the Chinese government to formulate appropriate reforms that can strengthen national food security in future decades.

2. Problem statement

Even though China has made great strides in term of national food security in the past, how to satisfy food demand in the future is still a critical issue for the Chinese government, especially in face of the decreasing amount of cultivated land, a growing population, rural poverty and accelerating urbanization. Therefore, it is important to identify the future food security situation in China and identify sustainable approaches to safeguard national food security. Arable land protection is a fundamental requirement. To satisfy food demand by increasing food import is another approach. However, given China's situation where approximately 46% of the labor force is in the agricultural sector but agricultural GDP only contributes 10% to national GDP in 2013 (World Bank 2014b). In addition, rural households are the most vulnerable group in China. They primarily depend on agricultural income. Decreasing tariff barriers on grain products not only conflicts with policies concerning grain self-sufficiency, but also put

at risk of rural household welfare. Improving agricultural productivity by increasing agricultural technology investment and research should be a sustainable method to safeguard national food security in the long term. To investigate these issues, this study is going to measure the food security situation in 2030¹. In addition, the study evaluates China's "red line" land policy and finds out how to achieve better food security conditions by adjusting various policy alternatives, including tariff reductions, free trade agreements, subsidy programs, mandated grain growth rates and increasing agricultural productivity.

3. Research objective

The objectives of this study are to investigate China's food security situation in 2030 and investigate the impacts of alternative policies on food security. The analysis is based on a global computable general equilibrium model—GTAP, which covers a large number of regions and detailed agricultural information. The food security situation is assessed using selected indicators, including changes in outputs of agricultural commodities, exports and imports, grain self-sufficiency rates, private household food consumption, domestic food prices, welfare implication, factor return to rural labor, GDP effects and poverty implication. The following issues are addressed in the study.

- Project food consumption, production and trade of China in 2030 under business as usual (BAU).
- Find the minimal arable land required to meet 90% and 95% grain self-sufficiency rate in 2030 and 2050. So as to access the "Red Line" policy whether it is sufficient to meet grain self-sufficiency rate targets.
- Assess the implications of tariff adjustments of meat and grain on food security in 2030.
- Estimate the implications of machinery subsidy and fertilizer subsidy on food security in 2030.
- Measure the implications of the current mandated of the grain growth rate in the 12th Five-Year plan on food security in 2030.
- Evaluate the implications of agricultural productivity promotion on food security in 2030.

¹ Since grain self-sufficiency rate and arable land are critical to China's food security assessment, the study is

4. Thesis structure

The second chapter outlines the evolution of China's agricultural policies. A brief description of China's trade pattern and agricultural trade development are provided in chapter three. The fourth chapter reviews methodologies that have been used in food security assessment. The fifth chapter outlines the methodology employed in the study, including the GTAP model framework, model specification, data and aggregation strategy and experimental design. The results of the study are presented in the sixth chapter. The last chapter consists of conclusion, policy recommendation and future consideration.

Chapter 2 Policy Review

This chapter provides a review of the current agricultural and food security policies in China. The following five areas will be reviewed: the evolution of the national guidelines in agricultural policies, in particular arable land regulations and protection policies, agricultural machinery management systems, international trade policies and domestic agricultural support programs.

1. General agricultural policies

China's agricultural market evaluation has three taken important steps. First, in the late 1970s, government purchased agricultural commodities from farmers at below-market prices. Second, in the 1980s, the government allowed farmers to sell agricultural commodities on the open market at market prices and developed cultivated land contracting systems. Finally, China has opened its border to the world since joining the WTO and has shifted to more export-oriented production.

Five-year plans have played an important role in the development of China in many areas. These policies provide the major policy orientation for China. This section provides an overview of related policies in agricultural and food security in the previous five-year plans (1953-2010), followed by an outline of agricultural guidelines in the 12th Five-Year Plan (2011-2015). Prior to the founding of PRC China, China experienced a long period of war², so when new China was found in 1949, it was a very weak and poor country. The annual output of yarn was 445 thousand tons, cloth was 2.79 billion meter, coal was 61.88million ton, electric energy production was 6 billion kilowatt. The grain and cotton output were just 0.15 billion tons and 8.49 billion tons, respectively (XinHuaNet 1996). This is the starting point of China. The Chinese government pursued domestic economy industrialization from the 1st five-year plan to the 11th five-year plan (1953-2010). Since the Chinese government focused on rapid economic accumulation and development, investment and, policy supports in the agricultural sectors were much lower than in industrial sectors. During the Third Five-Year Plan (1966-1970) to

² China was at war with Japan from 1931 to 1945 and in the KMT-CPC civil war from 1945 to 1950.

the Fifth Five-Year Plan (1979-1980), state-led industrialization caused rural-urban income disparity, rural-urban unbalanced development and agriculture and industrial uncoordinated development. In the Sixth Five-Year Plan (1981-1985), the state council began to emphasis on rural development and undertook bold reforms to rural institutions, namely the household responsibility system³ (HRS). During this period, the average annual growth rate for industrial and agricultural output was about 11% (Deng et al. 2013). This was a great achievement in rural institution reforms. It is worth noting that, the previous five-year plan failed to consider some issues as food security, strengthening price support systems for agricultural commodities, development of the crop insurance system, protection of farmers from subsidized imports of agricultural commodities and land reforms(Dutt 2008). The government did not launch many agricultural support programs and did not regulate arable land. Innovation and technology development in agriculture was slow. In the face of decreasing amount of arable land, increasing food demand and dissatisfied agricultural production productivity, the government shifted their focus to national food security.

The latest five-year plan began to substantially shift government emphasis to the agricultural sectors. The 12th Five Year Plan (2011-2015) Guideline of National Economy and Society Development of P.R. China was launched on March 16th 2011.

The agricultural sector reform in this new five-year plan aims to promote agricultural modernization while deepening industrialization and urbanization, strengthen the long-term mechanism of “industry supporting agriculture” and “the urban areas supporting the rural areas”, improving government’s support in agriculture, providing more benefits for rural residents, enhancing rural people’s living standards (The National People's Congress 2010) .

China’s government firstly highlighted national food security as the first goal in the 12th

³ Household responsibility system (HRS) was an agriculture production system, which allowed households to contract land, machinery and other facilities from collective organizations. On one hand, it could preserve basic unified management of the collective economy. On the other hand, households could make operating decisions independently within the limits set by the contract agreement, and freely dispose of surplus production over and above national and collective quotas (Lin 1988).

Five Year Plan. Improvement of food production capacity requires a stable arable land for grain production and optimal varieties to production capacity to more than 540 million tons of grain (The National People's Congress 2010). The government wants to speed up rural institutional reform, as well as agriculture and rural development. In term of policy, the government emphasized rural land laws, regulations and policies, especially on the land use rights certification.

The government plans to accelerate innovation and extension in agricultural by developing the breeding and seed industry, reinforce the integration of science and technology on cultivation, disease control and water conservation in this five-year plan. The government wants to increase mechanization of agriculture by providing agricultural mechanization on 60% of the arable land (The National People's Congress 2010). In addition, the government plans to develop agricultural information technology in order to enhance the level of information management in agricultural production.

Another goal of the 12th Five-Year Plan in the agricultural sector is raising farmers' income. The government encourages farmers to improve their skills and expand their income sources, such as with household business operations, wage income, and government transfers. To guarantee farmers' income, it is necessary to establish a reliable price protection mechanism; moreover, the floor purchase price for key grain varieties should be gradually increased. The government also encourages farmers to adjust their planting schedule and improve their production management. In the development of agricultural industrialization and new rural cooperative organizations, the government guarantees a reasonable share of revenue for farmers. Grain production is always highlighted in China's food security, so farmers who grow grains can be continuously and directly subsidized. In addition, high-quality seed and agricultural machinery purchasing subsidies are continuously provided by government (The National People's Congress 2010). The government has attempted to develop agricultural insurance policy and expand the coverage of crops in the insurance program. Since poverty and hunger are closely related, continuous poverty alleviation is also required.

In summary, previous Chinese development plans focused on industry and economy development. The development pattern of “agriculture supporting industry” has gradually changed. The hallmark event was the abolition of agricultural taxes in the 10th Five-Year Plan (2000-2005). This policy effectively reduces farmers’ financial burden and narrows the income gap between urban residents and rural residents. In the 12th Five-Year Plan, the government us committed to address the problems of food security, rural development and arable land protection.

The major objective of the five year plan in food security and to maintain 95% self-sufficiency rate for grain (Beddington et al. 2012). The amount of arable land area is not allowed to decrease below 120 million hectares. However, a lot of scholars remain skeptical of the rural land “Red Line” policy and the 95% self-sufficiency rate. Since the 1990s, land administration laws have been strengthened progressively, but arable lands are still decreasing. Some scholars project that China will break its 120 million hectare redline by 2015 and total arable land is estimated to decline to 105.4 million ha (Zhao et al. 2006). According to the land law, when arable lands is decreased, compensation is required by reclaiming new arable lands, but the majority of the reclaimed land is in the northeast part of China, where the growing season is short and arable land is not rich. In addition, limitation of water resources and lack of advanced technology on cropping makes the 95% self-sufficiency target dubious.

2. Arable Land policies

Chinese agricultural land policy developed from its communist roots to the current modern property right system has evolved from earlier communist system to one that takes into account the current reality.

In 1949, China was under the leadership of Mao Zedong and the Chinese Communist Party (CCP). The Chinese government collected all of the agricultural land from influential landlords and redistributed it equality to the poor peasants. From 1951 to 1956, the government consolidated farmers’ land holdings into large agricultural cooperatives (Dean and Damm-Luhr 2010). Farmers worked together as collective cooperative organizations, and shared equally of the harvest to meet their dietary need.

The rest of the harvest was collected by government and compulsory sold at a low price. The equal distribution system did not provide farmers with enough incentive to work hard and did not encourage farmers to invest in production. This resulted in a considerable reduction on grain output. The Household Responsibility System (HRS) comes into force in 1987. Village cooperative organizations allocated “land-use” rights to individual farmers using short-term contracts (Dean and Damm-Luhr 2010). The new land institution boosted farmers’ productivity and ultimately raised grain output during the period 1979 to 1984 (Bruce 2009). Nonetheless, from 1983 to 1998, the short term “land use” right and the frequency of administrative land readjustment caused insecurity in rural land use rights (Dean and Damm-Luhr 2010). Farmers with well-defined land rights have an incentive to invest in land, such as irrigation, drainage, and terracing (Brandt et al. 2002). To address this issue, the “land-use” contracts were renewed for 30 years in 1998. The Central government also limited the ability of local officials to readjust farmers’ land-use rights. The agricultural land tenure system did not changed until 2002, when the *Law of the People’s Republic of China on Rural Land Contracting* was promulgated. The new land law offers more flexibility to individual farmers to independently transfer and lease their land-use rights⁴.

Current rural land use rights are administrated by three important laws, including the 1986 Land Administration Law, the 2002 Rural Land Contracting Law, and the 2007 Property Law. The Land Administration Law and the Rural Contraction Law are the milestones of the rural land administration, while Property Law does not make a large contribution to rural land management.

I. Land Administration Law (LAL)

According to Dean and Damm-Luhr (2010), the Land Administration Law (LAL) aims to strengthen the administration of land, safeguard the socialist public ownership of land, and protect cultivated land. The Land Administration Law sets the rules for granting use rights to rural people though HRS contacts. It controls the transfer of rural land for construction purpose. The law was introduced to control cultivated land reduction

⁴ Unlike the land ownership in western countries, the land in the cities is owned by the state and land in the rural and suburban areas are owned by collectives (2007 Property Law of PRC). Citizens only enable to transfer their land-use right rather than the property of land.

caused by urbanization and industrialization. Central government restricts land competition between construction and agricultural production. This policy is also consistent with the national food security policy. Rural land protection is the first and fundamental step to ensure domestic agricultural production. Unfortunately, the substantial benefits from urban and industry development leads local government and not to follow the full extent of the law. Reduction in arable land is still a serious problem. The problem of rural land loss is most obvious in the Yangtze River delta and Chu Chiang Delta, where the fast economic development areas in China (McBeath and McBeath 2010) . To ensure sufficient amount of grain-sown area, the government reclaims new arable land in Sinkiang, Inner Mongolia, and Heilongjiang (The Ministry of Land and Resources of China 2004). However, the land in the Yangtze River delta and Chu Chiang Delta are endowed with fertile agricultural land and water resources, while the new reclaimed areas are not.

II. Rural Land Contracting Law (RLCL) in 2002

Rural Land Contracting Law (RLCL) expands the scope of farmers' land-use rights and secures those rights. This law mandates the specific rights and obligations of the contractors. Moreover, contractors are able to transfer land rights to other people, which were not allowed in the LAL. RLCL defines the scope of the transferability of land. Farmers have rights to lease, assign, exchange, and engage in other means of transaction of their contracted land, while they cannot sell and mortgage (Dean and Damm-Luhr 2010). Agricultural land transfer is a core policy of reform in China's rural development. Regarding land transfer rights, it was firstly introduced in the NO.1 document in 1984. It announced that farmers who could not farm or decide to do other business could transfer their land use right to other farmers after the permission of the villager's committee. This document indicates that China begin to gradually permitted arable land to be transferred. In addition, a more detailed and comprehensive policy document, "Regulations on Transfer of Rural Land Management", was published by the Chinese Agricultural Ministry in 2005. In 2008, the 17th CPC central committee strengthened the supervision of the land contract management right transfer contract. The fundamental principles of agricultural land transfer include: agricultural lands are still owned by the collective, agricultural land cannot be used for other purposes, and rights of contracting farmers cannot be harmed (Yuneng and Bo 2011).

Land use is not allowed to change into private ownership, but land maybe required to be converted to industrial use by the local land administration. With the commission of local government, the use of agricultural land is allowed to change. Motivated by huge economic benefits, the increasing amount of cultivated land, especially in east coast and the Pearl River delta being converted to non-agricultural purposes. Government should watch because it will impact future arable land regulations.

In face of the rapid conversion of agricultural land to other non-agricultural uses and the pressure of safeguarding national food security, CCP issued two NO. 1 Documents concerning rural reforms in October 2008 and February 2009. There are three major changes to current rural land-use law. First, NO.1 document extends land-use rights from 30 years to indefinite. Second, government supports the establishment of a rural land-use rights market. Third, government reinforces their commitment to maintain enough arable land for agricultural purposes. The LAL and the RLCL emphasize the importance of arable land protection on improving farmers' income and national grain security, while they do not prohibit the conversion of agricultural land for non-agricultural purposes. These two NO. 1 document employs stronger rights concerning arable land protection and grain security.

3. Agricultural mechanization management systems

The application agricultural machinery is one of most important factors for productivity improvement, especially for China, where agricultural production is dominated by small-scale peasant economy. Currently, there are three major agricultural machinery operating patterns from a property right perspective, including private ownership, cooperative ownership, and agricultural machinery operation association ownership (He 2010). Large agricultural machinery operators are a relative new operation system. Large farm owners and agricultural machinery services organizations constitute agricultural machinery operation associations. They aim to increase farm scale, control productions costs and promote agricultural mechanization. Agricultural machinery operation associations play a significant role in facilitating coordination and cooperation of agricultural machinery, as well as providing timely market information

to farmers. It is a community economic organization, instead of an economic entity (Liang 2010). In 2012, 31,000 agricultural machinery cooperation groups had been established (Ministry of Agriculture and Agricultural Mechanization Management Division 2014)

At present, subsidy is the most common policy to encourage the adoption of agricultural machinery. The central government has begun to subsidize farmers when they purchase large agricultural machinery since 2014. The government increases its support for purchasing agricultural machinery, from 400 million Yuan in 2004 to 10 billion Yuan in 2009 (Du et al. 2013). According to the Ministry of Finance of the People's Republic of China, the subsidy for agricultural machinery was over 21.5 billion Yuan in 2012. 6,010,000 agricultural machinery are subsidized and 4,600,000 farmers received benefit (Du et al. 2013). The subsidy program improves agricultural mechanization level and accelerates the development of agricultural machinery cooperation.

However, the subsidy program is not sufficient to assist 900 million Chinese farmers. Meanwhile, the expansion of agricultural machinery applications has generated some environmental problems. For instance, the emission from agricultural machines, such as carbon dioxide and carbon monoxide, may cause climate change and pollution. In addition, the agricultural subsidy program can generate government budget pressure, which may affect total welfare.

4. Agricultural support programs

China's government has implemented various domestic support programs. The major instrument is market price support. The National Development and Reform Commission sets minimum prices for rice and wheat and adjusts it each year, aiming to ensure grain sales and the protection of rural income. The minimum prices have increased in recent years, but are still below the world market price (FAO 2012). If the market price is below the support price, farmers may then sell their grains at the minimum price to state enterprises, such as SINOGRain (China Grain Reserves Corporation), COFCO (China National Cereals, oils, and Foodstuffs Corporation), and CGLC (China Grain and Logistics Corporation) (FAO 2012). This policy stabilizes rural income when prices are

low and protects farmers' welfare. Meanwhile, this policy effectively stabilizes the grain price for consumers, allowing more accessible to poor residents.

Another major support program for producers is budgetary transfer. There are direct payments at a fixed rate per unit of land or input subsidy. For instance, direct payment to grain producers, which was introduced in 2004, is given based on sown areas of corn, rice and wheat. The standard payment is about 10RMB per mu (=1/15 Hectares) (FAO 2012). This subsidy boosts grain production and enhances grain producers' income. For three years from 2007 to 2010, the total payment of grain direct payment was 15.1 RMB billion per year(FAO 2012). The comprehensive subsidy, which was launched in 2006, reduces production input costs, including costs of fertilizers, pesticides, plastic films, and diesel. The subsidy payment is paid on the basis of arable land rather than the input consumption amount. The government expenditure on this program has increased from 12 billion RMB in 2006 to 71.6 billion RMB in 2010 (FAO 2012). To improve the quality of seed and livestock, new variety extension payment was introduced to cover the main crops and livestock. Wheat, corn, rice, soybean, rapeseed, cotton, potatoes, peanuts, barley, pugs, dairy cows, beef cattle, and sheep are all included in the program (FAO 2012). The level of subsidy is different by crop, ranging from 10 RMB per mu for early rice to 15 RMB per mu for cotton (FAO 2012).

Exports of fertilizers and agricultural machinery are under the control of the government. For example, the export tax on fertilizer is 75% in 2011(FAO 2012). This high export tariff discourages fertilizer exports and maintains sufficient fertilizer supply for domestic use. Government also encourages fertilizer imports with tariff reduction. Fertilizer producers are supported by price control programs, such as preferential prices for electricity, natural gas, and transport and exemptions from VAT (value added tax) (FAO 2012). The total agricultural machinery subsidy investment has increased from 2 billion RMB in 2007 to 15.5 billion RMB in 2010 (FAO 2012).

The agricultural insurance system was established in 2007. The major target of this program is to protect farmers from the risk of drought and flooding. The central and local governments pay the major part of the premium, ranging from 70% to 80% of the balance. But this support has not been widely implemented in all provinces (FAO 2012).

Since agricultural insurance developed very late in China, the system is still unsound and immature and will require improvement to be viable. Currently, the low agricultural insurance coverage and the unprofitable agricultural insurance business operation are major issues of China's agricultural insurance. According to Chen (2007b), a few kinds of insurance are not enough to protect farmers from risks. As well as, most insurance companies are not interested in developing agricultural insurance, because of low insurance income, high-risk and loss ratios of insurance, and low degree of government financial support. Moreover, there is no specific insurance law for agricultural insurance. The majority of farmers are lack of enthusiasm and incentive to buy agricultural insurance. To overcome those limitations and difficulties, the government should optimize agricultural insurance management system. An organization has taken initiatives on behalf of the government to manage insurance businesses directly to the commercial insurance company along with the government. The main idea is to share the burden between government and private insurance companies. Government also needs legislative perfection in agricultural insurance field. The policy support and economic support related to different types of subsidies for agricultural insurance could offer China to enter an improved system. Eventually, it is necessary to educate farmers learn how to manage production risk and importance of insurance.

China has launched the "Grain-for-Green" project in 2000 in western China. These areas are characterized with immature economy vulnerable ecological environment. For years, farmers reclaimed new cultivated land by cutting forest and occupying grassland. As a result, serious soil erosion and natural disasters have occurred in these areas. The government gives subsidies for western farmers in the form of grain and money if they turn their cultivated land back into forest and grassland (Liu and Zhang 2006). The payment is made on the basis of 20 RMB per mu or 1.4 RMB per kg of crop per year (FAO 2012). The program has been in existence for last over 10 years. With more and more forest and grassland coming back, the government's budget for this program is decreasing. The cost of this program was 42.8 billion RMB in 2009, while it was only 24.3 billion RMB in 2011 (FAO 2012).

In accordance with China's WTO domestic support reduction commitments, the support

programs belonging to Amber Box⁵ must be adjusted in order to control distortions in trade. China has not significantly changed support to the grain sectors, such as price supports, subsidies for high quality seed. Its major adjustment has been in the non-specific support programs. The green box⁶ supports programs are exempted from reduction commitments. The majority of support programs in China belong to the green box, such as an ecological programs and services programs. An example of ecological programs is the “Green-For-Grain” program. The general service programs include agricultural infrastructure services, the investment of new technologies, pest and disease control, which are helpful to improve productivity. Current programs tend to focus on direct payments to farmers in order to enhance rural income, which is considered to be less distortive on trade.

5. Evolution of agricultural trade policy in China

Since China became a WTO member on December 11, 2001, China has undertaken number of national agricultural and trade policy reforms to meet its commitments under WTO rules. The range of reforms include reducing import tariffs, partially removing license requirements on imports and exports, abolishing and converting quotas to tariff rate quotas, removing some price controls, and moving toward market orientation(FAO 2012).

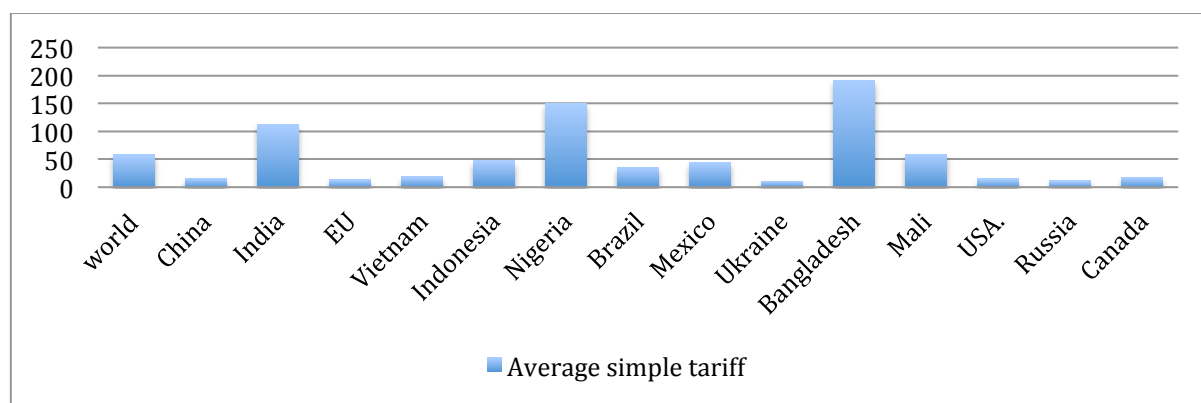
On the import restriction side, the average tariff level over all products has decreased from 15.3% to 9.8% from 2001 to 2013 (WTO 2014). Simple average tariff on agricultural products has decreased from 18.8% to 15.2% (WTO 2014). Simple average tariff on non-agricultural products has decreased from 14.7 to 8.9% (WTO 2014). Compared with other countries, the simple average tariff rate in China is lower than in most developing countries, and is lower than it in some developed countries, such as Norway (130.9%) and Switzerland (48%) and Japan (2.2%) (WTO 2013). Figure 1 indicates that China’s average tariff is 1/4 of world average tariff for agricultural

⁵ Amber box and Green box: “In WTO terminology, subsidies in general are identified by “boxes” which are given the colors of traffic lights: green (permitted), amber (slow down — i.e. be reduced), red (forbidden).” “All domestic support measures considered to distort production and trade (with some exceptions) fall into the amber box”(WTO 2014)

⁶ “Green box subsidies must not distort trade, or at most cause minimal distortion.” (WTO 2014)

commodities (WTO 2013). In 2009, the ratio of tariff over total import value was 1.8%, which is lower than many developing countries, such as India, Argentina and Egypt, as well as some developed countries, such as Australia and New Zealand. This ratio is close to Japan and the U.S. (Ministry of Finance of the People's Republic of China 2011).

Figure 1 Average simple tariff of agricultural products in major agricultural countries in 2013 (%)



Source: WTO (2013)

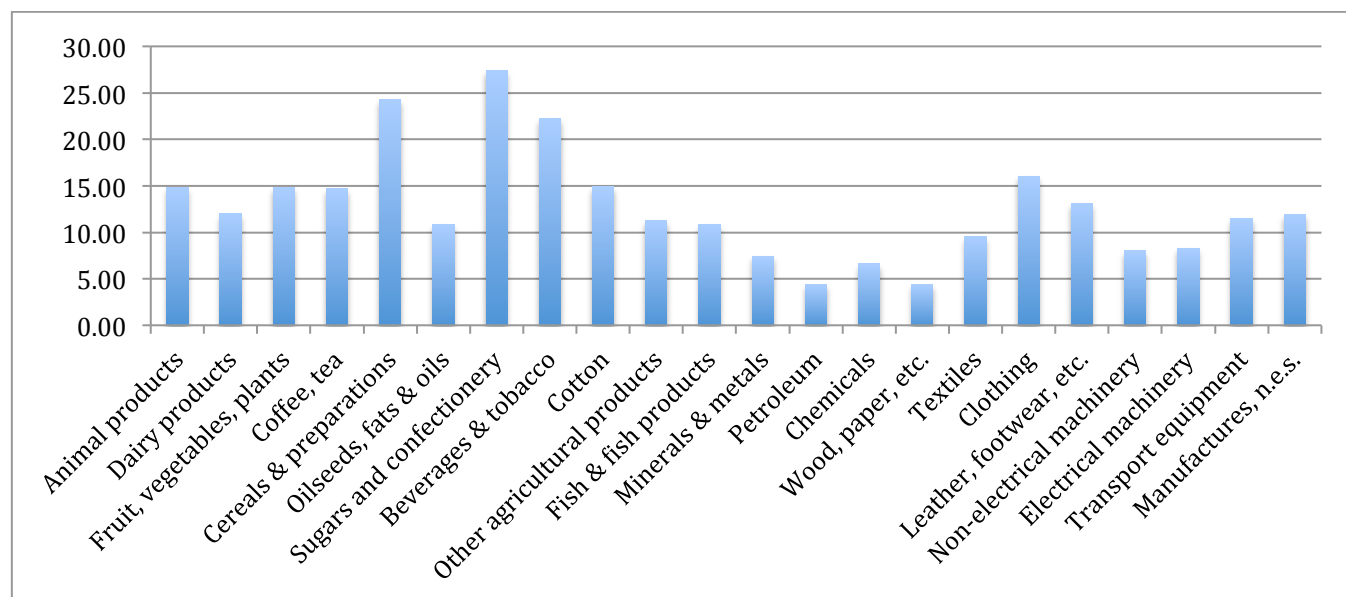
The applied average tariff on agricultural commodities in China is presented in Figure 2. The import tariff rate differs considerably among different food categories. To protect grain producers and maintain food security, China applies relative high tariffs on cereals. According to a WTO report, the highest tariffs are applied to grain products (24.3%) and sugar (27.4%) (WTO 2013). The applied average tariff for products, such as fruits and vegetables, which China has comparative advantage in production, are below the average (FAO 2012). Tariff quotas⁷ are still used on the imports of wheat, maize, rice, sugar, and cotton and wool through seven tariff quotas on 39 tariff lines⁸. Compared with 55 tariff lines in 2005, China's agricultural import tariffs have been reduced (FAO 2012). Furthermore, tariff quotas are no longer used on soybean oil, palm oil and rapeseed oil since 2006. In term of trade method, majority share of trade is operated through state trading enterprises. This method ensures domestic supply and price on

⁷ Tariff quota: the main purpose of tariff quota is to protect a domestically produced commodity or product from competitive imports. Tariff quota system has two-tiered tariff; inside tariff quota rate and outside tariff quota rate. The inside quota tariff will be applied when import below quota; the imports above the quota's quantitative threshold face a much higher outside tariff quota rate (WTO 2014).

⁸ Tariff Line: a product as defines in lists of tariff rates. Products can be sub-divided, the level of detailed reflected in the number of digits in the Harmonized system code use to identify the products (WTO, 2014).

key commodities. Corn, rice, wheat, sugar, tobacco, cotton and chemical fertilizers are mainly imported by state trading enterprises, because a large proportion of tariff quota is allocated to state trading enterprises, while the remaining tariff quota are distributed to private enterprises. 90% of wheat quota, 60% of maize quota and 50% of the rice quota, 70% of sugar quota and 33% of the cotton quota are allocated to state trading enterprises (FAO 2012).

Figure 2 Applied average tariff (%) on agricultural commodities in China (2013)



Source: WTO (2013)

On the export regulation side, in accordance WTO accession commitments, China does not provide export subsidies for agricultural products any more. During the global food price peak period, the Chinese government adjusted its export policy. To reduce food price inflation and maintain a stable domestic supply, China applied an export tax during 2008. The side effect of an export tax is that farmers' incomes are reduced. In order to compensate farmers, other policies are implemented at the same time, such as production supports, direct payments, and input subsidies. Direct income payments are less trade distorting. The state trading system is a dominant player in agricultural exports. Only state trading enterprises are allowed to export cotton, rice, corn, and tobacco. China also imposes export quotas on these commodities, in addition to wheat (FAO 2012).

Recently, China has engaged in unilateral, bilateral and regional trade agreements. The

China-ASEAN Free Trade Agreement (CAFTA) was established in 2010 and has the widest country coverage. It was established in 2010. In accordance to this agreement, tariff on 90% of the products are to be reduced to zero on trade between China and Brunei, Indonesia, Malaysia, the Philippines, Singapore, and Thailand. This agreement will cover more countries in 2015, such as Cambodia, Laos, Myanmar, and Vietnam (OECD 2011). Moreover, China is a member of the Asia-Pacific Trade Agreement (APTA). The average applied tariff rate to the APTA members is lower than it is for most favorite nation (MFN) by 0.6% on 1662 tariff lines in 2009 (OECD 2011). Another important free trade partnership is TPP. The U.S. administration envisions the TPP as a sort of trendsetter for the next generation of trade agreements. Accordingly, the Obama administration has placed a heavy emphasis on the TPP being a “high-standard agreement” with an ambitious (and U.S.-friendly) definition of free trade and open markets. As it currently stands, China would not meet those standards. Those “high standards” have been a point of contention. China would be interested in joining the TPP. China is “very open” to the global economy and plans to continue its decades-long process of “reform and opening up”.

As with the TPP, the key question for the U.S.-China Bilateral Investment Treaty remains how high the standards will be. China is facing a real challenge domestically to shorten the negative list of products. However, China needs to promote domestic restructuring. The whole process to over will take some time for China and the U.S (Shannon 2014). China also has signed a number of bilateral free trade agreements (FTA) with other individual countries, such as New Zealand (2008), Singapore (2008), Peru (2009), and Costa Rica (2010), Iceland (2014) and Switzerland (2014). A number of FTAs are still in negotiation, such as the China-Saudi Arabia, China-Australia, China-Norway, China-Korea (China FTA Network 2014). A free trade agreement with Australia attracts a lot of attention, since Australia is expected to be an important Asia food supplier. In summary, the majority of agricultural products would be tariffs free in several phases with free trade agreement partners, but grain products are exempt from tariff elimination in all free trade agreements. This policy is consistent with China’s grain security policy and grain self-sufficiency targets.

China’s policy reforms have moved from “Agriculture support industry” to “Agriculture and industry integrated development”. The central government has emphasized and

strengthened the national food security and arable land protection (NO. 1 Document, 12th Five-Year Plan, land administration law, rural land contracting law). Domestic support programs and subsidies are continuously growing and expanding, especially for grain production. In term of agricultural international trade policy, China has offered considerable zero-tariff and tariff reductions for a bundle of agricultural products, resulting in China being more integrated in the world market. However, the tariff and import restrictions for grains, which are the main focus of the national food security, are on an exemption list for all the free trade agreements. The import tariffs on rice, wheat, and corn still apply MFN treatment. Australia is expected to be very important food suppliers to China, but the free trade agreement with Australia is still in negotiation.

The question still arises. Is the current arable land “red line” enough to meet China’s grain security target? Is it good to the meet food security goal by continuously increasing agricultural subsidy? Is it necessary for China to maintain relative high grain tariffs to secure a high grain self-sufficiency rate? Is it possible to expand grain imports by tariff reduction to feed the domestic population? Will the free trade agreement with Australia bring benefits to China’s food security? Such policies should be evaluated comprehensively in context of food security, as well as integrating implications on farmers’ income, national welfare and poverty alleviation.

Chapter 3 Agricultural Trade in China

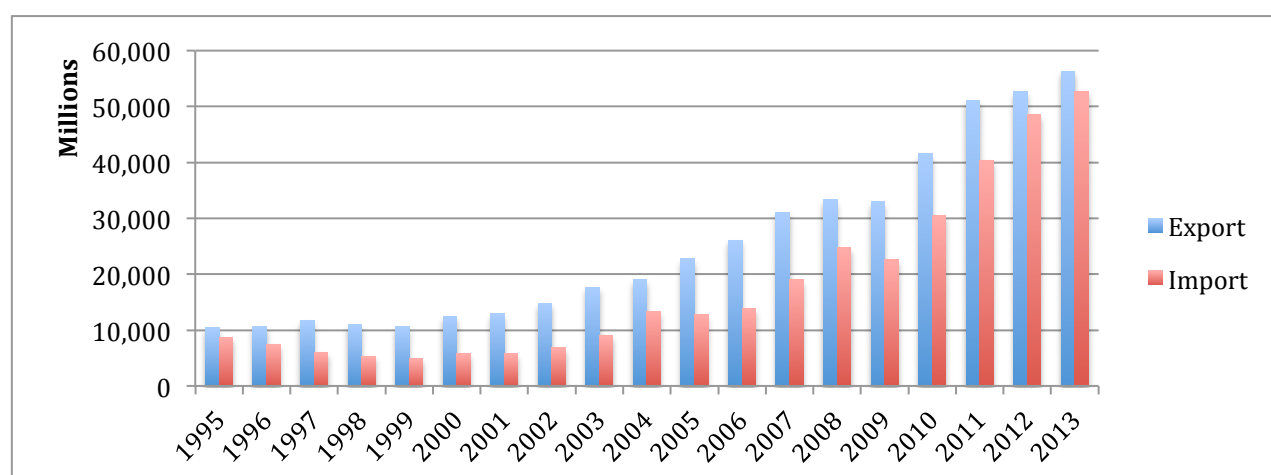
China's international trade in agricultural commodities has been growing rapidly since joining the World Trade Organization (WTO) in 2001. China's total trade value; imports and exports, increased from \$620.8 billion in 2002 to \$4,159 billion in 2013 (Comtrade 2013). The data indicates that China's total trade value declined in 2009. This was the after effect of the 2008 global financial crisis. According to the WTO (2009), the global financial crisis caused the first decline in total world output since the 1930s. According to the WTO (2009), the exports of developed countries decreased by 10% in 2008. Developing countries were less affected than developed countries because they are less dependent on trade and less open to the world market. The Chinese economy is also affected because its important trade partners are in recession. This is the first decline in China's trade value since entry the WTO. China's economy is in the process of liberalizing trade after its entry into the WTO. During the same period, China's agricultural trade has also increased significantly in term of absolute trade value (Figure 3). From 2001 to 2013, the total agricultural trade value; imports and exports, has increased from \$20 billion to \$116 billion (Comtrade 2013). Even though China is a traditional agricultural country and its share of agricultural output is large, agricultural imports and exports occupy a decreasing share of exports and imports of total commodities⁹. This has occurred because of the economic development and industrialization of China. China produces more than 1/3 of the world rice. It is also one of the leading exporters of wheat (Comtrade 2013). On the other hand, China is also the world's large consumer of meat and grain. Therefore, analysis of international agricultural trade of China is critical for this study.

One obvious feature of China's agricultural trade is that agricultural imports increase more rapidly than agricultural exports. From 2002 to 2013, the average annual growth rate of agricultural imports was 22%, while that for agricultural exports was only 13% (Comtrade 2013). As a result, China's agricultural trade deficit continues to increase in recent years. The agricultural trade deficit is expected to grow in the future.¹⁰

⁹The trade commodities and agricultural trade commodities used Standard International Trade Classification (SITC) Rev. 3 product groupings, because the study's methodology is GTAP. The database of GTAP consists with SITC Rev. 3. Agricultural commodities include food and live animals (0), Beverage and tobacco (1) and Animal and vegetable oils, fats and waxes (4). The agricultural trade data are from United Nations Statistics Division's Commodity Trade Statistics Database, COMTRADE.

¹⁰ An economic measure of a negative balance of agricultural trade in which a country's imports exceeds its exports. It means more and more food demand relied on agricultural imports.

Figure 3 China agricultural trade value (million \$) 1995-2013



Source: UN Comtrade 2013

1. China's trade pattern

Table 1 and 2 indicate that China's international trade is dominated by manufactured goods, machineries and transport equipment in both exports and imports. The trade value of agricultural products is small. Before joining the WTO, the data for the period 1998 to 2001 shows that China's agricultural trade developed very slowly (Table 1 and 2). After 2001, China's agricultural imports and exports began to rise and reached \$116 billion in 2013. In terms of agricultural trade patterns, Figure 4 indicates that China's agricultural exports are dominated by fishery and vegetable and fruit products. The export value of grain products, oil seeds and oils & fats are small. Figure 5 indicates that China's major imports of agricultural commodities are oils and fats, followed by fishery products and grain products. Especially after 2011, grain import increased at a higher rate and its import value exceeds that of fishery products. The exports and imports of animal products were relatively low in 1998 but they began to increase after 2001 (Figure 4 and 5). This agricultural trade pattern is the result of by China's agricultural production comparative advantage. China comparative advantage is in the export of labor-intensive agricultural products, such as vegetable and fruits. The leading export products are processed and fresh vegetable and fruits. For example, in 2010, horticultural products accounted for 50% of China agricultural exports to the U.S. (United States International Trade Commission 2011). Canned fruits and fruit juice are major export products from China. China first of all has rich land resources but given

the size of its population the land resources are very limited. Therefore, China imports land-intensive agricultural products, such as vegetables oil and oilseeds to meet domestic demand. China does not export a lot of meat and live animals, but it still exports those products to Japan and Hong Kong.

Table 1 China import pattern (billion \$) 2003-2011

Import	2003	2004	2005	2006	2007	2008	2009	2010	2011
Total value	4127.6	5612.29	6599.53	7914.61	9561.16	11325.67	10059.23	13962.47	17434.58
Primary goods	727.83	1173	1477.1	1871.41	2429.78	3627.76	2892.02	4325.56	6043.76
food and live animals	59.59	91.56	93.88	99.97	114.97	140.5	148.24	215.66	287.65
beverage and tobacco	4.91	5.48	7.82	10.41	14.02	19.2	19.54	24.29	36.85
crude materials, inedible, except fuels	341.19	553.78	702.12	831.64	1179.09	1672.08	1408.22	2111.18	2852.55
mineral fuels, lubricants and related materials	292.14	480.03	639.57	890.02	1048.26	1691.09	1239.63	1887.04	2755.6
animal and vegetable oils, fats and waxes	30.01	42.14	33.7	39.38	73.44	104.88	76.39	87.4	111.11
manufactured goods	3400.53	4441.23	5124.09	6044.72	7128.41	7703.11	7163.53	9622.72	11390.82
Chemicals and related products	489.8	657.44	777.42	870.79	1074.99	1191.95	1121.24	1496.36	1811.44
manufactured goods classified chiefly by materials	639.05	740.72	811.59	869.6	1028.67	1071.59	1077.32	1311.13	1503.28
Machinery and transport equipment	1928.69	2526.24	2906.28	3571.08	4125.08	4419.18	4079.99	5495.61	6303.88
miscellaneous manufactured articles	330.17	501.55	608.72	712.95	875.04	976.19	851.92	1135.26	1277.09
commodities and transactions not classified	12.82	15.29	20.08	20.3	24.65	44.2	33.06	184.37	495.13

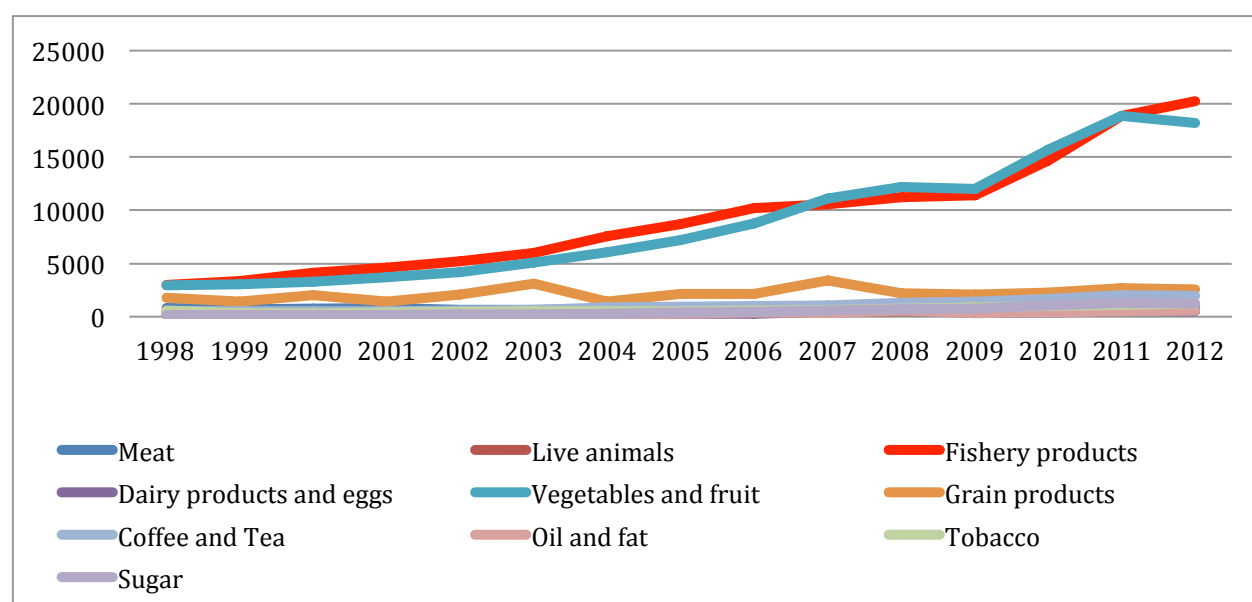
Source: China National Statistics Bureau 2013

Table 2 China export pattern (billion \$) 2003-2011

Export	2003	2004	2005	2006	2007	2008	2009	2010	2011
Total value	4382.28	5933.26	7619.53	9689.78	12204.56	14306.93	12016.12	15777.54	18986
Primary goods	348.1	405.5	490.39	529.25	615.47	778.48	630.99	817.17	1005.5
food and live animals	175.33	188.7	224.81	257.22	307.51	327.64	326.03	411.53	504.9
beverage and tobacco	10.19	12.14	11.83	11.93	13.96	15.3	16.41	19.06	22.76
crude materials, inedible, except fuels	50.33	58.43	74.85	78.62	91.54	113.46	81.56	116.02	149.78
mineral fuels, lubricants and related materials	111.1	144.76	176.21	177.76	199.44	316.35	203.83	267	322.76
animal and vegetable oils, fats and waxes	1.15	1.48	2.68	3.73	3.03	5.74	3.16	3.56	5.26
manufactured goods	4035.6	5528.18	7129.6	9161.47	11564.68	13506.98	11385.64	14962.16	17980.4
Chemicals and related products	195.86	263.68	357.72	445.31	603.56	793.09	620.48	875.87	1147.8
manufactured goods classified chiefly by materials	690.3	1006.54	1291.26	1748.36	2198.94	2617.43	1847.75	2491.51	3196
Machinery and transport equipment	1878.88	2682.91	3522.62	4563.64	5771.89	6733.25	5904.27	7803.3	9019.1
miscellaneous manufactured articles	1261.01	1563.93	1941.91	2380.29	2968.53	3346.06	2996.7	3776.8	4594.1
commodities and transactions not classified	9.56	11.12	16.09	23.88	21.76	17.15	16.45	14.68	23.39

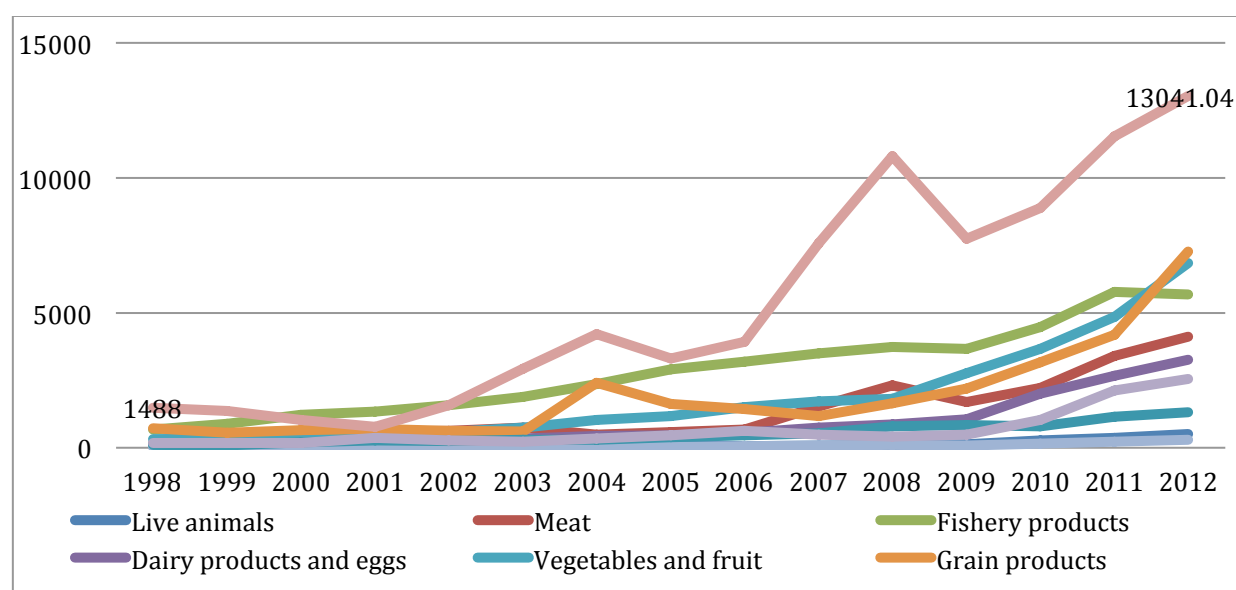
Source: China National Statistics Bureau 2013

Figure 4 China major agri-commodities export value (million \$) 1998-2012



Source: China National Statistics Bureau 2013

Figure 5 China major agri-commodities import value (million \$) 1998-2012



Source: China National Statistics Bureau 2013

2. China's major agricultural trade partners

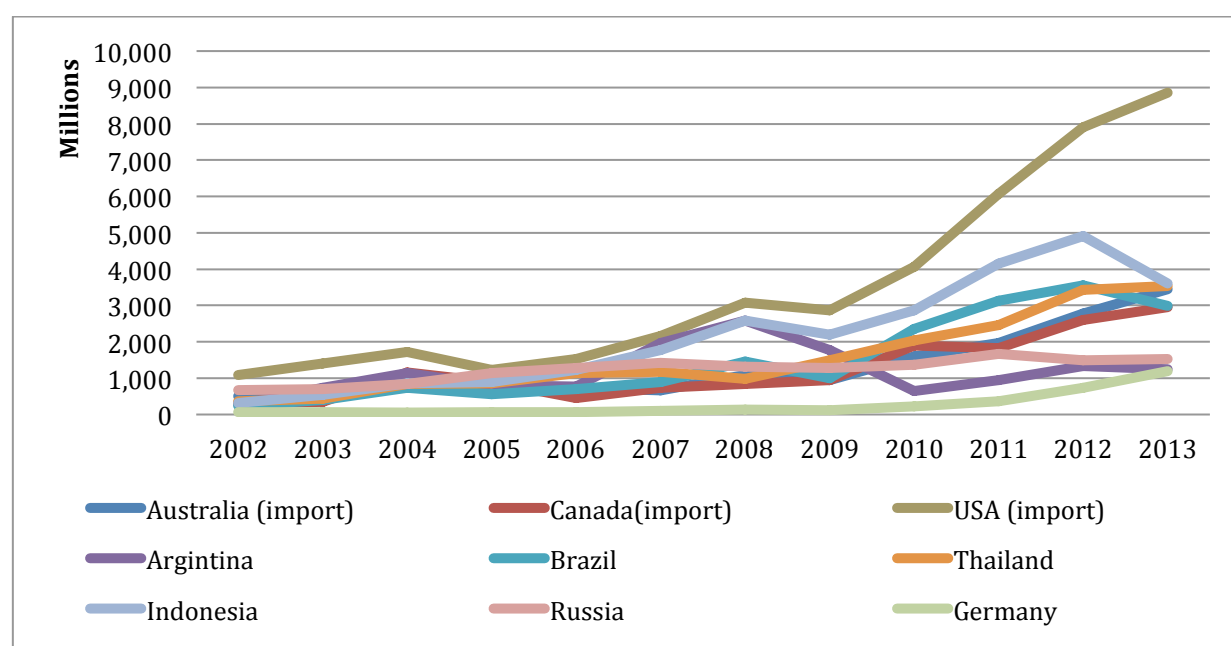
On the export side, the top four China agricultural export markets are Japan, EU, Hong Kong and the United States. China export partners are not diverse. Japan is the largest export market for China, but its share has decreased from 33% in 2002 to 17% in 2013

(Comtrade 2013). The close distance between the countries makes them natural trade partners. Many Japanese firms have invested in China's agricultural production. Most of products from these investments are exported to Japan. Processed meat is the largest agricultural commodity exported from China to Japan (United States International Trade Commission 2011). EU is the second largest export market, accounting for 14% of export. Its share keeps growing overtime; except in 2009. Processed fruits and vegetables are the main export goods from China to the EU. Hong Kong's share is relative stable at around 10% from 2002 to 2013 (Comtrade 2013). Meat and live animals products are the major imported commodities to Hong Kong. The share of export to the U.S. is about 10% (United States International Trade Commission 2011). The US imports mainly fishery products and processed fruits and vegetables from China.

On the import side, China's agricultural import comes from a few major trade partners. The largest agricultural commodity supplier is the USA. After the USA, the other major suppliers are: Indonesia, Brazil, Canada and Thailand (Figure 6). The growth of imports from Australia was not significant prior to 2010, but this rate begun to increase since 2010. The major import commodities to China are oil and oilseed. The USA is an important supplier of these commodities. Canada is the dominant rapeseed, oilseed and oil providers. Indonesia and Malaysia are the main palm oil provider of China (Rosillo-Calle et al. 2009). With the rapid growth in domestic demand, imports of animal products and grain products have rapidly increased. It is worth noting that the food consumption demand from the new Asian middle class is expected to benefit Australia's agricultural sectors (Keogh and Tomlinson 2013). Australia has a geography advantage to export agricultural products to Asia due to lower ocean transportation costs. In term of grain, the transportation fee from Australia to North East Asia is \$21/ton, while this is \$45/ton and \$47/ton from the U.S. and Canada to North East Asia, respectively (Keogh and Tomlinson 2013). In spite of this advantage, Australia grain exports are lower than the US exports. The possible reasons of this include unfavorable exchange rates and poor government trade negotiations with China. Compared with its competitors, such as the U.S., Australia's currency is strong which decreases its competitiveness. In addition, compared with its other competitors such as US, Brazil and New Zealand, Australia has been less success in negotiating on agricultural trade agreement with China. The free trade agreement between China and Australia began in

2005, but it is still under negotiation, while the free trade agreement between China and New Zealand has come into force 2008. On average, New Zealand products' import tariff is 1/3 of it levied on equivalent on Australia's products (Keogh and Tomlinson 2013).

Figure 6 Direction of China agricultural import 2002-2013



Source: UN Comtrade 2013

Given China's trading patterns, 13 regions and countries were identified as being major trading partners. These 13 countries (regions) accounted for more than 70% of China's exports and over 60% of China's imports from 2002 to 2013 (Comtrade 2013). They are Australia, New Zealand, Japan, Korea, Germany, Russia, UK, Canada, China Hong Kong, USA, Indonesia, Thailand and Viet Nam.

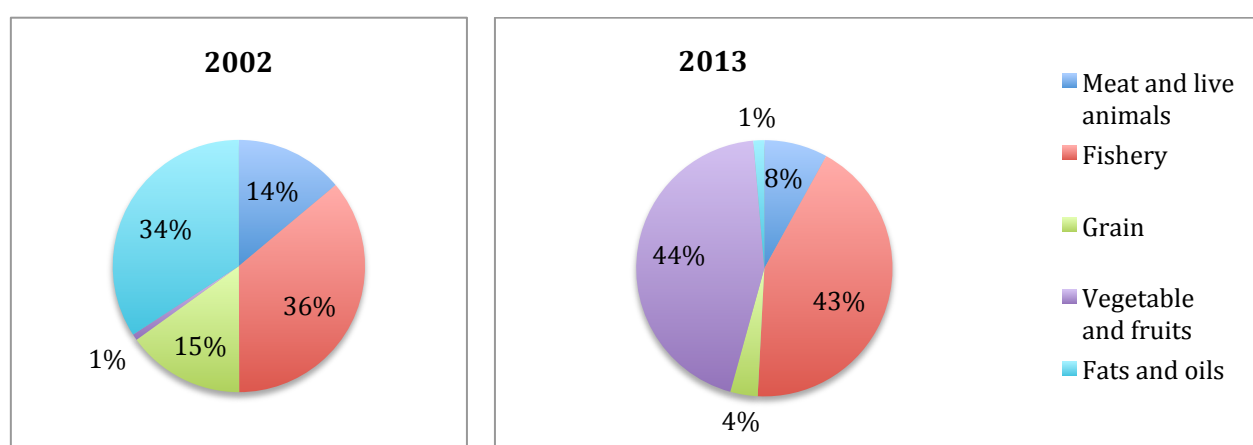
3. Sectoral trade analysis of China

Figures 7 and 8 provide a general picture of the share of the major agricultural commodities in 2002 and 2013. Figure 7 indicates that the export structure of China's agricultural goods changes significantly from 2002 to 2013. In 2002, fishery and fats and oils accounted for a large export share, while the vegetable and fruits accounted for a small share. This occurred because the dollar value of vegetable and fruits are quite small. In 2013, vegetable and fruits account for the largest share, followed by fishery

products. Export share of meat, grain and fats and oils decreased significantly due to considerable domestic demand. Compared to the export structure, the import structure is quite stable between 2002 and 2013. Changes in the sectoral share between 2002 and 2013 did not change significantly.

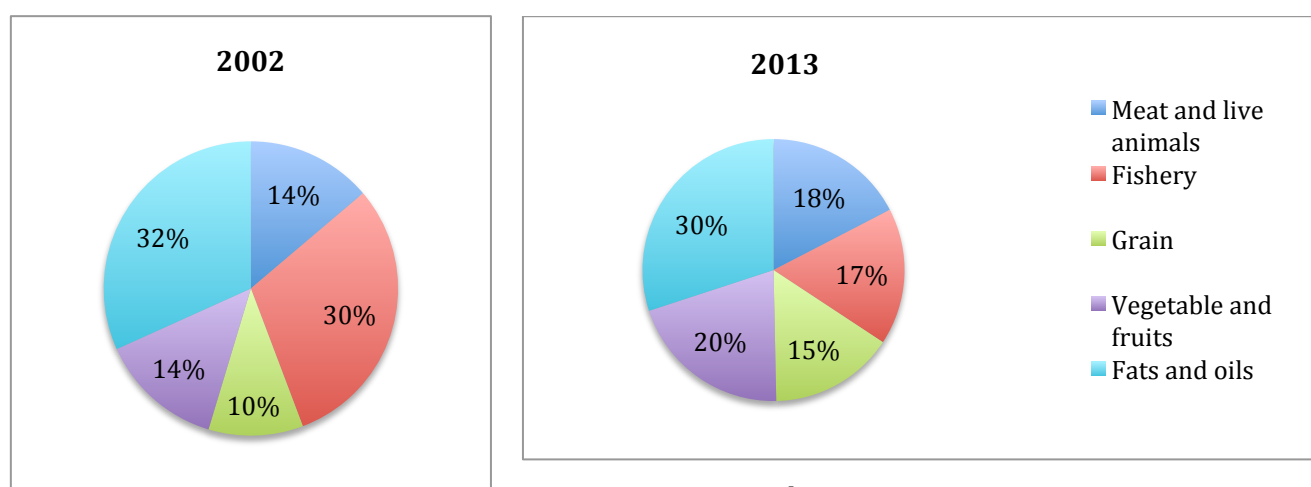
The next sections focus on commodities, which are important to China's food security and agricultural trade. These commodities include grain, vegetables and fruits, oils and fat, livestock and fishery products.

Figure 7 The share of each agricultural commodity out of total agricultural export



Source: UN Comtrade 2013

Figure 8 The share of each agricultural commodity out of total agricultural import 2002-2013



Source: UN Comtrade 2013

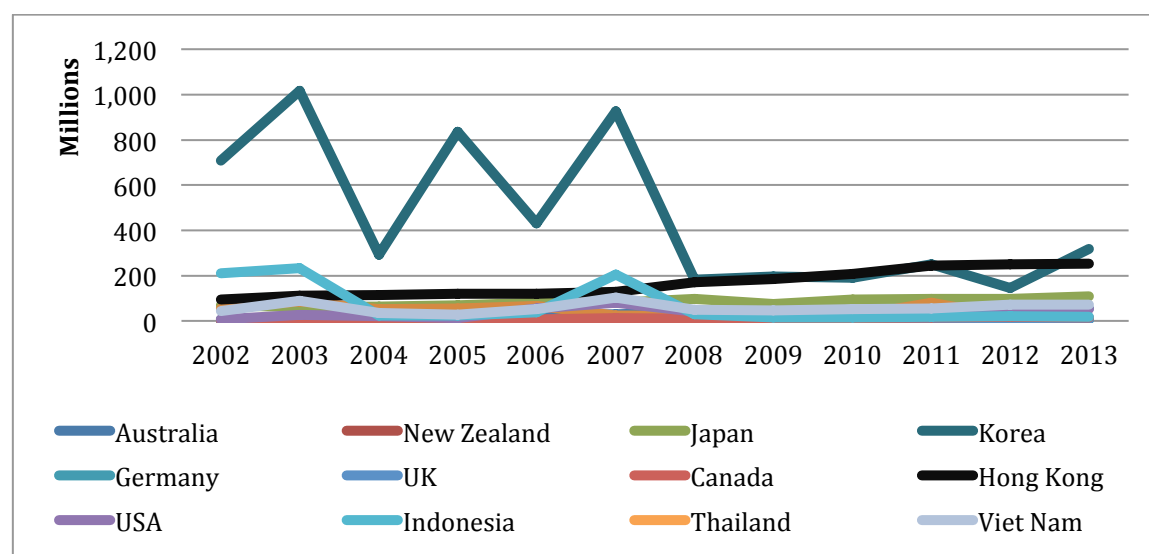
I. Grain

China imports an increasing amount of grain from the international markets; meanwhile, it also exports grain to Japan, South Korea and Hong Kong. Figure 13 shows that in the period between 2007 and 2008, China's grain exports dropped significantly. This is the result of a series of export restriction policies applied in this period to address the world grain price increases. In this period, many grain exporting countries attempted to maintain domestic grain prices, such as Russia, China, and Argentina (Dollive 2008). China had begun to implement export restraints since December 2007. It cancelled the 13% grain export rebate on value-added taxes (Dollive 2008). The Chinese government also controlled grain exports by using a licensing and registration system. It stopped giving new exports quotas for wheat and corn. In 2008, China implemented an export taxes on grains and grain powders. Figure 9 indicates that Chinese grain exports began to decline significantly in 2007 and 2008. A series of policies effectively kept sufficient domestic grain supply and maintained domestic grain price, therefore they are consistent with the national food security target. However, these export restriction policies has a large impact on China's trade partners, such as South Korea and Japan. China is a dominant grain provider for these two countries. South Korea is the largest grain export market in China. From 2002 to 2013, South Korea accounted for 30% of China's total grain exports on average (Comtrade 2013). According to Dollive (2008), in 2006 and 2007, South Korea accounted for 64.5% and 69.2% of China's total corn exports, respectively. In 2008, China stopped exporting corn to South Korea, as well as Malaysia, Iran, and Vietnam, so South Korea had to find other grain supplier, such as India, U.S. and Indonesia.

Between 2004 and 2013, China's grain imports fluctuated (Figure 10). During the period 2004 to 2010, grain imports decreased from \$ 2,278.6 million in 2004 to \$615 million in 2007 before rebounding to \$1,748 million in 2010 (Figure 10). The fluctuation was the consequence of government policies. China's food security policy focused on grain self-sufficiency. Wheat, rice and corn are important components of grain self-sufficiency. In fact because of low grain price in 2005, the government launched support programs to maintain domestic production and encourage domestic producers to grow grain. Those policies were consistent with the government grain security target. Sufficient domestic production released the grain import demand in the

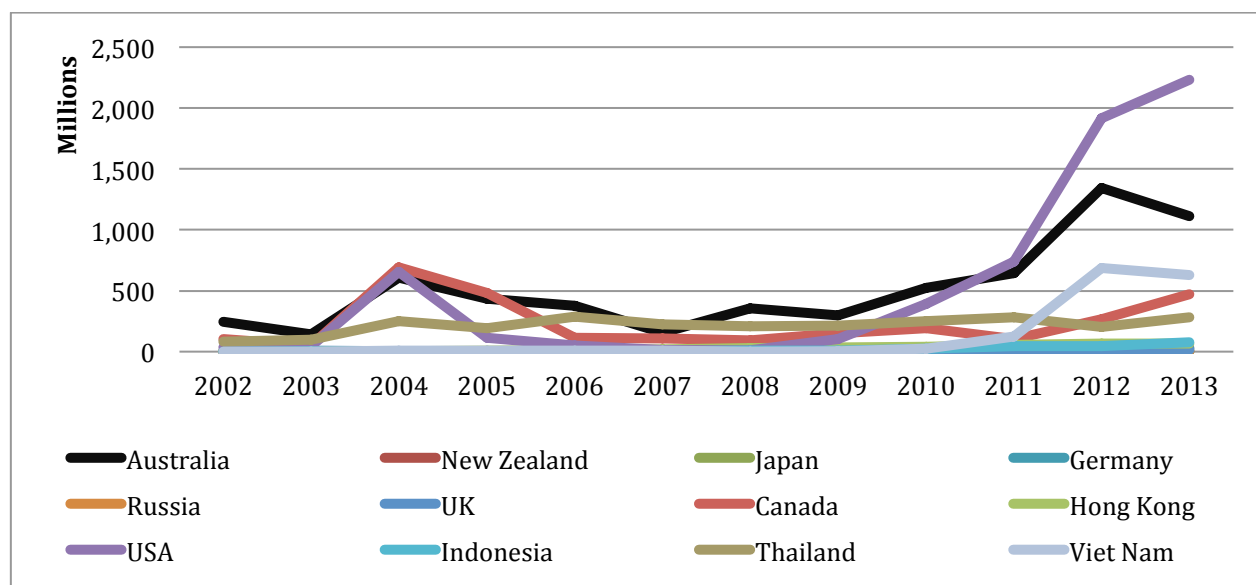
following two years. In 2008, the world grain price rose to \$697/Ton for rice, \$344/Ton for wheat, and \$ 209/Ton for corn (Figure 11) (International Grains Council 2014). The government adopted export restriction policies to maintain domestic prices. As a consequence, the domestic price was lower than the international price. These policies efficiently improved domestic consumers' accessibility to grain and safeguarded food security. The price difference released grain import demand at the same time. After 2010, China's grain imports begin to increase dramatically. U.S. is the largest grain supplier to China (Figure 10). Domestic consumption is the main driver of rising import demand. Even though China's grain production has kept growing for almost ten years, the domestic demand is growing even faster. The gap between domestic grain demand and supply becomes wider each year. China imports more grain to meet its domestic demand. The U.S. is the dominant grain supplier to China, followed by Australia (Figure 10).

Figure 9 China-13 major trade partners trade (export, million \$) in grain 2002-2013



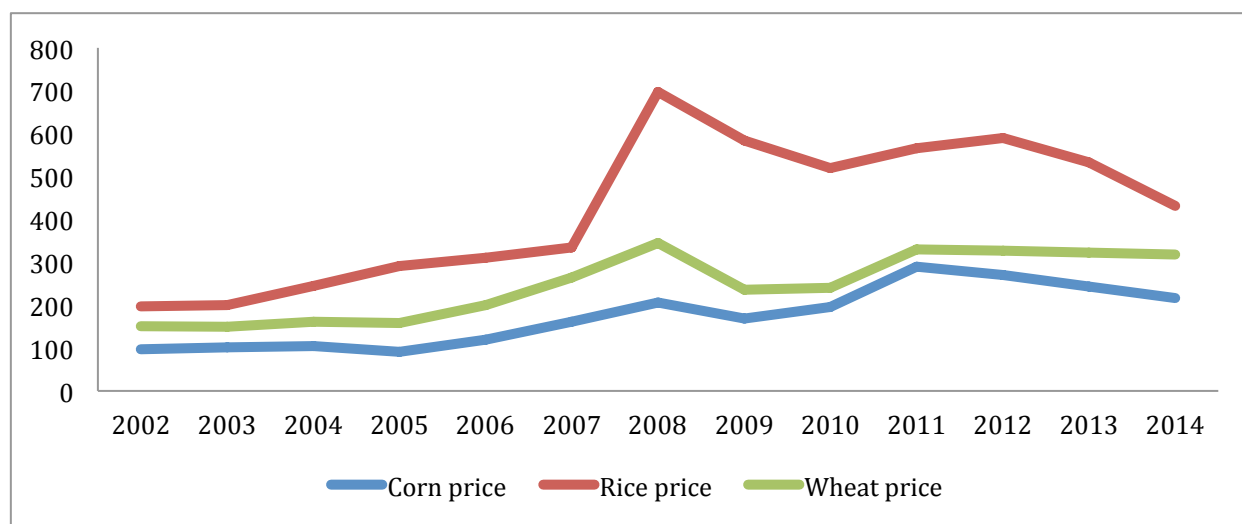
Source: UN Comtrade 2013

Figure 10 China-13 major trade partners trade (import, million \$) in grain 2002-2013



Source: UN Comtrade 2013

Figure 11 Grain products world price 2002-2014



Sources: International Grain Council and USDA 2014

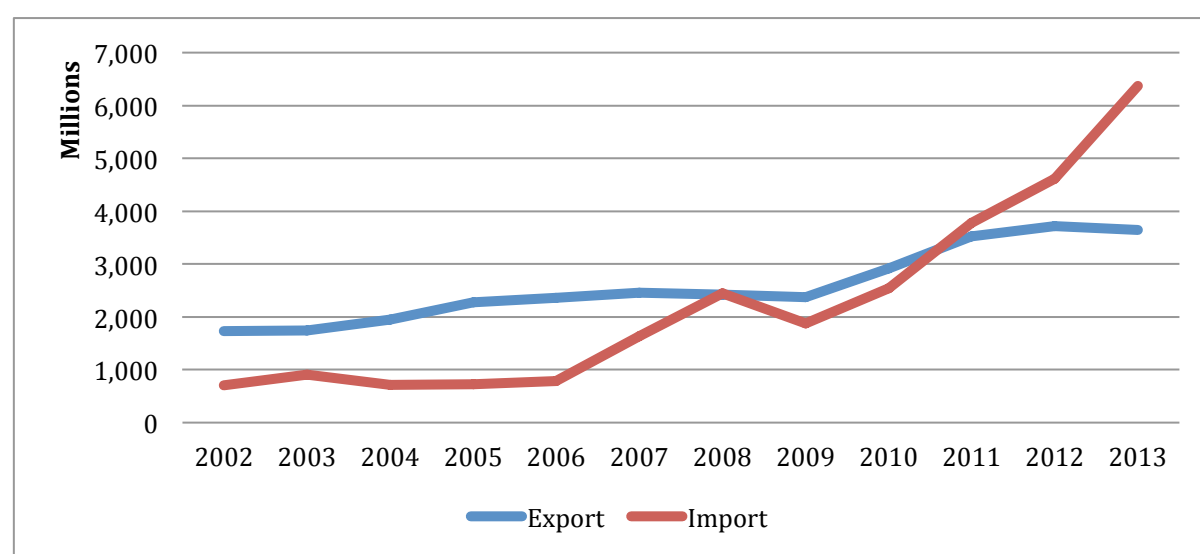
II. Live animals and meat

From 2002 to 2013, China's animal products imports, including live animals and meat products, grew by almost ten times. The main driver of the increase in imports is was capita meat consumption that resulted from income growth. In the period 2005 to 2010, poultry accounted for 3/4 of China's meat imports. Pork made up 13% of meat imports. Sheep and lamb meat accounted for a 9% share (United States International Trade

Commission 2011). Consumer preference in China is shifting to a more healthy diet, which has resulted in more poultry imports. Compared with imports, exports of animal products have remained stable since 2011. Since 2011, China has become a net animal products importer (Figure 12). The U.S. is the largest meat supplier of China. It made up almost half of China's meat imports (Table 3). In 2010, the import share of meat from the U.S. fell significantly, from 77% in 2002 to 17% in 2010. The reasons for the decline were China's countervailing duty, antidumping investigations and import tariffs on the U.S. poultry meats (United States International Trade Commission 2011). Imports from the U.S. picked up again after 2010 and it is still the dominant meat importer of China at present. Brazil was the second largest meat supplier to China prior to 2013. In the period of poultry trade friction with the U.S., Brazil is expected to expand its export to China to satisfy the increasing poultry meat demand. Consumption of poultry meat is expected to expand, therefore, diversification of trade partners are expected in order to better fulfill domestic demand and maintain sufficient supply. Australia and New Zealand have accounted for large share of China animal products' imports since 2012. In 2007, they accounted for 4% of China's meat import. In 2013, Australia and New Zealand made up 21% and 13%, respectively. In addition, Australia became the largest animal products supplier of China in 2013 (Figure 13). The trade pattern between China and Australia reflects the comparative advantage of the two countries. Australia exports resources-intensive products to China, such as live animals, vegetable oil and fats, because it has abundant arable land, grassland, and highly developed animal husbandry. China exports labor-intensive products to Australia, such as food and beverage.

On the export side, Hong Kong and Japan take largest percentage of China's meat exports. Densely populated Japan and Hong Kong are endowed with limited arable land resources. Generally speaking, lacking of sufficient land and water resources, China does not have a comparative advantage to produce and process animal products; therefore, exports of animal products are believed to have limited potential to expand in the future (Figure 14).

Figure 12 China-World animal products trade value (million\$) 2002-2013



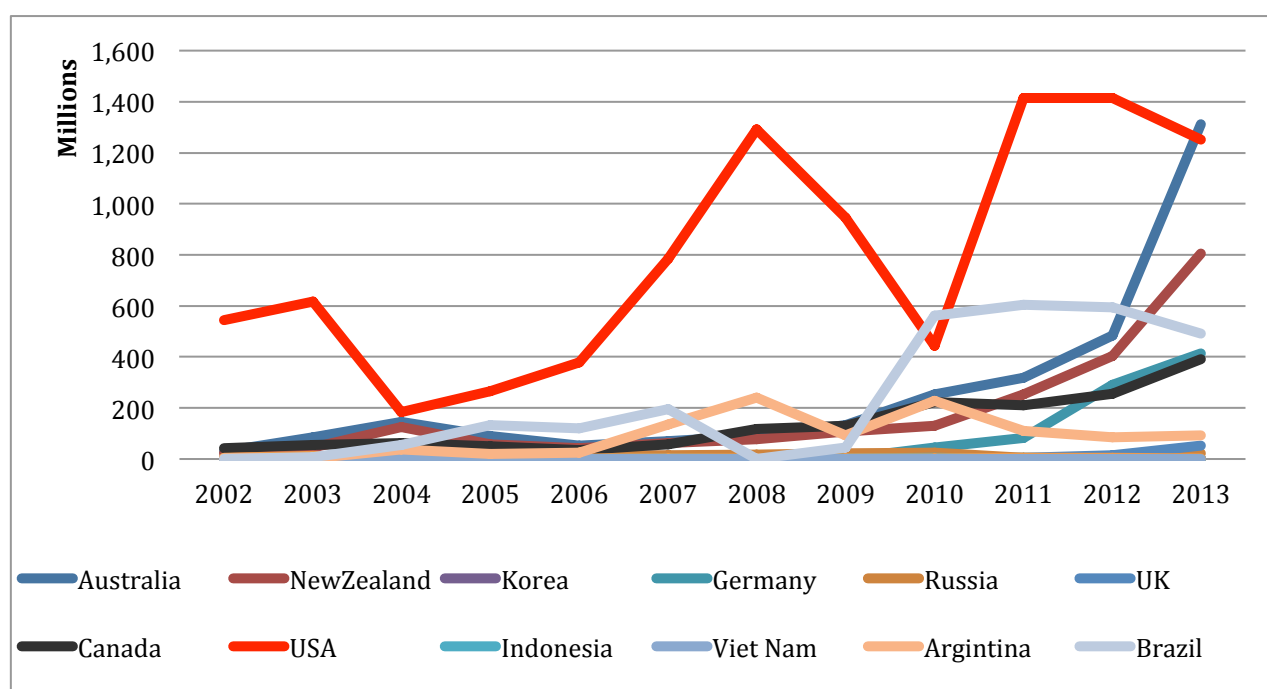
Source: UN Comtrade 2013

Table 3 Import share of top five animals products import countries

Import share of top five animals products import countries						
Year	USA	Australia	New Zealand	Brazil	Argentina	Canada
2002	77%	4%	3%	0%	0%	6%
2003	68%	9%	5%	1%	0%	6%
2004	26%	20%	17%	8%	5%	9%
2005	36%	12%	8%	18%	3%	7%
2006	48%	7%	5%	15%	3%	4%
2007	48%	4%	4%	12%	8%	4%
2008	53%	4%	3%	0%	10%	5%
2009	50%	7%	6%	2%	5%	7%
2010	17%	10%	5%	22%	9%	9%
2011	37%	8%	7%	16%	3%	6%
2012	31%	10%	9%	13%	2%	6%
2013	20%	21%	13%	8%	1%	6%

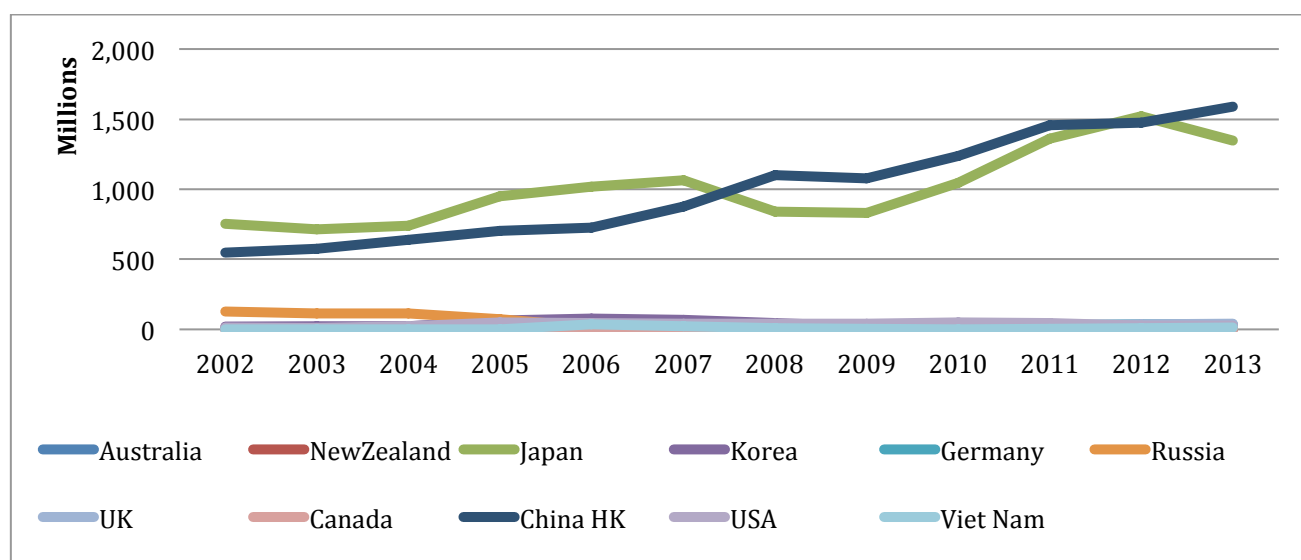
Source: UN Comtrade 2013

Figure 13 Animal products import value (million \$) 2002-2013



Source: UN Comtrade 2013

Figure 14 Animal products export value (million \$) 2002-2013



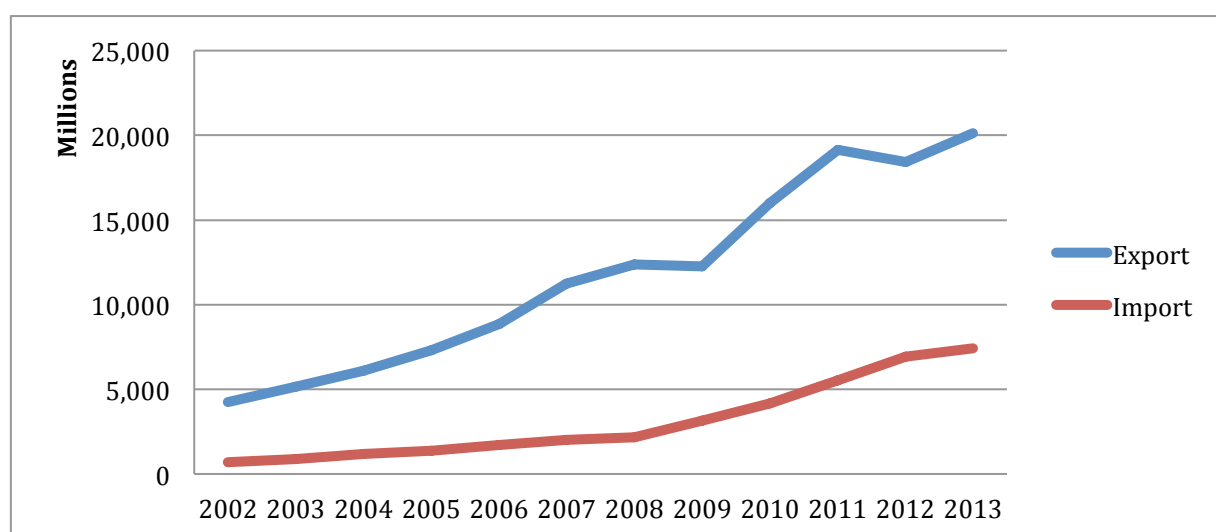
Source: UN Comtrade 2013

III. Vegetables and fruits

The study includes vegetables and fruits in the sectoral analysis, because it is an important agricultural export commodity for China. Figure 15 presents the export and import trends for vegetables and fruits in China. It indicates that China's import and export value in vegetable and fruits have recently increased, and that China has large

trade surplus in vegetable and fruits trade. Vegetables and fruits products accounted for over 35% of the total China agricultural export value on average from 2007 to 2013 (UN Comtrade 2014). Since labor cost and inputs costs are low in China, the production and processing of labor-intensive products are profitable for Chinese exporters. Processed vegetables are the largest export product in China's horticultural exports with \$6.4 billion in 2010(United States International Trade Commission 2011). The leading product in processed vegetable is tomato pasta. Most of it is distributed to Russia, EU, and Africa. Processed mushroom is the second largest vegetables export product. The import countries include EU, U.S., Thailand and Japan. China's fresh vegetables' export value was over \$3.6 billion in 2010, while this value was only \$1.2 billion in 2005 (United States International Trade Commission 2011). If China is able to improve cold storage technology and vegetable quality, the export value of vegetables is expected to increase substantially. Among fresh vegetables, fresh garlic makes up 2/3 share of this export. The largest garlic import country is Indonesia. Fresh and processed fruits export value was approximately \$3.6 billion in 2010(United States International Trade Commission 2011). Fresh apples are the leading fruit in this regard, followed by pears and mandarin oranges. The largest share of them is imported by Asia countries, such as Indonesia, Thailand, Bangladesh and Philippines. U.S. and Japan are major markets for processed fruits exports, such as canned fruit(United States International Trade Commission 2011). On the import side, given China's comparative advantage in fruits and vegetables, the import values of these products have grown slowly. The leading import fruits are Philippines's banana, Chile's grapes, dragon fruit from Vietnam and longans from Thailand (United States International Trade Commission 2011).

Figure 15 China-World trade in vegetable and fruits (million \$) 2002-2013



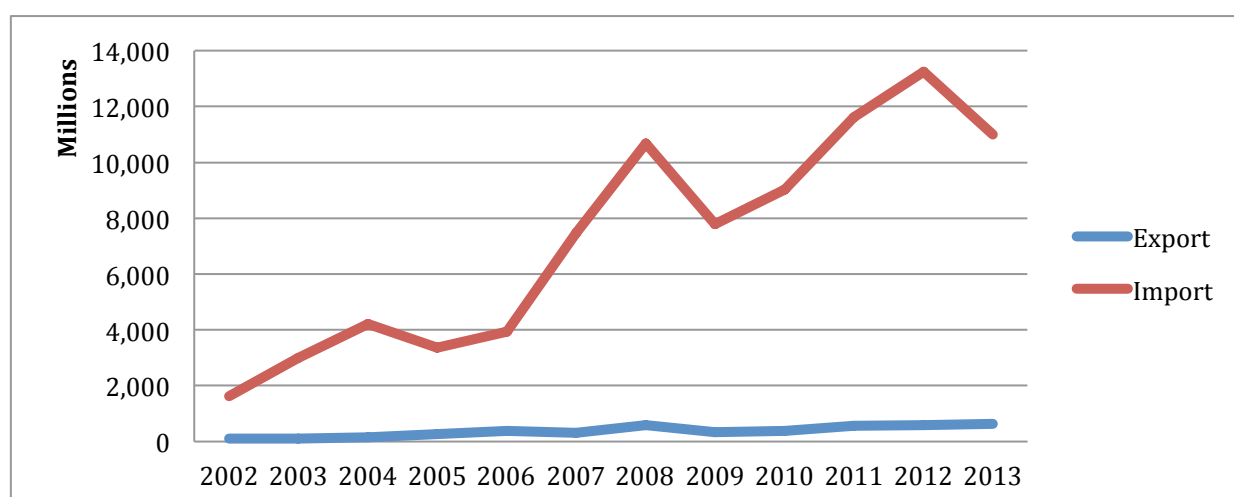
Source: UN Comtrade 2013

IV. Fats and oils

China is one of major oil and fat buyers in the international market (OECD-FAO 2013). Oils and fats imports accounted for a large share of agricultural imports. Figure 16 shows that the import value of fats and oils are much higher than the export of those products.

According to Chen (2013), China's per capita oils and fats consumption is close to 26 kg/year. The production of oils crops is increasing at a slow rate. The small domestic supply and rising demand has lead import to a continuous increase in import in past years. Consumption of oils and fats rely on the imports to China. This occurred because of increasing income, increased population and urbanization. Increasing amounts of soybeans ARE needed to satisfy feed demand as a result of increasing meat demand. In addition, when the 11th five-year plan came into force, 75% of the imported palm oil from Malaysia was for biodiesel.

Figure 16 China-World trade in oil& fats (million \$) 2002-2013

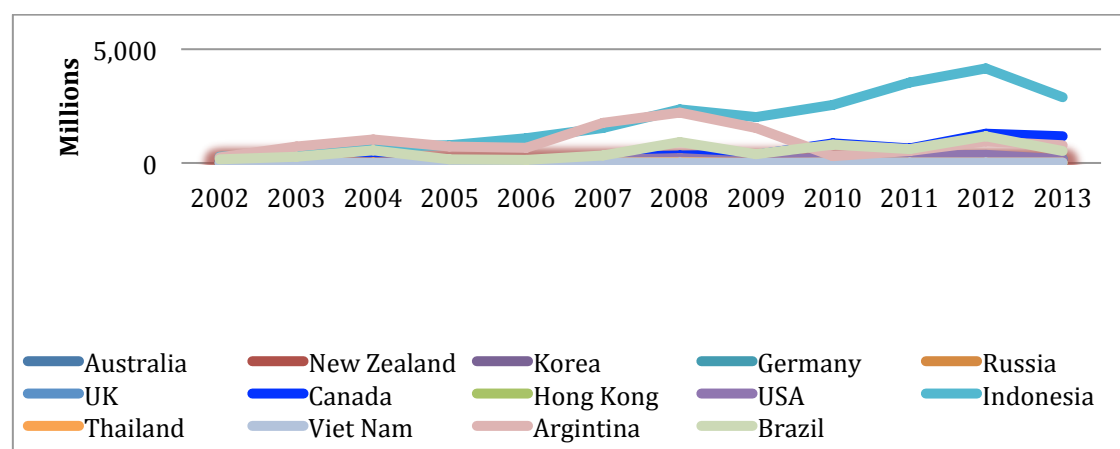


Source: UN Comtrade 2013

On the production side, oilseeds production and grain production have strong competition for land resources. Price of oilseeds has large fluctuations and low profit margins and therefore, oilseeds are less preferred among Chinese farmers. According to UN Comtrade data (2014), the import value of oils and fats was \$1.6 billion in 2002, while it grew to \$10.9 billion in 2013. The peak year of import was in 2010, where the imports value of oil and fats was over \$13 billion. Compared to imports, oils and fats export value was quite small, which was just \$ 97 million in 2002 and \$629 million in 2013. The world largest exporters of oils and fats have Argentina, Brazil, Canada, India, Indonesia, Malaysia and U.S. (Figure 17). They represents about 75% of the total world production (Rosillo-Calle et al. 2009). Palm oil production is dominated by Malaysia and Indonesia; moreover, Argentina and Brazil are improving their palm oil production capacity. In the international market, the top exporters of palm oils are Malaysia and Indonesia. In 2007, their exports accounted for over 90% of the total palm oil trade volume (Rosillo-Calle et al. 2009). On the demand side, the world largest importers are China, India, EU and Pakistan in 2007. China imported 5.2 Mt in 2007. The imports continuous to increase and have reached 6.3 Mt in 2013 (FAO 2013) . In July 2014, China imported 6.6 Mt in current fiscal year (USDA 2014). The top rapeseed production countries, by the order of output, are the EU, China, Canada and India. In term of rapeseed oil, China was the 2nd largest producer after the EU. China's output was 6.3 Mt in 2013. EU's output in 2013 was 9.4 Mt (USDA 2014). Even though China's rapeseed oil production capacity is increasing, but domestic consumption is still above its total

output. In 2013, China's rapeseed oil consumption was 6.8MT (FAO 2013). The increasing domestic consumption makes China are the biggest rapeseed oil importer in the world (USDA 2014). Soybean production is dominated by the US, Brazil, China and Argentina. Besides China, the other top producers are the leading exporters in the world. In 2007, soybeans were the largest agricultural import product to China. Almost the entire domestic production of China has been distributed to domestic market. China's import of soybeans rose from 38 Mt in 2007 to 73 Mt in 2014 (USDA 2014). Soybean oil is a major by-product of soybean meal in the process of animal feed. The major soybean oil producers are the U.S, China, Argentina, Brazil, EU and India. Argentina, Brazil and the U.S. supplied approximately 90% of the total soybean oil trade in 2007 (Rosillo-Calle et al. 2009). China is also the largest importer of soybean oil. In recent years, the situation has not change. China is still the largest producer, consumer and importer of fats and oils products in the world.

Figure 17 China-13 major trade partners trade in fat & oils (import, million \$) 2002-2013



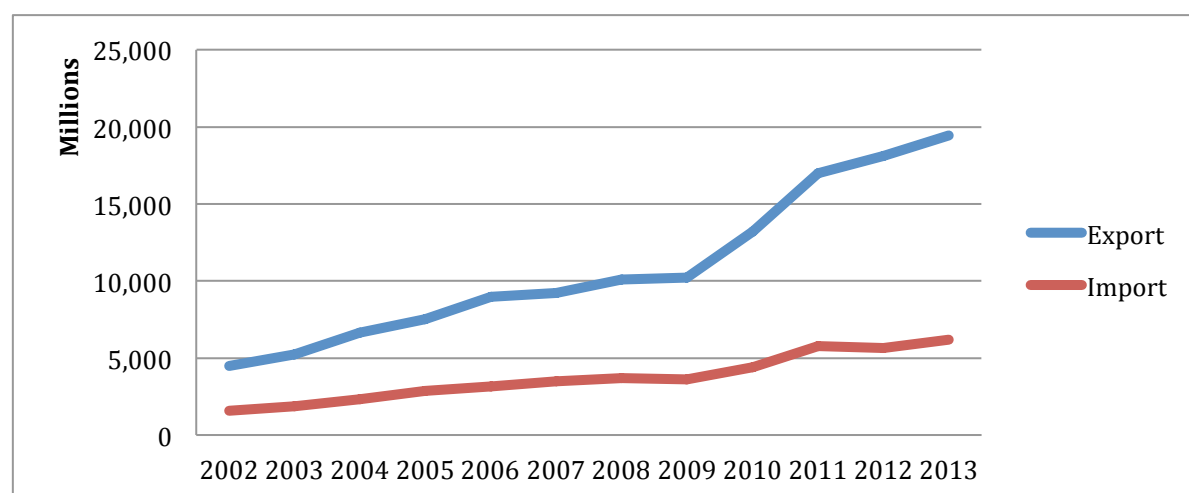
Source: UN Comtrade 2013

V. Fishery and aquatic products

The study includes fishery and aquatic products in the sectoral analysis, because China is one of major fishery and aquatic products exporters in the world. China's international trade value of fishery products in 2002 was \$6 billion. Out of it, the export value was \$4.4 billion and import value was \$1.5 billion (UN Comtrade 2014). In 2013, the trade value increased by more than three times. The export value was \$19.4 billion and import value was \$ 6 billion in 2013(Comtrade 2013). Both exports and imports

rose substantially during the period from 2002 to 2013 (Figure 18). On the export side, the largest export destinations of fishery products were Japan, Korea, the U.S., Hong Kong and Germany. These markets accounted for 90% of total fishery products export of China in 2002. Their aggregated share has declined to 56% in 2013 (UN Comtrade 2014). The data indicates that the export destinations of China's fishery products has become more diverse in the past years (Appendix 1) (UN Comtrade 2014). In term of products, frozen fish fillet is most popular export products to the EU, USA and Japan, followed by cuttlefish and sleeve-fish, sea eel and shellfish (Liu and Ding 2008). On the import side, the increase in domestic consumption has lead to an increase in import demand. According to UN Comtrade (2014), the total import value rose from \$1.56 billion in 2002 to \$ 6.1 billion in 2013. The increasing in import value has resulted in China being the 4th largest fishery importer in the world, after the EU, Japan, and the USA in 2013.

Figure 18 China-World trade in fish and aquatic product (million \$) 2002-2013



Source: UN Comtrade 2013

The Chinese economy, as well as its agricultural market, has become increasingly open since it joined the WTO in 2001. This increased openness has affected the agricultural production structure, national food security and grain self-sufficiency target. The essence of the discussion in the current chapter has been to demonstrate the importance of agricultural trade. In addition, information about key agricultural commodities for China's food security, such as grain products and meat products, as well as key agri-commodities for China's agricultural trade, such as vegetable and fruits,

oils and fats and fishery products has been provided. According to the agricultural trade analysis, China has large trade deficits in grains and meat, which are significant for food security. The central government attempts to safeguard high grain self-sufficiency and stable domestic grain prices by import and export interventions. In addition, the government takes action against dumping to protect the domestic industry and diversify its trading partners, such as the poultry meat anti-dumping case in 2009. According to the report of department of commerce of China, the demand for poultry keeps increasing, the domestic production capacity also increases, but the sales of domestic poultry industry decrease, and its market shares keeps declining. To protect domestic poultry industry (Department of Commerce of China 2009).

Chapter 4 Literature Review

There are a large number of studies on food security emphasizing food security assessment systems, food security early warning system, and estimating the relationship between food security and climate change, biofuels and arable land. However, few studies have addressed the issue of future food security. This literature review covers food security projection studies for various countries and regions. Scholars and international organizations have estimated the future impact of food security using a number of alternative models. The current review includes studies that have used regression models, or simulation models such as partial equilibrium models and computable general equilibrium models. Given the focus of this study, multi-regional CGE modelling studies will be emphasized, with particular attention to GTAP modelling studies.

1. Regression modelling studies

Regression models have been used to investigate the correlation between food demand or supply and covariates, such as population growth, income growth, and urbanization rate. These models have been used to predict future trends in food security under given assumptions. Examples of these studies include (Alexandratos and Bruinsma 2012); Ma (1994); and Chen and Chen (1998). The FAO (2009) used a regression model to predict the supply and demand of crops. The global food demand estimates took into account the effects of population growth, income growth and urbanization. Urbanization has the effect of shifting diet structures, which impacts the demand for food (Alexandratos and Bruinsma 2012). For example, the demand of meat, fats and oils products and eggs increase as their income growth, while the demand for staple food decrease. According to UN population projections, the world's population will exceed 9.1 billion in 2050 under the medium growth scenario. Economic growth has an impact on both the quantity and type of food demanded and its supply where growth projections from the World Bank are used. The World Bank has estimated that the average annual rate of GDP growth rate is expected to be 2.9 % during the period 2005 to 2050 (Alexandratos and Bruinsma 2012). On the supply side, the FAO explores the natural resources base,

such as land and water. According to Millennium Ecosystem Assessment (United Nations 2005), natural resources have already showed signs of degradation. The baseline projection of Alexandratos and Bruinsma (2012) estimates that global cereal production would need to increase by 40% by 2050 to meet global average daily calorie requirements, which is 3,600 kcal/capita for developed countries and 3,000 kcal/capita for developing countries.

Regression models have been widely used to project food security issues. However, this method could mislead forecast and projection if the historical relationship is policy-irrelevant. If the future policy structure changes, this will lead to changes in the underlying individual behavior and thus demand. Motivated by this problem, many economists have built computation-based simulation and projection models using the structural approach since the 1990s.

2. Simulation models

Simulation models are widely used in the analysis of global agricultural markets, but none of the models is appropriate for all purposes. The geographical coverage, sectorial disaggregation, theoretical framework, database, and estimation methods will determine the applicability of the model (Tongeren et al. 2001). There are two general branches for simulation models, either partial equilibrium models or general equilibrium models.

I. Country-level food security projections

Partial equilibrium projection studies

Partial equilibrium models treat non-agricultural markets as being exogenous, which require the researcher to make assumptions about the path of the macroeconomic variables in the future. Also, there is assumed to be no feedback from the development of agricultural markets to the whole (all commodity) market (OECD 2007). The international model for policy analysis of agricultural commodities and trade (IMPACT) provides a fundamental methodology for application to the raw food market. The basic model framework includes four major components, namely, food supply, food demand,

price and trade. The result of IMPACT provides information about long-term food demand and supply at a regional level (Rosegrant et al. 2008). IMPACT has been used in many important research publications to examine the food demand and supply, and food security at the national level. Rosegrant et al. (2008) examines the hypothesis that high-meat diet in developed countries limit the improvement in food security in developing countries. Some analysts has a hypothesis that meat consumption in the developed countries is expected to release the grain from livestock feed to provide food for poor people in developing countries. The study firstly projects the global grain and meat demand and supply resulting from changes in income and population size. Then, the study simulated alternative scenarios to explore effects on the food security in developing countries resulting from the large reductions of meat consumption in the developed countries. The baseline results of study concluded that food security in developing countries is expected to improve slowly. The scenarios analyses of the study concludes that changes in dietary patterns in developed countries, such as shrink the meat consumption in developed countries, are not effective method to improve food security in developing countries.

Scott et al. (2000) develops a projection of supply, demand and trade for tuber and root crops to the year 2020, since the world's poorest farmers and those people below the poverty level are dependent to a great degree on those crops. Under the baseline scenario, roots and tubers are expected to decline in their market share relative to other food and feed crops. Under the high demand and production growth scenario, both demand and supply of tuber and root crops is estimated to increase slightly. Under this scenario, China is expected to account for the bulk of additional sweet potato output (Scott et al. 2000). Another study examines the impact of livestock production on nutrition, as well as the influence of this increased production on food demand and income growth of the poor in developing countries (Delgado et al. 1999) . It reveals that food prices are projected to decline in the long term in the study, despite the rapid increases in demand for cereals (Delgado et al. 1999). This assumption has been applied in regional studies. For example, Rosegrant and Ringler (2000) attempt to investigate the impacts of the Asian financial crisis of 1997 on long-term food security in global food supply, demand, trade and food prices under different scenarios at 2020. The study concludes that, in the short term, the financial crisis poses little threat to Asia, which is

still the major trading region for global cereal and livestock markets, while a long-lasting crisis would have a substantial impact on the region's position in the global livestock market. China and several Southeast Asian countries are expected to shift from importer to exporter status in the global livestock market.

The simulation of the severe crisis scenario shows substantial negative effects on food security in the Asian region. The number of malnourished children is expected to increase by 15 million by 2020. The crisis is also expected to result in a drop of global calorie availability for developing countries. The result indicates that daily per capita calorie availability is predicted to drop from 2852 to 2714 calories by 2020 (Rosegrant and Ringler 2000). Rosegrant and Hazell (2000) provide information on the quality of rural life in Southern Asia. Since a large proportion of the population lives below the poverty line in rural areas in Southern Asia they face a continuous degradation of nature resources that suggests that the future, in terms of local food production, will be expected to continue to decline. The study suggests that the size of the agricultural sector is expected to decline compared with other industries. As a result, it will have a negative impact on food security leading to increases in child malnutrition in many Asian countries. The study developed three scenarios. Under the first scenarios, the study assumed that the governments invested less in rural areas. The size of malnourished children would remain unchanged in 2010 from 140 million in 1993. Under the second scenario, the study assumes that if government keeps agricultural policies as usual, the size of the malnourished children is expected to drop to 113 million by 2010. However, if the government increases the investment in agriculture, the size of malnourished children is estimated to decrease to 76 million by 2010.

Projections based on partial equilibrium models have made a huge contribution to world food security analysis. Some economists, however, argue that such partial equilibrium models ignore significant interactions and feedbacks between various industries, especially the inter-sectoral input and output links. In order to overcome limitations of the partial equilibrium model, a number of research studies using general equilibrium models have been conducted. Such general equilibrium models offer a methodology for analyzing impacts on food security and economic welfare resulting from a country's agricultural policy reforms, technology development, environment and

resources base changes. A review of these general equilibrium models is presented in the following section.

Computable general equilibrium projection studies

Computable general equilibrium (CGE) models have been widely used for studying the interrelationship between agriculture sectors and other sectors in an economy. In addition, the typical research goal is to examine policy alternatives under different scenarios concerning the future and how it might be expected to evolve (Rosegrant et al. 2009). Van Dijk and Meijerink (2014) pointed out that over the last decade, scenario analysis and policy simulations have been developed as tools to be employed to explore global food demand and supply in the future (Van Dijk and Meijerink 2014). Global CGE models have been widely employed to investigate impacts of trade liberalization, climate change, and biofuels on food security.

Most general equilibrium models include aggregated agricultural commodities while GTAP (Global Trade Analysis Project, GTAP), a multi-regional CGE model, contains a comprehensive database including a large number of agricultural commodities that are not aggregated. GTAP database consists of bilateral trade, transport, and protection metrics that link individual country/ regional economic databases. The regional database is derived from the individual country input-output tables, for various years. From 1991 to 2015, GTAP database was and is keeping incorporated more and more regions and sectors. GTAP is designed to allow one to conduct quantitative analyses of international policy issues, such as: a) global trade liberalization under future WTO trade agreements; b) regional trade agreements; c) and, domestic impacts of economic shocks occurring in other regions (Hertel et al. 1997). GTAP has been applied to food security issues. Anderson and Strutt (2012) employ GTAP to analyze agriculture and food security in Asia to 2030. Results show that Asia's share of global agricultural GDP is projected to double by 2030, but this increase is not enough to keep pace with the region's food consumption growth. Asia accounted for one-third of the world's global agricultural production and consumption in 2007, and this figure is expected to rise to 50% in 2030. The study also concludes that the investment in food research and development (R&D) is one option for improving food security in Asia by boosting the income of the foods' sellers and raising the food availability to buyers. Increasing R&D

investment is expected to enhance national food self-sufficiency rates. Import-restricting food policies are assumed to increase national food self-sufficiency rates, but it is at the cost of reducing income and increasing food prices to food buyers, resulting in decreasing the level of domestic food consumption. Food security status of net food buyers are estimated to decline (Anderson and Strutt 2012). Rada et al. (2013) explore the potential impacts of global agricultural TFP growth on food security in developing countries from 2012 to 2022. The results indicate that increasing TFP is likely to improve food security rates, especially in Asia and Africa. Agricultural TFP growth simulates food production, which translates into lower food prices and greater food availability. Improving Agricultural TFP is also likely to boost food producers' income through more trade value. The aggregate number of food insecure people is estimated to be 55 million in 2022 (Asia, Latin American, African) under the baseline scenario, while, under the higher TFP scenario, the total number of food insecure people is expected to decline to 7 million by 2022 (Rada et al. 2013).

Mold et al. (2014) employ GTAP to show that south-south trade liberalization (trade between developing countries) is beneficial to food security in Asia. The authors argue that current agricultural tariffs in the context of south-south trade are too high. Tariff reduction, however, is assumed to be beneficial with respect to food security in the developing world. Their results indicate that China is expected to import more food products under the tariff reduction scenario. The welfare gain is estimated to be 20 billion US dollars. Yu and Bandara (2014) investigate India's food security using GTAP. They argue that current government intervention for food security; such as minimal support prices, a targeted public distribution system and centrally determined prices are costly and not efficient. These policies generate large costs to the administrative authority. The study authors developed scenarios by adjusting government agricultural support policies, such as tariffs and subsidies. Strutt and Nelgen (2013) explore the issue of food security in the Asia-Pacific regions using a GTAP model. They focused on the effects of agricultural productivity and export tariffs on food security in 2015. They found that high rice self-sufficiency rates require a high level of import restriction, but this policy is expected to lead to a lowering of household food consumption. Therefore, they pointed out that increasing TFP is likely to lead to positive food security outcomes.

Evaluating the existing literature, computable general equilibrium models have been extensively applied for food security studies. However, researchers have to select models on the basis of scenarios and their distinctive research objectives. GTAP has been widely applied in agricultural and food related studies because of its coverage of regions and sectors, due to data availability, and its impact on other non-agricultural commodities.

II. Food security projections in China

Partial equilibrium projection studies

Since China has become a member of the WTO, its share of world trade and foreign direct investment have grown at a very fast pace. Globalization requires that policy makers and government must face more challenges. Thus, policy makers require more comprehensive models to assess policies and to forecast the impacts of policies in the future. In China, a large number of policy simulation models are used to study the effects of joining the WTO on the national economy, but only a few policy simulation models have been focused on agricultural markets and food security issues. The most important simulation model focused on agriculture in China is the agricultural policy simulation and projection model (CAPSIM), which provides a framework for analyzing impacts of policy changes, and external shocks on China's food demand, supply, price and net trade. Currently, it is one of the most extensively used partial equilibrium models to study China's food market projections and to evaluate policy opinions for the Center for Chinese Agricultural Policy (CCAP) (Ryan 2003). Using CAPSIM, Huang et al. (1999) project that China's grain demand was 512 million tonnes and grain production was 486 million tonnes in 2010. The total grain deficit was therefore 26 million tonnes. In 2020, their results indicate that grain production and grain demand are expected to be 570 million tonnes and 594 million tonnes, respectively which imply that there should be a grain surplus, which could lead to exporting of grains from China.

However, this model has the similar disadvantages as the other partial equilibrium models. It fails to take into account the interactions between different sectors of the economy after a shock occurs in one sector. Compared with the partial equilibrium model, a general equilibrium model is believed to provide a more comprehensive analysis of economy-wide effects.

Computable general equilibrium projection studies

CGE models have not been widely applied in the Chinese agricultural sector to project future food supply and demand. Most current CGE model applications employed by Chinese scholars have been used to explore the effects of trade liberalization on the Chinese economy. With the widespread application of computable general equilibrium models, a few scholars have begun to adopt single country CGE models and multi-regional CGE models for food market.

Single country CGE models

Diao et al. (2003) constructed a CGE model and used it to analyze the effects of tariff reduction on food demand and supply after China joined the WTO. Fan et al. (2008) constructed PRC-CGE model (People Republic China Computable General Equilibrium Model, PRC-CGE) to analyze the potential economic effects on China of its accession to the WTO. Zhang (2009) investigated the impact of the rapid development of the bio-fuel industry on national food security. The study was based on the input and output table for 2002. The study concluded that bio-fuel production is likely to threaten food security based on the analyses of key indicators, such as food production and food prices. DRCCGE (Dynamic Recursive Chinese CGE) model was developed by Li and He (2010) which has been widely applied by the central government to project economic growth figures for China. Results of the model have focused on key macro variables, such as industry outputs and household disposable income. Huang et al. developed China's agricultural CGE model to explore the food security of China under different agricultural technology improvement scenarios (Li et al. 2010). Results of their study indicate that chemical fertilizer technology improvement has direct positive effects on grain production capacity and production cost reduction. Simulation results also reveal that if chemical fertilizer technology is improved, agricultural outputs and agricultural exports are expected to increase while agricultural imports are likely to decrease (Li et al. 2010). Huang et al. (2010a) use the same CGE model (China agricultural general equilibrium model) to analyze agricultural subsidy policy implications on China's food security for 2020. It evaluates the food security implications of increasing agricultural subsidies by 100%, 300%, and 500%. The results indicate that, grain prices are expected to decrease by 7.32%, 21.37% and 34.59%, respectively; grain imports are expected to decrease by 8.74%, 24.33% and 37.48%, respectively. On the other hand,

grain exports are estimated to increase by 29.28%, 85.48% and 138.36%, respectively (Huang et al. 2010a). The study, which used the same CGE model, concludes that a reduction in cultivated land is likely to result in the fluctuation of food prices and thus threaten national food security (Huang et al. 2010b).

The aforementioned models are single country general equilibrium models. The trade partners are all aggregated into one group – “the rest of world”; therefore, these studies are lacking detailed trade information by country. In addition, they fail to take into account the impact of trade agreements on China in general and the agriculture sector in particular. The major purpose of both PRCCGE and DRCCGE models is to provide macro policy recommendations and guidelines. These models focus on the agriculture sector as a whole, not on a disaggregated form of the agricultural sector. The ‘China agricultural general equilibrium model’ is designed to provide agricultural policy analyses, with the baseline year being 2002, which has not updated since the Asian financial crisis. To overcome these limitations, more and more scholars have applied GTAP models to investigate China’s food security. The latest version of GTAP is version 8 based on the reference year of 2007. It includes detail information about the agricultural sectors.

GTAP applications on China’s food security analyses

The following food security projection studies are based on the GTAP model. Bach (1966) analyzes the implications of China’s trade policies on its food security. This study is pioneer on China’s food security. More and more studies begin to focus on China’s food security. The author was interested in variables such as output, import and export, as well as society welfare. The projection period of the simulations was from 1966 to 2005. The study concludes that trade liberalisation is expected to decrease China’s grain output and reallocate the factor endowments. Land degradation and lower TFP in the grain production sectors are expected to threaten future food security. This study is pioneer on China’s food security. More and more studies begin to focus on China’s food security. Huang and Yang (2006) adopt the GTAP model to investigate implications of China’s food security and world food security due to the speed of economic growth in China. They have four projection phases of 2001-2005, 2006-2010, 2011-2015, and 2016-2020. In the business as usual scenario, the study assumes that

China's GDP growth rate is 8% in 2001-2010, 7.2% in 2011-2015, and 6.3% in 2016-2020. The simulation results indicate that import of land-intensive agricultural products (such as rice and wheat) will likely grow. The study results show that the self-sufficiency rate of grain is expected to decline.

On the other hand, oilseeds are the fastest growing import products. The majority of imported grain is used for animal feed, such as corn. In 2020, wheat imports for human consumption are expected to be marginal. China is likely to maintain a net export position on rice, but the export quantity is not large. The export of labour-intensive products, such as fruits, vegetables and meat, are expected to increase. Processed meat and fish products are estimated to occupy a relatively large export share. In the faster economic growth scenario, the study determines that there will be no significant change in China's agricultural production, consumption, and thus trade. In the faster TFP growth scenario, the self-sufficiency rate of agricultural products is estimated to increase substantially. The study concludes that China's fast economic growth does not threaten food security of either China or the world, because imports of important staple foods are not expected to markedly change. In the context of globalization, China should adjust its agricultural production structure based on its comparative advantages.

Agricultural productivity is a very important factor with regard to safeguarding national food security. Huang and Yang (2006) assessed the impacts of China's entry into the WTO on grain markets. As China increasingly integrates into the world market, the fluctuations of supply and price in the world market are expected to result in significant impacts on domestic food prices. Huang and Yang (2006) concluded that China would likely have to confront risks of national food security after entry into the WTO, but unstable agricultural market prices are likely to affect farmers' income levels. Ren (2012) pointed out that climate change has an impact on food security. The underlying relationship is climate condition would influence food production, as well as food trade; then food production and food trade will influence national food security status. For the varied climate condition scenarios, different grain trade policy alternatives are simulated by the GTAP-E model. The author concluded that, in 2020, China would be expected to have large shortages of corn, while being close to self-sufficiency in other grain commodities. Regardless of the research scenario chosen, due to rising domestic

demand, imports were estimated to increase; therefore, import quotas should be adjusted.

The simulation results showed that grain subsidies would have positive effects on grain output in all climate scenarios A2 and B2 (see footnote). If the value of the grain subsidy was 5.5%, 6.5% or 7.5%¹¹ of total grain output (all below the WTO regulation for the yellow box), grain output was expected to increase by 1.45%, 1.7% and 1.95%, respectively and the corresponding grain price was estimated to decrease by 3.2%, 3.7% and 4.28% respectively. With increasing grain subsidies, grain output was expected to rise and price was predicted to decline, thus consumers were expected to benefit, however there would be negative impacts on farmers' income from the policy. Anderson and Strutt (2014) evaluate China's economy to 2030 with the GTAP model. The study assessed prospective interventions by government to address food security. Their selected food security indicators were: China's shares of world agricultural product exports and imports, self-sufficiency rates and per capita consumption levels. The study shows that the future grain self-sufficiency rate is likely to decline; therefore, government would apply alternative policies to deal with issues, such as imposing an import tax, market price intervention, and increasing public investment.

The study concludes that self-sufficiency rates were projected to fall more than 10% across many major agricultural products by 2030. Secondly, Chinese household income and output are likely to increase. Thirdly, food consumption per capita is estimated to increase as well. Fourthly, market price interventions reallocate resources toward rice, wheat and livestock production. Hence, Anderson and Strutt (2014) recommend that cash transfers and social safety programs are expected to boost agricultural productivity and thereby improve national food security. Strutt and Nelgen (2013) investigated food security scenarios for the Asia Pacific regions with a GTAP model. The study projects the world economy to 2015. They attempted various scenarios including TFP growth, export and import tariffs for rice, and decreased labor productivity. The results indicate that, if the Chinese government set 95% as the rice self-sufficiency rate, the import tariff would have to be increased substantially to protect the domestic

¹¹ The results of the study are the results of scenarios of A2 climate conditions. The results are the same qualitatively but of a different degree in another climate condition of the B2 scenario.

market. TFP improvement is expected to result in positive food security outcomes. Policies, aimed at promoting grain self-sufficiency, are likely to worsen some key food security indicators, such as household food consumption.

The aforementioned authors investigated China's food security from distinct perspectives, methodologies and assumptions. Though a lot of studies have addressed the food security implications, few studies have undertaken an integrated and comprehensive assessment of China's food security, including the impact of agricultural trade agreements, agricultural productivity, and agricultural subsidies for the coming decades. The current study deals with these issues.

Chapter 5 Method of Analysis

The most widely recognized method to undertake a global trade analysis is with a Multiregional Computable General Equilibrium (CGE) model. The Multiregional CGE modeling framework that has been used to undertake the analysis of the current study is produced by the Center for Global Trade Analysis at Purdue University, USA. The database and model were developed for the Global Trade Analysis Project (GTAP). The model is a multi-country and a multi-commodity model (Hertel et al. 1997). This chapter outlines the features of the GTAP model in terms of the underlying framework and assumptions, followed by a description of scenarios that were investigated for this study. The latter section offers a description of macroeconomic variables, which have been used to update the economies addressed by the model.

1. Model specification

The structure of the GTAP model is specified and described in Hertel et al. (1997) and Mukhopadhyay and Thomassin (2009). The model includes industrial sectors, households, governments and global sectors across countries where countries and regions in the model are connected by trade. Prices and quantities are generated simultaneously in both factor markets and commodity markets.

The model employs Leontief production functions and a constant return to scale (CRS) technology to produce final commodities in perfectly competitive markets. Firms minimize input costs for given levels of output and fixed technology. Firms are assumed to combine intermediate inputs and primary factors. Similarly, the relationship between the amount of intermediate inputs and outputs is also fixed. Firms purchase intermediate inputs, some of which are produced domestically, and some of which are imported.

In the derivation of factor input demands, the model structure uses constant returns to scale technology and nested constant elasticity of substitution (CES) functions with three levels to determine the firms' demand for primary and intermediate inputs. The top level determines intermediate good bundles and primary factor bundles in fixed

propositions. At the middle level, intermediate input bundles are formed through a combination of imported goods and domestic goods. GTAP uses the Armington assumption to distinguish between domestic and foreign goods¹². Similarly, primary goods bundles are a combination of labor, capital, and land where both bundles have CES aggregator function form. At the lowest level, imported goods bundles are a CES combination of imported goods from different origins.

In the GTAP model, each region or composite region has a single representative household that collects all the regional income. This representative household's aggregate income is exhausted through constant shares to private household consumption, government expenditures and national savings. The household behavior is described by an aggregate utility function. The household will purchase a bundle of commodities to maximize its utility subject to given budget constraints. The consumption behavior is described by a Constant Difference Elasticity Demand System. In addition, the consumption goods bundle is grouped by a CES aggregation of domestic goods and an import bundle where the imported bundle is a CES combination of goods imported from different regions.

Demand is assumed to equal supply in all markets, which are considered to be competitive. This implies equality between the price received by the producer and the producer's marginal cost. Regional governments intervene in their own markets by imposing taxes and subsidies on commodities and primary factors, thus driving wedges between prices paid by purchasers and prices received by producers. These policy interventions are modeled as ad valorem taxes, tariffs and subsidies, or quantitative restrictions in case of trade. Thus, these policies have a direct impact on the production and consumption sectors in the model.

Transportation and global banking are two global sectors in the model. The transportation sector accounts for the difference in prices of a commodity as a result of the international freight of the good between countries and global banking brings global

¹² The Armington elasticity is an essential component of trade policy analysis. International trade is linked through Armington substitution among goods differentiated by country of origin. Therefore, in markets for traded commodities, buyers differentiate between domestically produced products and imported products with the same name.

saving and investment into equilibrium.

Other general features of the model are its explicit recognition of savings by regional economies. These savings are completely exhausted on investments that are savings-driven in the model. The demand for investments, however, affects economic activity through its effect on patterns of production in the capital goods production sector in each region. Investment in each region is financed from a global pool of savings where each region contributes a fixed proportion of its income to the savings pool (Mukhopadhyay and Thomassin 2009). In each region, there are five primary factors; skilled labor, unskilled labor, capital, land and natural resources. The total supply of land is fixed in the model, while capital is allowed to be mobile across the country depending on the rate of return for this input. Labor and land are not tradable goods in the model, whereas capital and intermediate goods are tradable. In equilibrium, all firms have zero real profit, all households are on their budget constraint, and global investment is equal to global savings. Changing the model's parameters allows one to estimate the impact from a country's/region original equilibrium position to a new equilibrium position resulting from the policy scenario under consideration.

Variables in the model are classified as being either endogenous or exogenous variables. In the GTAP model, the exogenous variables include population growth, capital accumulation, industry capacity, technological change and policy instruments such as taxes and subsidies. For the model to be solved, the number of endogenous variables must be equal to the number of equations in the model. The standard GTAP closure is featured as all markets in equilibrium, all firms earn zero profits, and the regional households are on his budget constraints. Thus Macro closure is significant to CGE model.

GTAP is primarily a tool for global trade analysis and seems to be very well suited to studying the consequences of trade agreement issues. The current study was designed to aid in an investigation of China's future food security status under different policy scenarios or shocks. Thus, the model is appropriate for the study of the consequence of China's agriculture related trade policies. This is because GTAP has global coverage, distinguishes bilateral trade flows, and has sufficient coverage of agricultural

commodities to provide realistic results given that China is becoming more and more integrated into world trade and is thus playing an increasingly important role in the world food market. Further, a reduction in tariff and import quotas resulting in impacts on the country or countries under consideration can be captured and analyzed, along with the resulting impacts on other regions of the world. The models specify the economic structures and behavior of agents in detail and, using the appropriate framework, simulate the economic effects of existing or proposed trade agreements in the context of agriculture. The interdependence of the world economy and the comprehensiveness of the GTAP framework suit the purpose of the study.

2. Data and Aggregation

The study uses the GTAP version 8 database, which is based on 2007 base year Narayanan G et al. (2012). This version of the model includes 129 regions (countries) and 57 commodities (sectors). It has been calibrated to 2007 levels of production, consumption, trade and protection. 2007 is a good base year for the forward projection as it captures the recent temporary price spikes in both the food and energy markets, as well as the global financial crisis and recession (Anderson and Strutt 2014). The 129 countries (regions) and 57 industries sectors in the model provide a broad geographic coverage and disaggregation of the industrial sectors in each country.

The 129 regions are aggregated to 16 regions with an emphasis on China and its major trading partners in agriculture goods and services. The 16 countries (regions) include Australia and New Zealand, China, Hong Kong (China), Japan, Korea, Indonesia, Thailand, Vietnam, Canada, United States, Russia, Germany, United Kingdom, Rest of Asia, Rest of OECD and Rest of world. The individual countries on the list are China's traditional major trading partners. With regard to the aggregated regions, the Rest of Asia is a separate region as it contains some Asian countries that are naturally trading partners with China due to location, but also countries that do not have a large trading value with China. The Rest of OECD is separated from the Rest of World because of their distinct development stages that may influence their trade relationships and specific composition of trade with China. An overview of the regional aggregation can be found in Table 8. Given the agricultural emphasis of this study, there is no aggregation of

agricultural sectors, food sectors and industries related to agricultural sectors while the other non-agriculture sectors are aggregated. The 57 industry sectors have been aggregated to 36 sectors on the basis of trade intensiveness in China. The sectoral and regional aggregation schemes are provided in Appendix 2 and Appendix 3.

3. Modifications of GTAP model to 2030

In order to undertake the desired projection and simulation exercises, a decision was made that the static GTAP model with a base year of 2007 was to be updated to the projection year 2030¹³. For the purposes of model updating this study uses the recursive-updating process that is based on forecasting the countries' (regions') economies by exogenously shocking the baseline model with projections of macroeconomic variables.

I. Macroeconomic variables estimates and underlying assumption

The first step in the modeling process is the generation of a Business as Usual (BAU) projection from the benchmark 2007 GTAP 8 database. New economies can be generated for the years 2007-2013, 2013-2020, 2020-2030, and 2030-2050 using macroeconomic shocks for the key variables (Table 4). The exogenous macro variable shocks include capital, population, skilled labor, and unskilled labor, and total factor productivity. The projection of each economy to 2013 is made with the assumption of a growth rate for the aforementioned variables. The projection of growth rate for total factor productivity for non-agricultural sectors is sourced from CEP II. The growth rate for total factor productivity for the agricultural sectors is based on the estimation work of (Ludena et al. 2007). The population growth rate projection was taken from the United Nations publication; 2012 Revised Population database, United Nation, Population Division. The growth rates for skilled labor, unskilled labor and for capital are also taken from CEP II. GDP is endogenously determined to accommodate the combination of these exogenous shocks.

¹³ It is known that China's government agencies are particularly interested in certain variables, such as arable land requirements in 2050 under 95% and 90% self-sufficiency rates, and grain self-sufficiency rates for the same year. Thus these are the key food security variables from the perspective of China's government. For the estimation of the arable land requirement and the grain self-sufficiency rates, the study provides estimates for these variables to 2050. For the other model variables, the projections are made to 2030.

Results provide a projection for the global economy in 2013 that is in equilibrium. The forecasted economy in 2013 provides the starting point for subsequent simulation exercises. This forecasting procedure is also applied to update the economy being studied to 2020, 2030 and 2050. The projections for the fundamental drivers of global economic change over the periods 2007-2013, 2013-2020, 2020-2030, and 2030-2050 are presented in Table 4.

Table 4 The projected growth rates for macro variables

Population projections (2007-2050)

POP (in %)	2007-2013	2013-2020	2020-2030	2030-2050
Country				
Australia & New Zealand	7.94	7.61	8.67	10.44
China	2.83	2.07	0.38	-7.24
Hong Kong, China	5.70	7.06	8.39	9.28
Japan	-0.13	-1.23	-3.74	-10.18
Korea, Rep.	2.66	2.10	1.05	-6.74
Indonesia	6.17	6.06	6.33	4.82
Thailand	3.56	2.60	1.69	-3.16
Vietnam	6.47	6.12	5.20	2.42
Canada	5.96	6.04	7.00	9.11
United States	5.25	5.70	7.06	10.87
Russian Federation	-0.52	-1.08	-3.31	-7.79
Germany	-0.87	-1.00	-1.89	-6.07
United Kingdom	3.69	4.08	5.21	4.94
Rest of ASIA	13.88	9.00	9.56	10.16
Rest of OECD	4.00	3.20	3.13	2.02
Rest of World	9.62	10.45	12.74	18.44

Capital projections (2007-2050)

Capital (in %)	2007-2013	2013-2020	2020-2030	2030-2050
Country				
Australia & New Zealand	10.05	14.00	24.32	50.84
China	48.77	54.56	65.63	91.57
Hong Kong, China	17.51	27.19	29.12	38.13
Japan	2.05	3.99	11.51	22.29
Korea, Rep.	18.40	28.74	37.42	55.97
Indonesia	26.75	27.23	36.09	58.39
Thailand	18.14	24.47	33.09	54.48
Vietnam	37.67	40.06	54.22	87.43
Canada	9.11	13.46	20.71	39.40
United States	10.55	9.34	11.50	22.10
Russian Federation	8.57	20.88	36.34	71.31
Germany	0.65	7.17	7.78	3.03
United Kingdom	7.35	9.67	16.66	28.63
Rest of ASIA	26.23	33.81	46.49	76.52
Rest of OECD	9.65	14.23	21.29	34.29
Rest of World	21.01	27.31	43.51	85.42

Skilled labor projections (2007-2050)

Skilled labor (in %)	2007-2013	2013-2020	2020-2030	2030-2050
Country				
Australia & New Zealand	16.34	21.64	21.83	36.60
China	33.37	31.83	24.24	35.07
Hong Kong, China	7.97	17.12	8.87	28.69
Japan	9.33	18.91	10.53	7.90
Korea, Rep.	17.65	24.42	13.76	11.69
Indonesia	17.72	21.29	34.94	80.12
Thailand	40.25	33.36	28.28	38.72

contd.

Vietnam	48.08	42.75	37.15	52.42
Canada	-4.97	14.77	15.90	36.01
United States	6.99	10.17	12.23	28.48
Russian Federation	7.88	-1.01	-3.00	0.68
Germany	-2.84	-2.39	-1.49	36.94
United Kingdom	24.12	36.08	30.50	41.37
Rest of ASIA	29.09	39.77	39.42	60.53
Rest of OECD	10.39	22.89	22.35	44.19
Rest of World	26.70	44.77	46.82	82.79

Unskilled labor projections (2007-2050)

Unskilled labor (in %)	2007-2013	2013-2020	2020-2030	2030-2050
Country				
Australia & New Zealand	0.83	-9.51	-9.94	-33.74
China	3.18	-1.41	-7.81	-28.19
Hong Kong, China	1.60	-1.43	-7.08	-6.94
Japan	-11.11	-20.11	-21.89	-54.68
Korea, Rep.	-1.65	-11.23	-18.20	-35.55
Indonesia	10.16	9.43	10.07	3.84
Thailand	3.01	0.13	-3.66	-19.79
Vietnam	10.44	4.87	0.94	-16.70
Canada	13.76	-7.63	-8.82	-27.02
United States	1.15	-4.32	-5.89	-22.03
Russian Federation	-10.26	-11.11	-12.91	-41.50
Germany	-1.81	-7.41	-14.66	-29.55
United Kingdom	-2.36	-11.70	-14.78	-38.01
Rest of ASIA	17.14	6.51	5.89	-6.07
Rest of OECD	1.50	-5.90	-9.18	-31.10
Rest of World	11.31	9.44	11.67	10.33

TFP for non-agricultural sectors projections (2007-2050)

TFP for non-agricultural sectors (in %)	2007-2013	2013-2020	2020-2030	2030-2050
Country				
Australia & New Zealand	3.32	13.06	17.80	29.59
China	35.19	31.85	39.90	66.04
Hong Kong, China	12.66	9.08	13.27	24.83
Japan	3.08	12.93	18.31	21.72
Korea, Rep.	12.24	18.74	27.28	34.29
Indonesia	18.06	11.77	16.60	35.62
Thailand	11.09	15.06	21.83	46.10
Vietnam	17.01	24.80	33.08	63.35
Canada	0.92	12.43	17.07	23.38
United States	0.77	6.31	8.87	17.76
Russian Federation	13.80	30.54	36.41	63.41
Germany	5.99	7.17	10.42	23.08
United Kingdom	-2.28	11.15	12.03	18.61
Rest of ASIA	8.87	17.43	22.17	43.36
Rest of OECD	1.29	11.86	16.27	31.57
Rest of World	10.28	17.65	23.58	45.56

TFP for agricultural sectors projections (2007-2050)

TFP for agricultural sectors (in %)	2007-2013	2013-2020	2020-2030	2030-2050
Country				
Australia & New Zealand	6.20	5.37	6.84	12.02
China	27.12	21.82	25.29	40.57
Hong Kong, China	6.20	5.37	6.84	12.02
Japan	6.20	5.37	6.84	12.02
Korea, Rep.	0.10	-0.38	-1.42	-5.49
Indonesia	0.10	-0.38	-1.42	-5.49
Thailand	0.10	-0.38	-1.42	-5.49

Vietnam	0.10	-0.38	-1.42	-5.49
Canada	6.20	5.37	6.84	12.02
United States	6.20	5.37	6.84	12.02
Russian Federation	10.65	8.55	10.22	17.69
Germany	6.20	5.37	6.84	12.02
United Kingdom	6.20	5.37	6.84	12.02
Rest of ASIA	3.37	2.90	3.38	4.54
Rest of OECD	7.10	6.11	7.71	13.52
Rest of World	8.06	7.28	9.37	16.20

II. Experimental design

The GTAP database provides a framework for economies in the year 2007 and projections for the economies have been generated for the years 2013, 2020, 2030 and 2050 using macroeconomic shocks of aforementioned variables. Five main scenarios have been investigated for this study as follows: (1) Business as Usual, (2) Tariff adjustment and free trade agreements, (3) agricultural subsidies, (4) TFPs, and (5) Government mandated rice and wheat growth rates.

Business as usual (BAU)

Taking 2007 as the base year and using macroeconomic shocks to generate a new economy for 2013, 2020, 2030 and 2050, this analysis assumes that the tariff structures for all regions and countries remains as they were in 2007. This Business As Usual (BAU) remains the same throughout the analysis and is the base against which the other scenarios will be compared. This BAU scenario projection is developed to provide a picture of how the global economy and world trade might look with the current tariff barriers. It provides a baseline against which a comparison may be made for the implementation of the various scenarios under study. It also facilitates a comparison of how the trade agreements may impact economies over time, relative to what would have been the case without implementing these scenarios. It provides a baseline for the comparison of the implementation of trade agreements, tariff reductions, subsidy implementations, agricultural TFP improvement and other agricultural policy interventions.

Tariff block

There are 6 experiments in the tariff scenarios. The first experiment is a meat tariff reduction (MTR). It describes a situation where import tariffs for all meat and livestock sectors are removed. Some people argue that to improve grain self-sufficiency, China could and perhaps should import more meat. They believe that if China imports more meat, domestic meat production will decline along with feed grain use. Since feed grain and food grains compete for natural resources, such as water and land, if demand for feed grain decreases, more resources will be allocated to food grain sectors such as wheat and rice. Therefore, the objective of this experiment is to investigate the effects of meat tariff reductions on grain self-sufficiency rates. The second experiment concerns grain tariff reductions (GTR). This would be the case if China was to open its grain markets to competition and eliminate the protection that the grain sectors receive. At present, China imposes higher import tariffs for grain products than for other agricultural commodities to maintain a high grain self-sufficiency rate. The third experiment would impose a high grain tariff (GTI) to protect domestic grain producers and thus to encourage a high grain self-sufficiency rate. The last two experiments in the tariff scenarios are related to the recent free trade agreements under negotiation. Since Australia is expected to become new Asia food supplier due to abundant natural resources and low domestic food demand, the fourth experiment, which is China and Australia free meat trade agreement (CAM), focuses on Australia. It explores the effects of import tariff removal for meat and livestock entering China. On the other hand, Korea Republic is one of the main meat export markets for China. The Korean government sets high tariffs for agricultural goods to protect their domestic agriculture from international market effects. Both countries, China and Korea, agreed to have free trade negotiations in November 2004. Currently, the two countries are negotiating several sensitive issues such as agricultural tariffs. This experiment China and Korea free meat trade agreement (CKM) describes a situation where Korea removes all meat tariffs for meat imported from China.

Agricultural subsidy block

Two experiments are simulated in this scenario. Increasing the machinery subsidy for agricultural sectors (IMS) and increasing the fertilizer subsidy (IFS) for grain sectors in China. Both machinery subsidy and fertilizer subsidy are likely to help farmers to

reduce production cost and provide an incentive to produce more grain. The Chinese government has invested large amounts of money to subsidize agricultural machinery investment and fertilizer use over past years. The annual growth rate of the fertilizer and machinery subsidies are 16% and 40%, respectively. Those two experiments are designed to measure whether such high subsidy levels would still be necessary for China in the future.

Ag- TFP block

The TFP scenario describes a situation that China's agricultural TFP is expected to increase by 2.5% per year for the projection periods. It is used to assess the implications on food security because of high productivity.

Government mandated rice and wheat growth rate

In the 12th Five-Year Plan (2010-2015), the central government of China sets the annual grain growth rate as 2.04% to meet its grain output target. The last two experiments describe the implications for China and her trading partners if China keeps mandated growth rates for rice (MRG) and for wheat (MWG) over the study period until 2030.

The above scenario descriptions require a change in the development of the GTAP model to undertake the simulation. The descriptions of those scenarios are presented in Table 5.

Table 5 Simulation description

Simulation Block	Simulation	Meat sectors	Rice sector	Wheat sector	Grain sectors ¹⁶	Agricultural sector
Tariff adjustment and free trade agreement block	MTR	Remove tariff				
	GTR				Remove tariff	
	GTI				Increase tariff by 50%	
Ag-TFP block	CAM	Remove tariff for meat from Australia				
	CKM	Korea removes tariff for meat from China				
Subsidy block	Ag TFP					Increase agri-TFP by 2.5% p.a. ¹⁴
	IMS					Increase machinery subsidy by 40% p.a. ¹⁵
	IFS					Increase fertilizer subsidy by 16% p.a.
Government mandated growth rate	MRG		Mandated growth rate is 18.34% p.a. ¹⁷			
	MWG			Mandated growth rate is 18.34% p.a		

¹⁴ The agricultural TFP growth rate assumption is taken from the study result of Deng (2010)

¹⁵ The machinery subsidy growth rate and fertilizer subsidy growth rate are calculated from China's subsidy budget data from 2006 to 2009.

¹⁶ Grain sectors include wheat, rice and other grain sectors in the GTAP database.

¹⁷ In the 12th Five-Year-Plan, the government sets the grain production target as 540 million tonnes in 2015; therefore the mandated grain growth rate is 18.34% per year during the period from 2007 to 2015. Since rice and wheat both are important grain products for China, two simulations (for rice and wheat) are undertaken in the study.

Chapter 6 Results and Analysis

This chapter presents results of an analysis of China's agricultural policies on China's food security based on scenarios described in the previous chapter. The results and economic analyses are presented in the business as usual (BAU) scenario for 2030 and 2050¹⁸ and various other scenarios as outlined in chapter 5. The important food security indicators in different scenarios and the BAU scenario are discussed, such as output growth, export and import growth, self-sufficiency rates, food prices, and private food consumption. In addition, the study presents a discussion of the poverty implications, welfare implications, GDP effects and returns to unskilled labor associated with each scenario.

1. Projected Results in the BAU Scenario

I. GDP Growth Rate

In the business as usual (BAU) scenario, the world economy is projected without implementing any policy shocks and GDP is assumed to be an endogenous variable in the model. Table 6 shows the projected growth rate of GDP of the different economies during the 2007 to 2030 period. China is expected to have the highest GDP growth rate throughout the period, growing by 8.26% per year in the period 2013-2020, and 5% per year in the period 2020-2030. The results are not surprising given the higher growth rate of ASEAN countries, such as Indonesia, Thailand and Vietnam. Developed countries, such as Australia and New Zealand, Canada, United States, United Kingdom and other OECD countries have stable GDP growth rate, which is estimated to be around 5.8% annually up to the year 2030.

¹⁸ Since arable land use and grain self-sufficiency rates are emphasized by China's central government, it was deemed important for this study to focus on future trends of these two variables. Therefore, the study presents analyses of these two variables to 2050, and to 2030 for the rest of the food securities.

Table 6 Simulation results of accumulated GDP growth rate in each period

GDP Growth Rate (%)	2007-2013	2013-2020	2020-2030
Australia and New Zealand	11.77	19.97	28.35
China	66.37	57.87	59.18
Hong Kong China	25.22	27.87	29.34
Japan	1.82	10.41	17.84
Korea	22.97	30.55	37.57
Indonesia	33.83	25.24	30.32
Thailand	26.53	31.88	38.82
Vietnam	36.13	35.59	39.04
Canada	8.47	17.53	24.53
United States	6.45	10.36	13.54
Russia	16.49	36.39	46.87
Germany	4.78	6.38	7.59
United Kingdom	5.65	19.65	21.3
Rest of Asia	30.8	38.76	44.53
Rest of OECD	8.73	21.38	27.09
Rest of World	28.88	40.06	49.5

Source: Results from the study

II. Output Growth

The study looks at changes in real output growth in the BAU scenario. The analysis in the BAU period (2007-2030) is divided into three sub-periods (2007-2013, 2013-2020, and 2020-2030).

The current study is primarily interested in China's food security and an analysis of agricultural policies, so the majority of results are focused on China's agricultural sectors. In particular, grain security is the top priority of the Chinese government. The demand for raw unprocessed animal products and processed animal products attract more attention because the middle-income class' diet pattern changes significantly as income increases. In addition, regarding vegetable, fruits, and fishery products, China is one of the dominant exporters in the world and these products account for the majority

of China's food exports. Since domestic oilseed consumption is increasing as income rises, oilseeds account for the majority of China's agricultural import value. Therefore, these agricultural commodities are emphasized in this chapter.

Table 7 indicates that live cattle, beef meat products, plant-based fibers, other grain products, and rice are the most important sectors in terms of their industrial output growth. The ranking remains almost constant in each BAU scenario period. In general, the actual level of output for all agricultural commodities is expected to increase while the annual growth rate of output for the majority of agricultural commodities are expected to decline over time. For example, the output growth rate for grain is estimated to decline. The average output growth rate for rice is estimated to be 5.3% per year in the first time period (2013-2020) and this rate is expected to decrease to 4.7% per year in the period of 2020-2030. Regarding wheat, the annual output growth rate is estimated to be 4.88% and 4.26% in 2013-2020 and 2020-2030, respectively. Other grain products exhibit a similar trend with the annual output growth rate being expected to decline from 5.59% in 2013 to 5 % in 2030. For the livestock sectors, other animal products¹⁹ are likely to decline by the greatest amount. The annual output growth rate for other animal products is estimated to decrease by around 27% and the other meat products' annual output growth rate is estimated to decline by 26%. For beef products, the output growth rate is expected to be 7.5% per year in 2013-2020 and 6.5% per year in 2020 -2030. Output of vegetables and fruits commodities is likely to grow at a decreasing rate in the future. The average annual output growth rate for these products in 2013-2020 is estimated to be 4.3% decreasing to 3.86% in 2020-2030. Vegetable and fruit are labor-intensive products. Given that China has a large population, a large labor forces along with low wages endows China with a comparative advantage for labor-intensive products. China's population controlling policy and an increase in urbanization has led to a reduction in labor for the agricultural sectors. Meanwhile, labor wages have been increasing in recent years. For these reasons China's comparative advantage has been weakened for labor-intensive products. Fishery products tell a similar story as vegetable and fruit. From 2013 to 2020, the average growth rate is estimated to be 4% per year while for the 2020-2030 period; the growth

¹⁹ China is the largest pork consumer and producer in the world. In the GTAP database, pig and pork are included in other animal products and other meat products, respectively and they accounted for the majority share of other animal products and other meat products.

rate is expected to be 3.4% per year. China's domestic oilseed output is expected to rise at a decreasing rate with an annual output growth rate of 4.47% in 2013-2020; while its annual output growth rate is expected to be 4.4 % in 2020-2030.

Table 7 Output of agricultural commodities in China (% change)

	2013-2020	2020-2030
Rice	42.97	47.62
Wheat	39.04	42.67
Other Grain products	44.74	50.66
Vegetable and Fruits	34.35	38.66
Oil Seeds	35.77	43.83
Bovine cattle, sheep, and goats, horses	61.4	67.7
Other animal products	37.56	39.22
Raw milk	29.96	28.94
Fishery products	31.91	33.96
Bovine meat products	57.8	63.18
Other meat products	32.39	34.26
Vegetable oils and fats	41	45.58

Source: Results from the study

III. Self-sufficiency rates

China's government has increased grain self-sufficiency rates over time. It is the main food security indicator from the central government's perspective. Since rice and wheat are two dominant staple foods for Chinese consumers, China's government has expressed a commitment to being self-sufficient in rice (Qian 2014). In the 12th Five-Year Plan, the government sets a 95% self-sufficiency rate for rice and wheat as an objective to maintain food security (Qian 2014). Corn is also one of the important grain products for China as an animal feed. In the GTAP's grain classification, corn is included in the 'another grain group'.

A number of studies on China's food security have estimated the country's grain

deficit²⁰ (Chen 2012; Chen 2004; Huang 1997; Kang 1998). It is useful to make a comparison of their results with the current study's results, therefore, the balance of grain demand and supply will be discussed first.

In terms of value, the projected results for 2020 show that total grain production will be 673.40 million tons and total grain consumption will be 692.878 million tons. Thus the grain deficit will be almost 20 million tons in 2020. This result is lower than the projection results of the National Food Grain Security medium and long term plan for 2008-2020 (32.5 million tons); FAO (60.5 million tons); Brown (258.4 million tons) IMPACT (41.1 million tons) (Brown 1994; Chen 2010; Kang 1998). However, this number is higher than the Huang and Yu (16 million tons) estimate (Huang 1997). In 2030, total grain production is projected to be 959.166 million tons while consumption is estimated to be over 1,027 million tons. The grain deficit is likely to increase to 67.897 million tons. The result of Brown is much higher than 67.9 million tons in 2030. Brown's projected result of China's grain deficit is 374 million tons in 2030 thus his work overestimated China's food insecurity. His high grain deficit projection result is probably due to his assumptions, which focused on China having a very high level of economic activity and a high population growth rate. The current study's result is similar to the projection results of the State Development Planning Commission (63 million tons), Zhu & Nie (63.3 million tons). The projection result is higher than the study results of Huang & Yu (45 million tons) and Zhu (25 million tons), and Kang (28 million tons) (Brown 1994; Huang 1997; Kang 1998; Zhu 1999; Zhu 1997). Grain output is predicted to increase significantly, but still cannot offset the large consumption growth rate. The possible reasons for the considerable grain consumption increases are industrial uses, such as brewing alcohol, starch production, and the pharmaceutical industry.

According to the BAU projection results²¹ (Table 8), self-sufficiency rates²² of rice, wheat, and other grain products are 98.61%, 96.8% and 96.46% in 2020, respectively.

²⁰ As the quantity results in other studies appear as percentage changes year by year, the first step is to construct 2013 quantities, which are from the Statistical Yearbook of China (Appendix 4 Table 1). From these quantities the percentage grain growth rate is extracted from GTAP's results. This allows for one to project production and consumption values.

²¹ The value of production and consumption for each grain products are provided in the Appendix 4 Table 2

²² The self-sufficiency rate is calculated by production divided by consumption.

In 2030, rice's self-sufficiency rate is 95.05%, which is just at the government target. Wheat's self-sufficiency rate is 93.82%, which is below the government target. Other grain product's self-sufficiency rate is 92.09%. The results are consistent with other studies' results, such as Chen (2012).

Table 8 The projection results of Grain self-sufficiency rates

Grain items	2020	2030	2050
Rice	98.61%	95.05%	82.25%
Wheat	96.8%	93.82%	84.97%
Other Grain	96.46%	92.09%	79.89%

Sources: Results from the study

The gap between production and consumption for corn will grow gradually; therefore the self-sufficiency rate of other grain is likely to fall at the fastest rate. Since feed uses and industry uses are expected to grow at a rapid rate, corn's domestic demand will increase much faster than its domestic supply. In the year 2050, all grain products are expected to fall below the government targets. Rice self-sufficiency will be only 82.25% and wheat self-sufficiency rate will be just 84.97%, whereas corn self-sufficiency will be less than 80%.

Specifically speaking, rice production is estimated to be 204.40 million tons in 2020 while its consumption will be 207.283 million tons. From 2020 to 2030, rice's output is expected to increase by 42% and its consumption is estimated to rise by 47%; therefore, the rice deficit is projected to increase from 2.88 million tons in 2020 to 15.118 million tons in 2030. The rice deficit is estimated to be even larger in 2050. Even though production is expected to increase by 40% from 2030 to 2050, rice consumption is expected to grow by a higher magnitude, which is 62%. The rice demand and supply are expected to be 495.680 million tons and 407.718 million tons, respectively, in 2050. The wheat demand (124.28 million tons) in 2013 is expected to increase to 173.203 million tons (39%) in 2020, 246.7 million tons (98%) in 2030 and 359.876 million tons (190%) in 2050, respectively. Over the next 36 years, compared with the production level in 2013, wheat production is likely to increase by 39% in 2020, 92% in 2030 and 185% in 2050, respectively. In 2050, wheat production is expected to be almost 1.85 times the

production level in 2013; while wheat consumption is expected be around 1.9 times the consumption level in 2013. Demand is expected to grow faster than supply, so the wheat deficit will keep increasing throughout the projection years. The deficit is likely to be 2.88 million tons, 15.12 million tons, and 54.08 million tons in 2020, 2030 and 2050, respectively.

According to Chen's projection results, China's supply and demand for wheat and rice are expected to be in balance in 2020, while the corn deficit will expand over time. He projects that China's output of corn will be 184 million tons in 2020, and consumption of corn will be much higher, at 201.25 million tons. The corn deficit is expected to be 17.25 million tons in 2020 in Chen's study. The current study's results show the corn deficit to be about 11.057 million tons, 37.536 million tons, and 310.664 million tons in 2020, 2030 and 2050, respectively. The results indicate that corn accounts for the majority of grain imports in the future. Corn is not a dominant staple food for China, but it is major feed crop. As income grows, demand for meat and livestock products bring substantial pressure on corn demand.

Table 9 The self-sufficiency rate of oilseeds and vegetable oil and fats

	2007	2020	2030
Oilseeds	50.6%	49.3%	48.1%
Vegetable oil and fats	87.2%	86.4%	85.4%

Sources: study's results

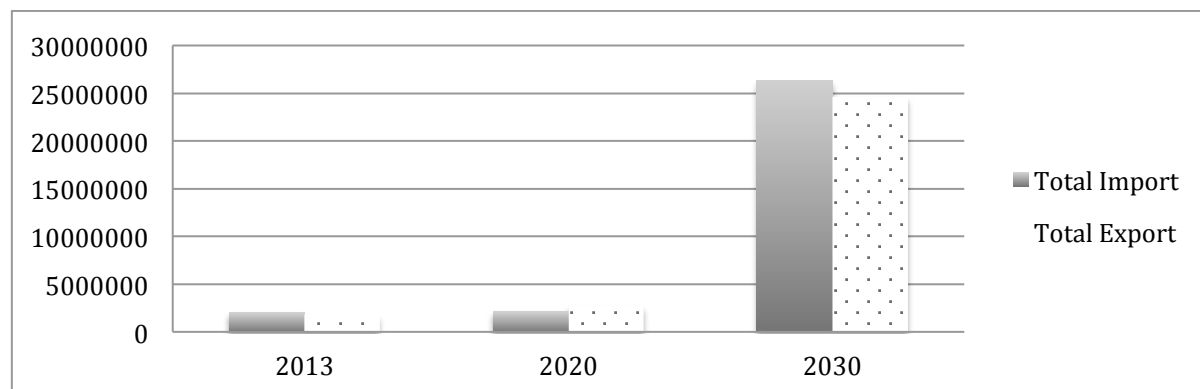
Self-sufficiency rates for oilseeds, and vegetable oils and fats are expected to decrease over the projection periods (Table 9). From 2007 to 2030, the self-sufficiency rate for oilseeds is expected to decrease from 50.6% to 48.1%. Vegetable oils and fats' self-sufficiency rate is likely to decrease from 87.2% in 2013 to 85.4% in 2030. The results are also consistent with other studies' results.

IV. Import and Export

Figure 19 indicates that China is expected to expand total import value from about 2 thousand million US dollars in 2013 to 26,3 million US dollars in 2030. Export appears a similar trend with import. In 2030, total export value is expected to achieve to

24,620,535 million US dollars in 2030. In 2013, China has small trade deficit. In 2030, the trade deficit is expected to grow to 1,674,207 million U.S. dollars.

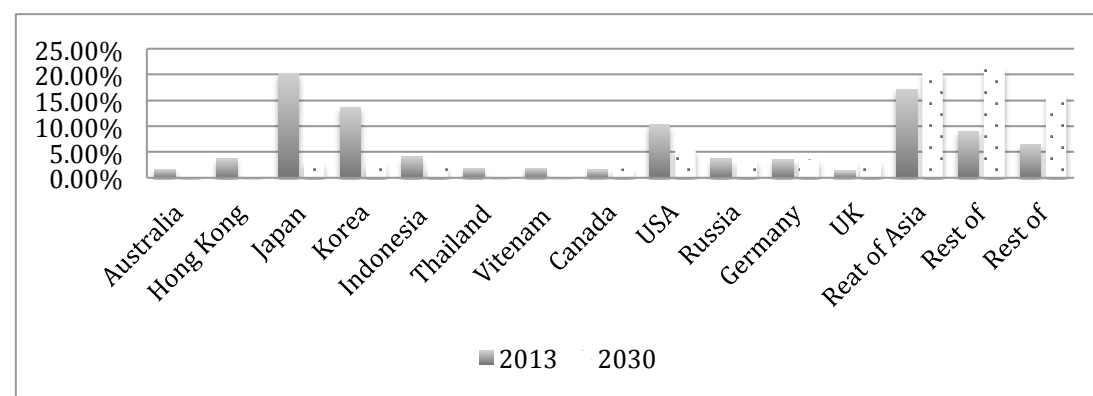
Figure 19 China's trade value 2013-2030



Sources: results from the study

Before going into the analysis of agricultural exports and imports, the study estimates the share change of China's major trade partners. The comparison for shares of the trading partners between 2013 and 2030 are given in Figure 20. Canada is becoming a more and more important trade partner with China. Australia and New Zealand account for only 1.09% of China's total imports in 2030, although they still have a great potential for growth. Russia is expected to account for 3.31% of China's total imports. The USA, replacing Japan, is likely to become the largest international supplier for China. Shares of Korea and Japan are estimated to decline significantly from 2013 to 2030. The results indicate that China's import partners are expected to be more diverse in 2030 than in 2013 which is assumed to be good for China as trade partner diversification might provide cheaper goods and thus favor trade policies for China.

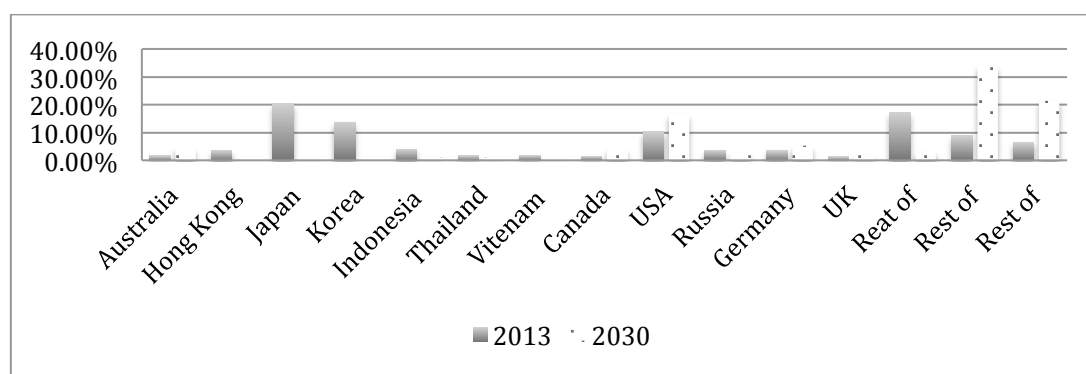
Figure 20 Direction of China's import in 2013 and 2030



Sources: results from the study

The export share of different regions in 2013 and 2030 is provided in Figure 21. The Rest of OECD is expected to account for the majority of China's exports (34.2%) in 2030, which is followed by the USA (16.67%) and Germany (5.18%). Russia and the UK are expected to maintain relatively constant shares albeit with a very slight increase in their shares of China's total exports. Overall, China is expected to expand its export markets to the rest of OECD countries and the Rest of World. The export markets are likely to be more diverse in 2030 than they are today.

Figure 21 Direction of China's export in 2013 and 2030

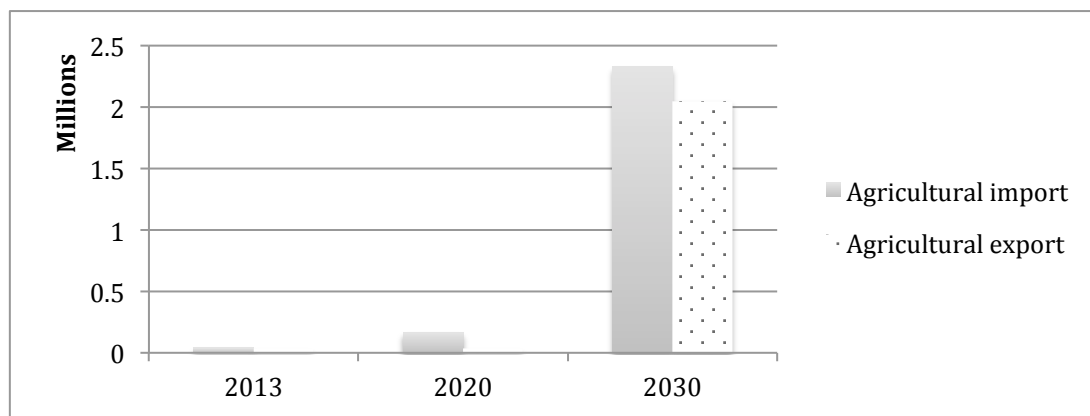


Sources: results from the study

Regarding agricultural trade, both agricultural exports and imports by China are expected to increase substantially by 2030 (Figure 22). The results of the analysis show that China's agricultural imports are expected to be higher than agricultural exports over the whole projection period thus the agricultural trade deficit is predicted to rise from 7.3 million US dollars in 2013 to 127,418 million US dollars and 280,553 million US dollars in 2020 and 2030, respectively. According to the results (Figure 23), exports of agricultural products are expected to increase at a faster rate than for machinery and equipment. Light manufacturing's export is expected to increase at a steady growth rate. On the import side (Figure 24), agricultural imports are expected to be the most imported commodity over the following decades. Machinery and equipment are expected to replace light manufacturing on the import ranking. The ranking of the rest of the top six imported sectors²³ is likely to remain constant for the BAU scenario.

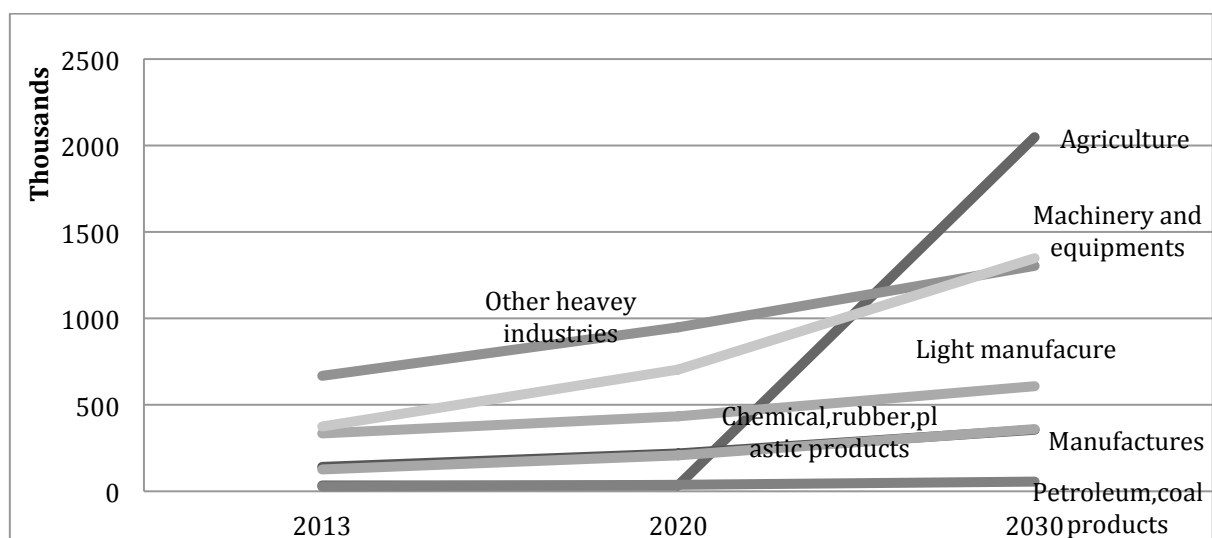
²³ The top import sectors include light manufacturing, petroleum, coal products, chemical, rubber, plastic products, other heavy industries, machinery and equipment and manufactory.

Figure 22 China's agricultural trade value in 2030



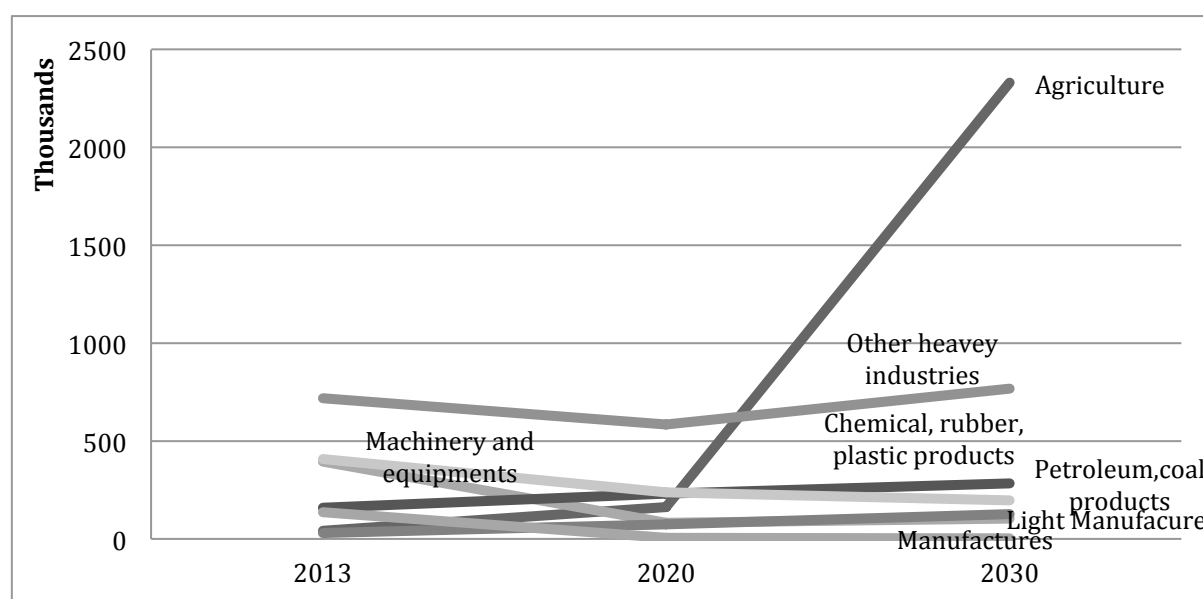
Sources: results from the study

Figure 23 China's export pattern



Sources: results from the study

Figure 24 China's import pattern



Sources: results from the study

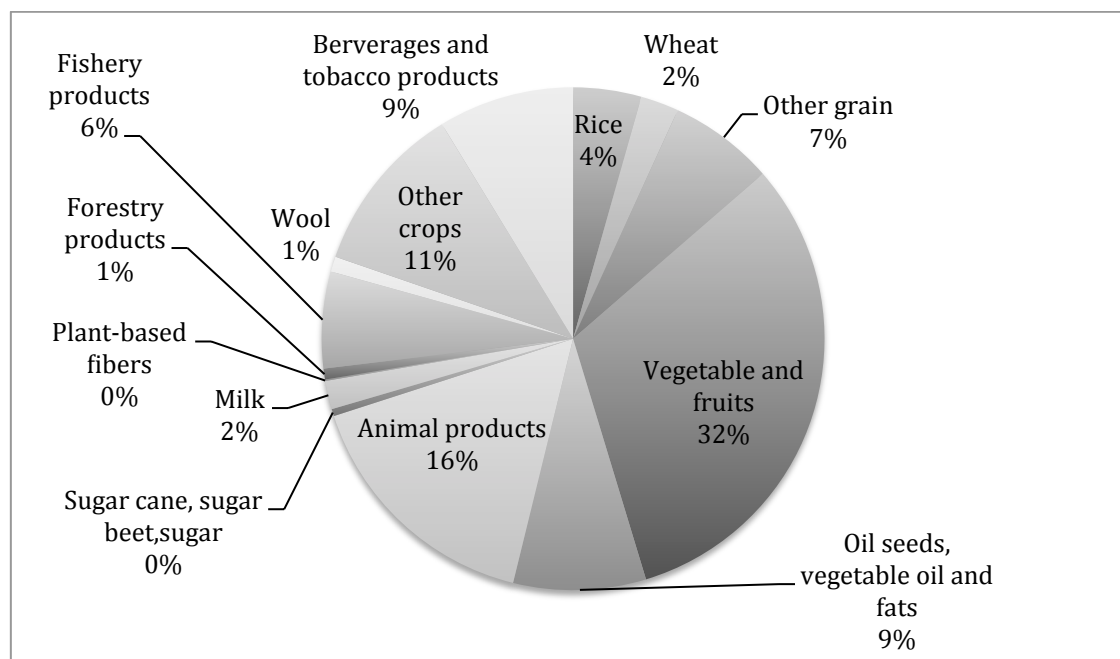
In term of real value, both imports and exports of all agricultural commodities are expected to increase from 2013 to 2030, while there is some fluctuation in the share of each commodity out of total agricultural imports and exports.

The current study determines that the highest import growth rates are expected to be for the meat and live animals' sectors. Oilseeds and Vegetable oils and fats are still the predominant imported agricultural commodities in 2030. The imports of oilseeds, such as soybean, are expected to amount to 91.53 million dollars US in 2020 and 133.149 million dollars US in 2030. The import of grain products is expected to grow rapidly in the coming decades. The import growth rates for rice, wheat, and other grains are expected to be over 50% from 2013 to 2030. According to previous analyses, China is the dominant vegetable and fruit producer in the world market. The results indicate that China's import growth rate for vegetables and fruits is higher than its export growth rate. In 2030, the export and import of vegetables and fruits are likely to achieve 208,65 million dollars US and 245,8 million dollars US, respectively. For fishery products, exports are expected to be 58,499 million dollars in 2030 while the import is 6,233 million dollars higher than export.

The import share of each agricultural commodity for 2013 and 2030 is presented in

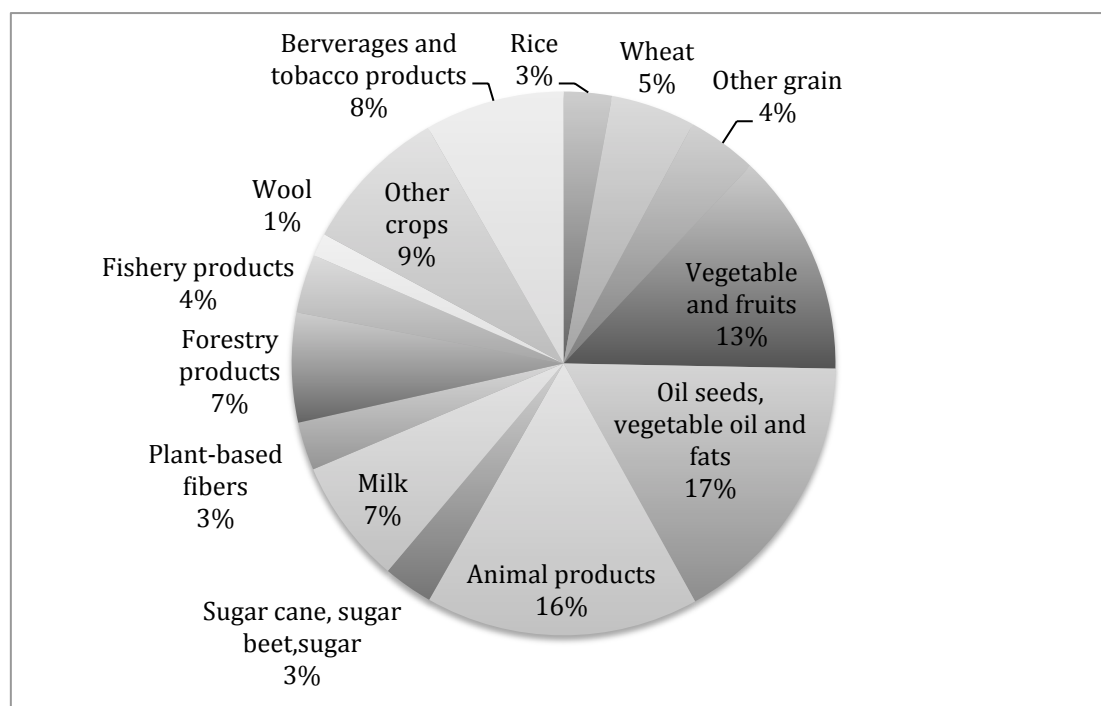
Figure 25 and Figure 26. Vegetables and fruits show a declining share of total agricultural imports, which decline from 32% in 2013 to 13% in 2030. The shares of oilseeds, vegetable oils and fats are expected to double by 2030. China is likely to increase imports of vegetable oils and fats by 2030. The import share of animal products is estimated to remain relatively constant throughout the BAU period.

Figure 25 Import share of each agri-commodity in 2013



Sources: results from the study

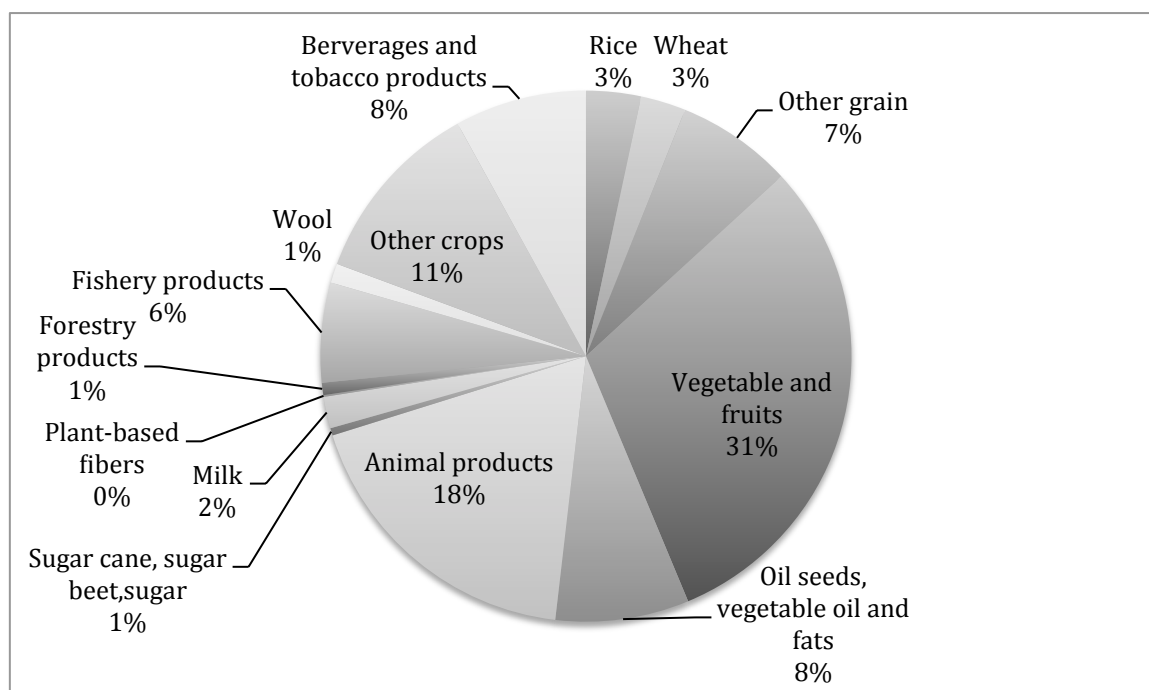
Figure 26 Import share of each agri-commodity in 2030



Sources: results from the study

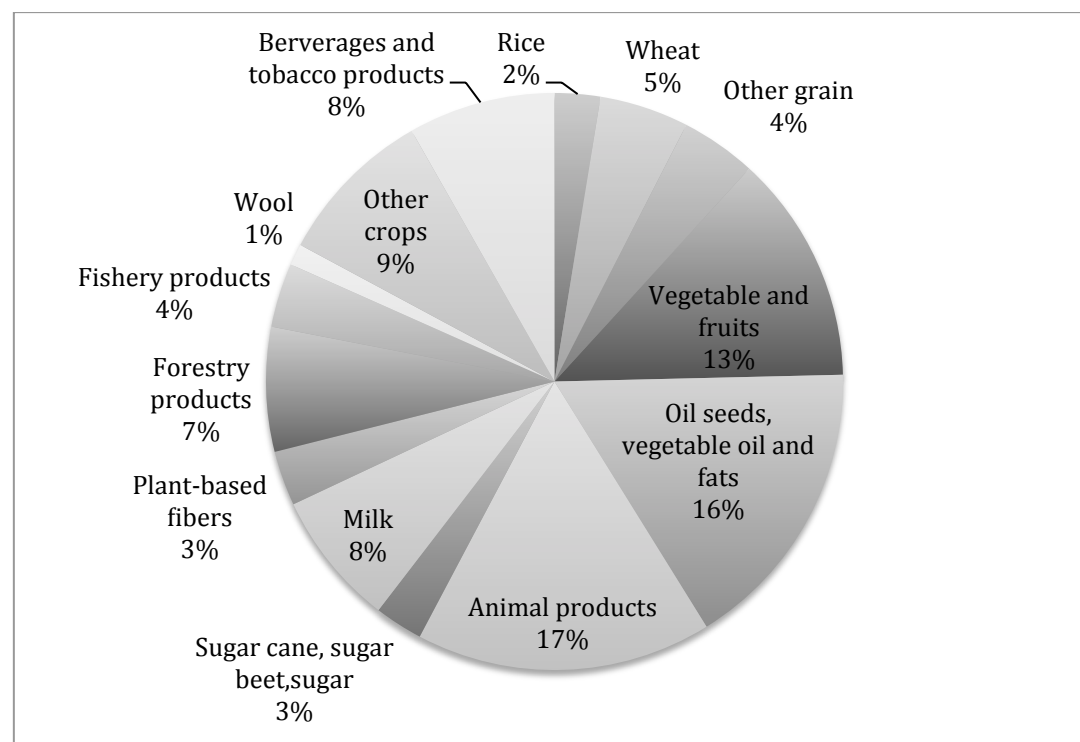
The export shares for each agricultural commodity for 2013 and 2030 are provided in Figure 27 and Figure 28. Vegetables and fruits are expected to be in the dominant position. The animal products' share shows a slight decline. Fishery products, grain products, fat and oil products are likely to have a stable share during the 2013 to 2030 period.

Figure 27 Export share of each agri-commodity in 2013



Sources: results from the study

Figure 28 Export share of each agri-commodity in 2030



Sources: results from the study

2. Arable land requirements calculation²⁴

According to the GTAP BAU scenario results, total wheat and rice consumption for 2020 and 2030 are 692.88 million tons and 1,027.063 million tons, respectively. The following arable land estimation assumes that the productivity of each unit of land is constant at the 2013 level. The minimal sown areas of rice and wheat are provided in Table 10. If the self-sufficiency rates for rice and wheat are 90%, the minimal sown areas²⁵ for rice and wheat are estimated to be 1,212.983 million mu²⁶ in 2020 and 1,760.693 million mu in 2030 and 2,727.194 million mu in 2050. After 2030, the current arable land “Red Line” policy, conserving China’s arable land above 1,800 million mu, is not enough to achieve a 90% grain self-sufficiency rate. With a 95% self-sufficiency rate for rice and wheat, the minimal sown areas of rice and wheat is calculated to be 1,280.37 million mu, 1,858.509 million mu and 2,879.022 million mu in 2020, 2030 and 2050, respectively. The higher self-sufficiency rate needs more arable land. Therefore, in 2030, the required sown areas for a 95% self-sufficiency rate for rice and wheat are higher than “Red Line” (1,800 million mu) by 58,509 million mu.

Table 10 Minimal arable land requirements

	2030	2050
Consumption in tons (000)	1,027,063	1,694,194
Production (90% self-sufficiency rate)	497,062	770,001
Land requirement in mu (000)	1,760,693	2,727,495
Production (95% self-sufficiency rate)	524,677	812,779
Land requirement in mu (000)	1,858,509	2,879,022

Sources: results from the study

²⁴ Since arable land “red line” policy provides a critical point of arable land, the study aims to assess whether this critical points are sufficiency to ensure high grain self-sufficiency rates in long term. Therefore, minimal arable land requirement estimation is projected up 2050.

²⁵ The minimal rice and wheat area calculations are determined by the following procedure: a) use rice and wheat sown areas in 2013 and outputs of rice and wheat in 2013 to calculate output per unit of land; b) the required output can be calculated by projected consumption taking into account required self-sufficiency rates; c) the minimal required arable land is calculated by required output divided by output per unit land.

²⁶ Mu is China’s land unit. 1 mu=0.067 hectare. China’s “Red Line” of arable land is 1,800 million mu.

According to the BAUS results analyses, without any agricultural productivity advancement, China is unable to achieve its grain self-sufficiency targets in 2030 and 2050. In addition, the current “Red Line” policy is not enough to produce sufficient grain to meet the 95% grain self-sufficiency rate. Thus, the arable land conservation policy should be strengthened, but it is just partial solution. Meanwhile, other agricultural policy alternatives, such as agricultural trade policy and agricultural support policy, should be attempted to improve food security.

3. Scenario analysis

Ten simulations were performed for this study. The study groups them into four blocks: (I) In the trade block, the first three experiments are shocked by the tariff rate. The last two experiments are related to free meat trade agreements with specific countries; (II) The subsidy block includes scenarios for machinery and fertilizer subsidies. (III) The TFP block addresses the situation with additional agricultural TFP improvement. (IV) The last block contains scenarios of mandated growth rates for rice and wheat. The scenario analysis will be discussed below in the sequence of the trade block, subsidy block, TFP block and mandated grain growth rate block. The present study is primarily focused on food security in China. To get more insight on each policy’s impacts on China’s food security, China’s output growth rates for the agricultural sectors, self-sufficiency rates for grain commodities, export and import performance for the agricultural sectors, and private consumption and food price changes will be discussed separately. After that, a presentation of the study’s estimates of welfare and poverty implications and GDP growth for all scenarios will be made.

I. Trade block

First, the study looks at how tariff and trade policies impact China’s food security. Under this block, the study looks at six experiments. The analysis will be presented in the order of three tariff adjustments experiments and two free trade agreement experiments.

Output growth rate

The output growth rates in 2030 under different tariff adjustment scenarios are

presented in Table 11²⁷. A reduction in the meat tariff (MTR) has a small impact on agricultural sectorial output in 2030, compared with BAU 2030. As expected, sectorial output of beef cattle, sheep and goats, horses, and beef meat products show negative effects. Beef cattle and sheep output growth rates are expected to decrease by 0.1%. The beef meat product output growth rate is expected to be lower than it is in the BAU by 0.6%. However, other animal products and other meat products are found to have increased output levels with the meat tariff reduction policies, which are 0.3% and 1.7%, respectively. This occurred because the import of beef animal products and beef meat products are higher than for other animal and meat products. Therefore, production of beef animals and meat products shrink, so as to release more production resources than from the other meat sectors. Therefore, the other animal and meat sectors show increased levels of output. For rice and wheat, the output levels are expected to increase by 0.008% and 0.03%, respectively. Other grain products are expected to have decreased output levels in the order of 0.04%. These results because the meat import expansion decreases feed grain demand domestically, thus more land and input factors are available for the wheat and rice sectors. The results indicate that the meat tariff reduction intervention is likely to have negative effects on other agricultural sector outputs, but they are not significant. For the grain tariff reduction (GTR), compared with the output growth rate in the BAU at 2030, the wheat sector and other grain sectors are expected to see a decrease in their output levels. The rice sector is likely to increase its output level. Since China is very good at producing rice, any grain tariff reduction is expected to have little effect on domestic rice production levels. The other agricultural sectors are likely to show a slight, but insignificant increase in output level. In the scenario of increasing the grain tariff (GTI), compared with output growth in the BAU at 2030, wheat and other grain product output growth rates are likely to increase by 0.002% and 0.01%, respectively, while the rest of the agricultural sectors, including the rice sector, are found to have slight declines in output levels.

²⁷ In the table, “-” indicates decline and “+” indicates increase. The rest tables follow the same rule.

Table 11 The output change compared with BAU

The output change compared with BAU			
Output Growth Rate	MTR 2030	GTR 2030	GTI 2030
Rice	+	+	-
Wheat	+	-	+
Other Grain products	-	-	+
Vegetables and Fruits	-	+	-
Oil seeds	-	+	-
Bovine cattle, sheep and goats	-	+	-
Other animal products	+	+	-
Fishery products	+	+	-
Bovine meat products	-	+	-
Other meat products	+	+	-
Vegetable oils and fats	-	+	-

Sources: results from the study

Self-sufficiency rate²⁸

Self-sufficiency rates are very important food security indicators for China's government. They believe the grain sufficiency rate must be higher than 95%. Table 12 summarizes changes in self-sufficiency rates for grain under tariff adjustment scenarios in 2030 and 2050, compared with the BAU at 2030 and 2050. If the government removes the meat tariff, the self-sufficiency rate for all grain products is likely to increase. Rice's self-sufficiency rate is expected to increase from 95.05% in BAU 2030 to 96.89% in MTR 2030. Regarding wheat, a meat tariff reduction (MTR) is expected to bring positive effects on self-sufficiency rates. In 2030, the wheat self-sufficiency rate is likely to increase from 93.82% in the BAU to 95.51% in the MTR. For both rice and wheat, the self-sufficiency rates with a meat tariff reduction policy will be higher than the government's grain security target. For other grains, such as corn, the self-sufficiency rate is expected to rise from 92.09% in the BAU 2030 to 93.93% in the MTR 2030. The

²⁸ Since current study is practically interested in grain-sufficiency rates, study will project for grain self-sufficiency rates up 2050.

other grain self-sufficiency rates are 92.09% and 79.89% in the BAU 2030 and 2050 scenarios, respectively. They are expected to increase by 1.84% and 7.76% in the MTR 2030 and 2050 scenarios, respectively.

For 2050, the positive effects of the meat tariff reduction policy are more obvious. The self-sufficiency rates for rice and wheat in the BAU 2050 scenario are much lower than government food security targets, while in the MTR 2050 scenario, both of the self-sufficiency rates are above 90%. In general, a meat tariff reduction is likely to enhance the grain self-sufficiency rates in all projection periods.

Table 12 The self-sufficiency rate for grain in 2030 and 2050 compared with BAU

The self-sufficiency Rate for grain in 2030 compared with BAU			
Simulation Exercises	Rice	Wheat	Other Grain
Meat tariff reduction	1.84%	1.69%	1.84%
Grain tariff reduction	0.00%	0.00%	0.00%
Grain tariff increase	3.76%	3.44%	3.76%
The self-sufficiency Rate for grain in 2050 compared with BAU			
Meat tariff reduction	8.11%	8.49%	7.76%
Grain tariff reduction	0.00%	-0.01%	0.00%
Grain tariff increase	18.03%	19.17%	18.18%

Sources: results from the study

The results show that a grain tariff reduction does not have significant effects on grain self-sufficiency rates. However for a grain tariff increase, the self-sufficiency rates for all grain commodities appear to indicate a considerable increase in 2030 and 2050. For instance, the rice self-sufficiency rate is expected to increase from 95.05% to 98.81% in 2030. Wheat has similar results. In 2030, the wheat self-sufficiency rate is 93.82% for the BAU in 2030 while it is expected to increase to 97.26% for the grain tariff increase in 2030. The other grain product self-sufficiency rate is expected to be higher than it is in the BAU scenario as well. In 2030, compared with the BAU, the other grain's self-sufficiency rate is expected to increase by about 3.75% if the grain tariff increases by 50%.

All the grain product self-sufficiency rates are lower than 90% in the BAU 2050 scenario, while rice, wheat, and the other grain self-sufficiency rates are expected to improve to 100%, 104% and 98% respectively for a grain tariff increase in 2050. The self-sufficiency rates for all the grain products are likely to be above government targets under the grain tariff increased scenario by 2050. Generally speaking, a grain tariff reduction does not have significant effects on self-sufficiency rates while a grain tariff increase raises China's grain self-sufficiency rates considerably. On its own, self-sufficiency is not a perfect food security indicator. To fully assess a country's food security status, the government also needs to take private consumption levels and food prices into consideration.

Import and export

Compared with the BAU 2030 scenario, the agricultural import changes for the meat tariff reduction 2030, grain tariff reduction 2030, and grain tariff increase 2030 are given in Table 13. The growth rate of import ranking is fairly constant for three scenarios. Comparing import growth rates between the BAU 2030 and the meat tariff reduction 2030, beef animals, and other animal products are expected to increase by 2.27% and 8.53%, respectively. Due to a tariff reduction, import growth rates for beef meat products and other meat products are expected to increase by 15.48% and 32.71% respectively by 2030. The import growth rates for rice, wheat and other grains are expected to decline by 2.6%, 2.7% and 0.4%, respectively, resulting in feed grain production and livestock products production to also decline. The interaction process is as follows: when the livestock sectors increase their production levels, more feed grain is required. Import and domestic production of feed grains are expected to expand. Meanwhile, feed grain (corn) and food grain (rice and wheat) compete for production resources. When more endowment factors are shifted into the feed grain sector, domestic food grain production and the resulting output level will shrink. Therefore, the import of food grain products is expected to increase. In the case of a meat tariff reduction, the government removes meat and live animal import tariffs, so the domestic livestock production levels are expected to encounter decline due to an increase in imported goods. The other sectors, with small percentage decreases in import levels, are not expected to be affected significantly.

Impacts of grain tariff interventions on the imports of each agricultural sector are

presented in Table 13. As expected, a grain tariff reduction (GTR) is likely to encourage an increase in grain imports. Compared to the grain import growth rate in the BAU at 2030, a grain tariff reduction is expected to increase rice imports from 5,461 million tons (BAU 2030) to 5,150.3 million tons (GTR 2030) and increase wheat imports from 6,836 million tons (BAU 2030) to about 7,119 million tons (GTR 2030). For other grain products, the import quantity is likely to increase from 5,194.6 million tons (BAU 2030) to 5,285.7 million tons (GTR 2030). On the contrary, a grain tariff increase (GTI) is expected to reduce grain imports by a small amount. For example, compared to the BAU 2030 scenario, the import growth rate for rice, wheat and other grain products in the GTI 2030 scenario are likely to decline by 0.9%, 1.08%, and 0.8%, respectively.

Table 13 Import growth rate change in 2030 compared with BAU 2030

Import	MTR 2030	GTR 2030	GTI 2030
Rice	-	+	-
Wheat	-	+	-
Other Grain products	-	+	-
Vegetable and Fruits	-	-	+
Oil Seeds	-	+	-
Bovine cattle, sheep, and goats, horses	+	-	+
Other animal products	+	-	+
Fishery products	-	+	-
Bovine meat products	+	-	+
Other meat products	+	-	+
Vegetable oils and fats	-	-	+

Sources: results from the study

Impacts of policy interventions on the export level of each agricultural sector are presented in Table 14. On the export side, a meat tariff reduction is expected to increase exports for the majority of agricultural products, except for fishery products. Compared with the BAU 2030 scenario, rice, wheat and other grain product output levels are expected to increase by 3.47%, 4.87%, and 1.06%, respectively. An interesting, and at first glance a counter-intuitive result shows in the beef meat, beef animal, other animal

and other meat sectors. These sectors are projected to have positive export growth rates for the MTR 2030 scenario. Thus China is likely to import more live animals in the MTR 2030 scenario, and at the same time the country will also export more processed meat in the MTR 2030 scenario.

Grain tariff changes do not result in significant effects on agricultural exports, including the rice, wheat, and other grain sectors. It is interesting that grain exports in the GTR 2030 scenario are less than they are in the BAU 2030 scenario, and grain exports in the GTI 2030 scenario are higher than they are in BAU 2030. It is likely because China imports more grain products due to the grain tariff reduction. There is sufficient grain supply in the domestic market, so China is expected to have extra grain to export. In the GTI 2030 scenario, it is the opposite case than the GTR scenario. The majority of domestic grain production has to be allocated to the domestic market, so there is less remaining for the export market. The changes in the export growth rates for the agricultural sectors due to grain tariff adjustment policies are lower than + (-) 0.01%, compared with the BAU 2030 scenario.

Table 14 Export growth rate change in 2030 compared with BAU 2030

Export	MTR 2030	GTR 2030	GTI 2030
Rice	+	+	-
Wheat	+	+	-
Other Grain products	+	+	-
Vegetable and Fruits	+	+	-
Oil Seeds	+	+	-
Bovine cattle, sheep, and goats, horses	+	+	-
Other animal products	+	+	-
Fishery products	-	-	+
Bovine meat products	+	+	-
Other meat products	+	+	-
Vegetable oils and fats	+	+	-

Sources: results from the study

Private consumption and food price

Compared with private consumption levels in the BAU 2030 scenario, private consumption levels for the majority of agricultural commodities are expected to increase in the MTR 2030 scenario (Table 15), particularly for other grain products (0.34%), oilseeds (0.69%), vegetables and fruits (0.34%), dairy products (0.21%), beef animals (0.12%), and beef meat products (0.3%). More interesting results are observed for the other meat sector products. Chinese consumers decrease their consumption for other meat products by 2.7%. Overall, private consumption is expected to increase for the majority of goods. The MTR scenario is expected to encourage Chinese consumers to increase their food consumption due to lower food prices, so that national food security is expected to improve under the MTR scenario.

Table 15 The private consumption change in 2030, compared with BAU 2030

Food items	MTR 2030	GTR 2030	GTI 2030
Rice	+	+	+
Wheat	+	+	-
Other Grain products	+	-	+
Vegetable and Fruits	+	+	-
Oil Seeds	+	+	-
Bovine cattle, sheep, and goats, horses	+	+	-
Other animal products	+	+	-
Fishery products	+	-	+
Bovine meat products	+	+	-
Other meat products	-	+	-
Vegetable oils and fats	+	+	-

Sources: results from the study

Grain tariff changes are expected to have little effect on private food consumption levels. Overall, a grain tariff reduction is expected to increase food consumption levels for the majority of agricultural good only slightly; while a higher grain tariff is predicted to decrease food consumption levels.

Table 16 The food price change in 2030, compared with BAU 2030

Food items	MTR 2030	GTR 2030	GTI 2030
Rice	-	-	+
Wheat	-	-	+
Other Grain products	-	-	+
Vegetable and Fruits	-	-	+
Oil Seeds	-	-	+
Bovine cattle, sheep, and goats, horses-	-	-	+
Other animal products	-	-	+
Fishery products	+	+	-
Bovine meat products	-	-	+
Other meat products	-	-	+
Vegetable oils and fats	-	-	+

Sources: results from the study

Table 16 shows results of the simulation for changes in commodity prices. Generally speaking, tariff reduction policies are likely to decrease food prices, resulting in the food becoming more accessible for poor people. In the case of the GTI scenario, food prices are likely to increase for the majority of food products but the resulting changes are not expected to be significant. Comparing the GTR 2030 scenario with the BAU 2030 scenario, most food prices are expected to decrease slightly. For the MTR 2030 scenario, grain product prices are likely to decrease by 0.36%-0.54% compared to the BAU 2030 scenario, resulting in less domestic demand for feed grains. The price for beef animal products and other animal products are expected to decrease by 0.46% and 0.72% in 2030, respectively. The most significant effect is shown in the beef meat sector, where the price is estimated to reduce by 1.34%. Compared to the BAU 2030 scenario, other meat product prices are likely to decrease by 0.78%. Overall, grain tariff changes are expected to have little impact on food prices while a meat tariff reduction is expected to have noticeable impacts on the price of livestock and grain products.

The following two scenarios are developed to discuss impacts of the free trade meat agreement with Australia (CAM), followed by a discussion of the free trade meat

agreement between China and Korea (CKM).

Output growth rate

Since these two experiments only shock the animal and meat sectors in one country, the changes in other agricultural sectoral outputs between the BAU scenario and the free trade agreement scenarios are insignificant. If China removes a meat import tariff for the meat imported from Australia, all meat sector outputs are expected to decline (Table 17). The beef meat sectors are expected to experience the largest impacts on output growth rates, which is about -0.01%. If Korea removes the meat import tariff for meat from China, China's meat sector outputs are expected to increase because of an increase in export demand. Beef meat and other meat sectors are most impacted in the CKM 2030 scenario.

Table 17 Output change in 2030, compared with BAU 2030

Food items	CAM 2030	CKM 2030
Rice	-	+
Wheat	-	+
Other Grain products	+	-
Vegetable and Fruits	+	-
Oil Seeds	+	-
Bovine cattle, sheep, and goats, horses -		+
Other animal products	-	+
Fishery products	-	-
Bovine meat products	-	+
Other meat products	-	+
Vegetable oils and fats	+	-

Sources: results from the study

Self-sufficiency rate

The rice and wheat self-sufficiency rates have been improved to target levels in the CAM 2030 scenario (Table 18). The self-sufficiency rates for rice and wheat are expected to reach 95.10% and 95.51% in 2030, respectively. Other grain self-sufficiency rates are likely to increase from 92.09% in the BAU 2030 scenario to 93.93% in the CAM 2030

scenario. For 2050, the self-sufficiency rates for rice, wheat, and other grains are expected to reach 90.34%, 93.58%, and 87.67%, respectively. As expected, meat import expansion is helpful to free more natural resources to rice and wheat sectors from feed grain production. Compared to the BAU 2030 scenario, Korea's free trade in meat does not change China's grain self-sufficiency rates in both 2030 and 2050. This results because Korea accounts for a relatively small share of China's meat export share in 2030; therefore, its trade policy impacts on China's grain self-sufficiency rates are negligible.

Table 18 The self-sufficiency rate for grain in 2030 and 2050, compared with BAU

The self-sufficiency Rate for grain in 2030 compared with BAU			
Simulation Exercises	Rice	Wheat	Other Grain
CAM	0.04%	1.69%	1.84%
CKM	0.00%	0.00%	0.00%
The self-sufficiency Rate for grain in 2050 compared with BAU			
CAM	8.09%	8.61%	7.77%
CKM	0.00%	-0.02%	0.00%

Sources: results from the study

Import and export

Meat trade liberalization is expected to have different impacts on exports and imports. The study addresses the export and import changes under the BAU and different trade agreement scenarios. The results are summarized in Table 19.

In the CAM 2030 scenario compared with the BAU 2030 scenario, export increases for most agricultural sectors, such as the grain, vegetables and fruits, sugar, plant-based fibers, milk, wool, vegetable oils and fats, and the dairy product sectors. For imports, the impacts on each agricultural sector are different. For instance, grains, vegetables and fruits, and the vegetable oils and fats sectors are expected to decrease their imports. Compared with the BAU 2030 scenario, imports of rice, wheat, and other grains are likely to decrease by 0.03%, 0.09%, and 0.06%, respectively. Imports of vegetables and fruits are estimated to decrease by 0.014% while vegetable oils and fats are likely to decline by 0.008%. The reason is similar to that for the results for the MTR scenarios.

For oilseeds, other crops and other meat products, both exports and imports are expected to be higher than they are in the BAU 2030 scenario, but exports are estimated to grow faster than imports. For the other meat sectors, including beef animal sectors, other animal sectors, and other meat sectors, the import growth is higher than export growth in the CAM 2030 scenario. Overall, China's tariff reduction for Australian and New Zealand meat products could expand China's agricultural exports.

Table 19 The import and export changes of CAM&CKM 2030, compared with BAU 2030

Import and Export's growth rate change	CAM2030		CKM2030	
	Import	Export	Import	Export
Rice	-	+	+	-
Wheat	-	+	+	-
Other Grain products	-	+	+	-
Vegetable and Fruits	-	+	+	-
Oil Seeds	+	+	+	-
Bovine cattle, sheep, and goats, horses	+	+	+	+
Other animal products	+	+	+	+
Fishery products	+	+	+	-
Bovine meat products	+	+	+	+
Other meat products	+	+	+	+
Vegetable oils and fats	-	+	+	-

Sources: results from the study

In the CKM scenario, the other meat product sector is most affected. Its export growth rate is expected to increase by 28.2%. The rest of the agricultural sectors do not exhibit significant effects. Overall, the import growth rate has increased slightly in the CKM 2030 scenario. If Korea increases meat demand from China, China needs to import more food to meet domestic consumption requirements. China's exports decrease in the grain, vegetables and fruits, oil seeds, sugar, plant-based fibers, other crops, milk and dairy products, and fishery products sectors. Compared with the CKM scenario, the CAM scenario is more favored in terms of China's agricultural trade surplus in 2030.

Private consumption and food price

The impacts of the meat free trade agreement on domestic private food consumption and food prices are presented in Table 20. The price results indicate that all agricultural commodity prices in the CAM 2030 scenario are expected to be lower than they are in the BAU 2030 scenario. Since the government loosens meat import restrictions, meat import expansion leads to an increase in domestic supply level which depress domestic meat prices. Prices of other agricultural sectors also are impacted indirectly. Compared to the BAU 2030 scenario, all agricultural sector prices are higher for the CKM 2030 scenario. If Korea removes meat import tariffs for China's meat products, China's meat exports are expected to increase. Meanwhile, livestock production is likely to expand to meet international demand. Meat and animal products are expected to attract more natural resources and labor, therefore other agricultural sectors have to face increasing endowment factor prices, resulting in the production in those sectors likely to decrease. In general, other agricultural commodity prices are likely to increase due to rising input costs.

Compared to the BAU 2030 scenario, domestic household consumption in the CAM 2030 scenario for the majority of agricultural commodities is likely to increase, except for other animal products and other meat products. Intriguing as these findings are, per capita consumption of other animal products and other meat products are likely to decrease, even though their price decrease. This could be due to the price reduction in those sectors not being significant and consumers allocating their food budgets to other products, which have significant price reductions. Compared to the BAU 2030 scenario, domestic household food consumption is expected to decline by a small degree under the CKM 2030 scenario. The domestic consumption decrease is in all probability caused by increasing product prices in the CKM scenario.

Table 20 Private consumption and food price change in CAM& CKM 2030, compared with BAU 2030

Food items	Private consumption		Food price	
	CAM 2030	CKM 2030	CAM 2030	CKM 2030
Rice	+	-	-	+
Wheat	+	-	-	+
Other Grain products	+	-	-	+
Vegetable and Fruits	+	-	-	+
Oil Seeds	+	-	-	+
Bovine cattle, sheep, and goats, horses	+	-	-	+
Other animal products	-	-	-	+
Fishery products	+	-	-	+
Bovine meat products	+	-	-	+
Other meat products	-	-	-	+
Vegetable oils and fats	+	-	-	+

Sources: results from the study

II. TFP block

In this simulation, it was assumed that agricultural total factor productivity (TFP) would increase by 2.5% per year over the study period. The main emphasis of the following discussion is to capture the effects of this productivity growth.

Output growth rate

Table 21 indicates that agricultural outputs are expected to increase significantly if agricultural TFP increase by an increment of 2.5% per year.

The wheat, oilseeds, other meat products and vegetable oils and fats sectors are the most affected sectors in 2030. Their output growth rates are expected to rise by 52.47%, 73.71%, 59.51%, 52.7%, respectively. Fishery products, beef meat products, and other animal product sectors also see a considerable increase in output level compared with their output growth rate in the BAU 2030 scenario. The output of rice and other grains are expected to increase by 39.01% and 37.54%, respectively. Even though agricultural TFP with a 2.5% increment is hard to achieve in the economy, the results are still

helpful in terms of investigating the impacts of productivity on agricultural output levels. The study concludes that agricultural productivity improvement significantly increases output levels.

Table 21 The output growth in Ag TFP 2030, compared with BAU 2030

	2030
Rice	+
Wheat	+
Other Grain products	+
Vegetable and Fruits	+
Oil Seeds	+
Bovine cattle, sheep, and goats, horses	+
Other animal products	+
Fishery products	+
Bovine meat products	+
Other meat products	+
Vegetable oils and fats	+

Sources: results from the study

Self-sufficiency rate

Table 22 indicates that agricultural TFP improvement promotes grain self-sufficiency rates to the target level (95%). For 2030, the total rice, wheat, and other grain consumption levels are 420,389.8 million tons, 363,278.7 million tons and 644,401.73 million tons, respectively. The outputs are 403,814.6 million tons, 352,959.36 million tons, and 601,381.79 million tons of rice, wheat, and other grain products. With the additional agricultural TFP increment, grain self-sufficiency rates in 2030 are higher than they are in the BAU 2030 scenario. For rice, the self-sufficiency rate is expected to increase from 95.05% in the BAU 2030 scenario to 96.06% in the agricultural TFP 2030 scenario. The self-sufficiency rate for wheat is likely to increase by 3.34% (93.82% in the BAU scenario; 97.16% in the agricultural TFP scenario). The self-sufficiency rate for other grain products is estimated to improve from 92.09% to 93.32%, for 2030. For 2050, the self-sufficiency rates for rice and wheat in the BAU 2050 scenario are projected to be lower than the government target. With the additional agricultural TFP

increment, the self-sufficiency rates are improved over the target level.

Production of rice is expected to rise to 597,850.349 million tons in 2050 with the additional 2.5% agricultural TFP growth per annum. The domestic consumption of rice in 2050 is expected to be 652,438.998 million tons. This means that the rice self-sufficiency rate is expected to increase from 82.25% in the BAU 2050 scenario to 91.63% in agricultural TFP 2050 scenario. In the case of wheat, the total wheat production and domestic consumption figures are expected to be 496,498.013 million tons and 512,702.242 million tons, respectively. This means that the self-sufficiency rate for wheat is will increase from 84.97% under the BAU 2050 scenario to 96.84% for the agricultural TFP 2050 scenario. As expected, the agricultural TFP enhancement results in both wheat and rice self-sufficiency rates being above government predetermined targets. Agricultural productivity advancement brings considerable positive impacts for China's national food security. Regarding other grain products, consumption and production have increased to 1,067,987.27 million tons and 946,050.944 million tons, respectively. The self-sufficiency rate for other grain products is expected to rise from 79.89% (BAU 2050 scenario) to 88.58 % (agricultural TFP 2050 scenario). Overall, the agricultural productivity advancement contributes greatly to national food security and contributes to an achievement of the government's grain self-sufficiency rate target.

Table 22 The self-sufficiency Rate for grain in 2030 and 2050 compared with BAU

	2030	2050
Rice	1.00%	9.38%
Wheat	3.34%	11.87%
Other grain	1.23%	8.69%

Sources: results from the study

Import and export

On the import side, agricultural productivity improvement is expected to increase imports in the following sectors: other grain products, oil seeds, sugar, plant-based fibers, other animal products, milk and dairy products, and beef meat sectors, while exports of those sectors are likely to increase by a higher magnitude than that of their

import growth. For rice, wheat, vegetable and fruits, beef animals, fishery products, other meat products and vegetable oils and fats, imports of those sectors are likely to decline. Those sector exports are expected to rise due to the agricultural productivity enhancement. Overall, higher agricultural productivity is expected to increase China's agricultural trade surplus.

Private consumption and food price

If the study adopts the 2.5% annual increment to the agricultural total factor productivity value, the average private consumption growth rate for agricultural products is expected to increase by 50% compared with the BAU 2030 scenario. Compared with the BAU 2030 scenario, domestic total grain consumption is estimated to be 40% higher than it is in the BAU 2030 scenario. Meat consumption is expected to rise by 49%. Consumption of oils and fats is expected to increase by 78.5%, compared with the BAU 2030 scenario. These results confirm that agricultural productivity advancement has quite a considerable impact on domestic food consumption and thus can be used to improve national food security as a higher level of agricultural production productivity could do a better job of feeding the Chinese people.

Food prices are a very important food security indicator since they influence food accessibility for low-income residents. Increasing agricultural productivity has an effect on all agricultural commodity prices. Compared with the BAU 2030 scenario, the price of grain declines by 59.43%, which can be explained by the considerable increase in grain production. The prices of livestock products are likely to decrease by 63% compared with their level in the BAU 2030 scenario. The results also indicate that the prices of oils and fats are estimated to drop by nearly 43%. Vegetable and fruit sectors are also affected to a great degree as their prices are expected to decrease by over 68%. The rest of the agricultural products are likely to see their prices decline by 21%-53%, compared with to the BAU 2030 scenario. As expected, agricultural productivity improvement leads food to become more affordable for low-income people and thus this improves national food security.

III. Subsidy block

There are a number of methods that can be employed to improve agricultural productivity, such as encouraging agricultural technological research and development,

enhancing machinery investment and use, and fertilizer application. Subsidies encourage farmers to adopt fertilizer and agricultural machines, which tend to reduce the cost of production. In this study, two subsidy experiments were conducted. They are increasing a machinery subsidy (IMS) and increasing fertilizer subsidy (IFS).

Output growth rate

As expected, both machinery and fertilizer subsidies have the intended positive effect on output levels. The results are presented in Table 23. Compared with the BAU 2030 scenario, rice's output growth rate is expected to rise by 0.075% for machinery subsidy and 0.38% for the fertilizer subsidy. For the wheat sector, compared with the BAU 2030 scenario, output levels of wheat are likely to improve by 0.08% and 0.46% in the IMS 2030 scenario and the IFS 2030 scenario, respectively. For all the grain sectors, wheat is more sensitive to agricultural subsidies than rice and other grains where in fact the output of other grains is expected to decline in the IFS 2030 scenario. This occurred because fertilizer application in China is already optimal. Therefore, increasing fertilizer has little effect on output growth. Meat sectors are expected to be more affected in the IFS scenario than in IMS scenario. In the IFS 2030 scenario, the outputs of beef meat and other meat products are expected to increase by 1.94% and 1.8%, respectively. The machinery subsidy leads to an additional 0.2% and 0.21% output growth for beef meat products and other meat products, respectively. Comparing the IMS 2030 scenario with the BAU 2030 scenario, outputs are expected to increase by 0.14% and 0.26% for the beef animal sector and the other animal sector. Contrary to expectations, increasing the fertilizer subsidy is not helpful in improving the output levels of the other grain sector, vegetables and fruits sector, vegetable oils and fats and the oilseeds sector.

Table 23 The output growth rate change in IMS &IFS 2030, compared with BAU2030

Food items	IMS 2030	IFS 2030
Rice	+	+
Wheat	+	+
Other Grain products	+	-
Vegetable and Fruits	-	-

Oil Seeds	+	-
Bovine cattle, sheep, and goats, horses	+	-
Other animal products	+	+
Fishery products	+	+
Bovine meat products	+	+
Other meat products	+	+
Vegetable oils and fats	-	-

Sources: results from the study

Self-sufficiency rate

The impacts on grain self-sufficiency rates of increasing the machinery and fertilizer subsidies are presented in Table 24. Generally speaking, the machinery subsidy is quite helpful in improving self-sufficiency rates for rice and wheat.

Compared to the BAU 2030 scenario, the self-sufficiency rates are expected to improve by 3.77% and 3.46% for rice and wheat, respectively, in the IMS 2030 scenario. The fertilizer subsidy is estimated to have positive effects on self-sufficiency rates as well, but to a smaller degree. Compared with the BAU 2030 scenario, the self-sufficiency rates for rice and wheat are likely to be enhanced by 0.08% and 0.2%, respectively.

In the IMS 2050 scenario, rice output is estimated to reach as high as 407,995.576 million tons in 2050 and consumption is estimated to be 406,749.549 million tons in the same year. Therefore, the self-sufficiency rate for rice is expected to increase from 82.25% in the BAU 2050 scenario to 100.31% in the IMS 2050 scenario. However, the fertilizer subsidy does not greatly improve the rice self-sufficiency rate for the same period. Compared with the BAU 2050 scenario, the rice self-sufficiency rate is likely to increase by only 0.2%. For the wheat sector, production and consumption of this crop are 306,150 million tons and 293,830 million tons in IMS 2050, respectively. Wheat's self-sufficiency is estimated to increase from 84.97% for the BAU 2050 scenario to 104.19% for the IMS 2050 scenario. The fertilizer subsidy is expected to increase the wheat self-sufficiency rate from 84.97% in the BAU 2050 scenario to 85.27% in the IFS 2050 scenario, which is still below the government's target. In the case of other grain

products, the self-sufficiency rate is estimated to improve under both scenarios, but the machinery subsidy tends to have larger positive effects than does the fertilizer subsidy. The self-sufficiency rate for other grain products is expected to be 97.13% and 80% for the IMS 2050 scenario and the IFS 2050 scenario, respectively. The results indicate that increasing the machinery subsidy contributes to an improvement in the national grain self-sufficiency rate above the government's target. Compared with the machinery subsidy, the fertilizer subsidy is likely to have smaller effects on grain self-sufficiency rates.

Table 24 The self-sufficiency Rate for grain in 2030 and 2050 compared with BAU

Food items	IMS		IFS	
	2030	2050	2030	2050
Rice	3.77%	18.05%	0.08%	0.15%
Wheat	3.46%	19.22%	0.20%	0.30%
Other grain	17.24%	0.00%	0.12%	0.10%

Sources: results from the study

Import and export

With regard to the impacts of the fertilizer subsidy on China's agricultural exports, particularly noticeable impacts are shown for other meat products (22.7%), rice (18.9%), beef meat products (14.2%), and beef cattle, sheep, goats, and horses (14.6%). The changes for the rest agricultural sectors compared with the BAU 2030 scenario are presented in Table 25. Imports of rice are expected to decline by 14.3% while imports of wheat and other grain products are likely to decline by 11% and 5.6%, respectively. For the IFS scenario, imports for the rest of the agricultural sectors are expected to experience insignificant changes.

Compared with the impacts of the fertilizer subsidy, the machinery subsidy is expected to have little impact on exports and imports. In the IMS 2030 scenario, the rice sector's export will likely increase by 2.5% and imports are expected to decrease by 1.9%. Wheat and other grain sectors experience smaller impacts than does the rice sector. The other meat sector is the most effected sector with a 3.3 % export increase and a 1.4% import decrease. In general, both fertilizer and machinery subsidy lead a majority of the

agricultural sectors' exports to increase and imports to decrease.

Table 25 The export and import change in IMS 2030& IFS 2030, compared with BAU 2030

Import and Export's growth rate change	IMS 2030		IFS 2030	
	Import	Export	Import	Export
Rice	-	+	-	+
Wheat	-	+	-	+
Other Grain products	-	+	-	+
Vegetable and Fruits	+	-	+	-
Oil Seeds	+	+	-	+
Bovine cattle, sheep, and goats, horses	-	+	-	+
Other animal products	-	+	-	+
Fishery products	-	+	-	+
Bovine meat products	-	+	-	+
Other meat products	-	+	-	+
Vegetable oils and fats	+	-	-	+

Sources: results from the study

Private consumption and food price

The impacts on private consumption levels and food prices of the IFS and IMS scenarios are presented in Table 26. The price for rice, wheat and other grains are likely to decrease by 0.3%, 0.1% and 0.3% in the IMS 2030 scenario, respectively. Compared with price changes in the machinery subsidy exercise, the fertilizer subsidy generates larger impacts on food prices. Due to a fertilizer subsidy, the prices of the aforementioned products are expected to decrease by 2.7%, 1.2%, and 2.4%, respectively. Compared with the BAU 2030 scenario, the prices for beef cattle, sheep, goats, and horses, other animal products, beef meat products, and other meat products are likely to decrease by 0.4%, 0.4%, 0.2% and 0.3% in the IMS 2030 scenario, respectively. The prices for the same products are estimated to decline by 3.4%, 2.6%, 1.8% and 2.4% in the IFS 2030 scenario, respectively. Compared with the BAU 2030 scenario, a machinery subsidy does not have significant effects on prices and private consumption levels for the oilseeds and vegetable oils and fats sectors.

The results for the vegetables and fruits sector in the IMS 2030 scenario indicate that the prices for vegetables and fruits are expected to decrease by 0.8% and private consumption levels for these products are likely to decrease by 0.2%, compared with the BAU 2030 scenario. A price reduction for vegetables and fruits does not lead to an increase in consumption. This might be explained because several factors influence private food consumption, such as income and prices of other food, and non-food, products. In the IFS scenario, the prices for vegetables and fruits are estimated to decline by 2.1%. Since prices of those products decline, private consumption of vegetables and fruits are expected to increase by 1.6% in IFS scenario. Moreover, both subsidies are likely to have little impacts on fishery products.

Table 26 Private consumption and food price change in IMS& IFS 2030, compared with BAU 2030

Food items	Price		Private consumption	
	IMS 2030	IFS 2030	IMS 2030	IFS 2030
Rice	-	-	-	+
Wheat	-	-	-	-
Other Grain products	-	-	-	+
Vegetable and Fruits	-	-	-	+
Oil Seeds	-	-	+	+
Bovine cattle, sheep, and goats, horses	-	-	+	+
Other animal products	-	-	-	+
Fishery products	-	-	-	-
Bovine meat products	-	-	-	+
Other meat products	-	-	+	+
Vegetable oils and fats	+	-	-	+

Sources: results from the study

IV. Mandated rice and wheat growth rate

Output growth

The output impacts due to the mandated rice and wheat growth rates are summarized in Table 27. For the rice mandated growth rate (MRG) scenario, its output growth rate is expected to be 20.6% higher than it is in the BAU 2030 scenario. The wheat and other grains sectors are expected to have higher output growth than the rice sector, which are 35.1% and 21.5%, respectively. The results suggest that the other agricultural sectors' yields are expected to rise as well. For the beef animals, other animals, beef meat products, and other meat sectors output levels are likely to increase by 17.4 %, 34.3%, 26.7% and 48.3%, compared with the BAU 2030 scenario. The output of oilseeds, and vegetable oils and fats are expected to be higher than they are in the BAU 2030 scenario by 50.2% and 49.3%, respectively. Overall, a mandated rice growth rate policy has had significant and positive impacts on major agricultural products.

The wheat mandated growth rate (MWG) experiment shows similar results (Table 27), but at a different level of magnitude. Under the WMG 2030 scenario, the wheat sector is the most affected sector as expected. Wheat output is likely to increase by 20.6% compared with the BAU 2030 scenario. For the rice and other grains sectors, their outputs do not show large improvement, as they are only 1.7% and 1% larger, respectively. For the beef animal sector, other animal sector, beef meat sector, and other meat sector increases were experienced in the order of 17.4%, 34.4%, 26.7% and 48.3% in the MRG 2030 scenario, respectively, compared with their growth rates in the BAU 2030 scenario. Compared with the MRG 2030 scenario, the output growth effects of these sectors are less significant in the WRG 2030 scenario. For the beef animal sector, other animal sector, beef meat sector, and other meat sector increases were expected in the order of 1.0%, 3.2%, 1.4% and 5.3% in the MWG 2030 scenario, respectively, compared with their growth rates in the BAU 2030 scenario.

The rest of the agricultural sectors were expected to have positive yield changes in both scenarios but the changes were found to be of a smaller magnitude in the MWG scenario (Table 27).

Table 27 The output growth rate change (%) in MRG &WRG 2030, compared with BAU2030

Output growth rate	MRG 2030	WRG 2030
Rice	20.6	1.7
Wheat	35.1	20.6
Other Grain products	21.5	1.0
Vegetable and Fruits	19.3	1.0
Oil Seeds	50.2	1.2
Bovine cattle, sheep, and goats, horses	17.4	1.0
Other animal products	34.3	3.2
Raw milk	34.4	3.0
Fishery products	3.2	0.2
Bovine meat products	26.7	1.4
Other meat products	48.3	5.3
Vegetable oils and fats	49.3	1.4

Sources: results from the study

Self-sufficiency rate

Table 28 The self-sufficiency Rate for grain in 2030 & 2050, compared with BAU

Food items	MRG		WRG	
	2030	2050	2030	2050
Rice	23.24%	23.91%	-0.01%	-0.03%
Wheat	0.71%	1.25%	29.18%	37.99%
Other grain	0.32%	0.44%	-0.02%	-0.03%

Sources: results from the study

The self-sufficiency rates that change under the MRG and MWG scenarios are presented in Table 28. These results suggest that the mandated rice and wheat growth rate policies are expected to improve the target grain (rice or wheat) commodity self-

sufficiency rates significantly, while little effects will be felt on the remaining grain product self-sufficiency rates. For instance, if the government sets the rice mandated growth rate at 2.05% per annum, the rice self-sufficiency rate is expected to improve from 95.05% to over 100% for 2030 and from 82.25% to 106.16% for 2050. Wheat and other grain self-sufficiency rates are expected to increase by 0.71% and 0.32% for 2030 and 1.25% and 0.44% for 2050, respectively. Therefore, wheat's self-sufficiency rate is still below the government's target for both 2030 and 2050 in the MRG scenario.

If the government sets a mandated growth rate for the wheat sector, the self-sufficiency rate for wheat is likely to improve by 29.18% for 2030 and 37.99% for 2050, which are above the government's wheat security target; however, the opposite results are shown for the rest of the grain sectors. The self-sufficiency rates for rice and other grains are likely to decrease by 0.01% and 0.02% for 2030, respectively. For 2050, the self-sufficiency rates for both rice and other grain products are expected to decline by 0.03% in the MWG 2050 scenario.

Import and export

The crop with a government mandated growth rate policy is likely to have an impressive increase in export volume and a considerable decrease in the volume of imports. For the MRG 2030 scenario, compared with the BAU 2030 scenario, volume for both rice and wheat are expected to decline in terms of imports and expand in terms of exports, while for other grain products, both exports and imports are likely to increase (Table 29). However, the export growth rate (39.54%) is expected to be higher than the import growth rate (0.12%). The other agricultural products are expected to exhibit similar effects as rice and wheat, except for oilseeds. Imports of oilseeds are likely to increase by 27.3% and exports are expected to increase by 8.2%. Thus, the import growth rate is much higher than its export growth rate.

The results are more complex for the MWG 2030 scenario as in this case there is likely to be a decrease of wheat imports and an increase in wheat exports while the opposite results show up in the rice sector. It might be because more inputs are shifted to the wheat sector from the rice sector due to the mandated wheat growth rate policy. For the other grains sector, even though both imports and exports are likely to increase, the import growth rate (2.09%) is higher than its export growth rate (0.27%). For all the

meat and livestock sectors, imports are expected to increase and exports are expected to decrease in the MWG 2030 scenario.

Table 29 The export and import change in MGR 2030& MWR 2030, compared with BAU 2030

Import and Export's growth rate change	MRG 2030		MWG 2030	
	Import	Export	Import	Export
Rice	-	+	+	-
Wheat	-	+	-	+
Other Grain products	+	+	+	+
Vegetable and Fruits	-	+	+	+
Oil Seeds	+	+	+	-
Bovine cattle, sheep, and goats, horses	-	+	-	+
Other animal products	-	+	-	+
Raw milk	-	+	-	+
Fishery products	+	-	+	-
Bovine meat products	-	+	-	+
Other meat products	-	+	-	+
Vegetable oils and fats	-	+	-	+

Sources: results from the study

Private consumption and food price

Table 30 presents private consumption levels and food price changes for different grain mandated growth scenarios (MWG & MRG) 2030 and the BAU 2030 scenario. Generally speaking, the majority of agricultural products and food commodities have consumption volumes that are expected to increase as a result of the policy interventions. Chinese consumers are predicted to consume more food under both the MRG 2030 and MWG 2030 scenarios, but the consumption of the majority of agricultural goods are increased more significantly under the rice mandated growth scenario.

In the MRG 2030 scenario, rice and wheat consumption is expected to increase 84.48% and 20.5%, respectively. Other grain product consumption rates will increase by

28.63%. The estimation of the nation's overall demand for meat, animal products, oilseeds and vegetable oil and fat commodities would be higher than they proved to be under the BAU 2050 scenario by 14%- 37%. For instance, private consumption for vegetable and fruits is expected to increase by 16% in the RMG 2030 scenario and by 1.11% in the WMG 2030 scenario. The consumption of oilseeds is likely to increase by 21% in the RMG 2030 scenario and by 0.67% in the WMG scenario. For beef animals and beef meat sectors, the levels of private consumption are expected to increase by 29% and 32%, respectively, while private consumption levels are likely to increase by 2.6% and 3.7%, respectively, in the MWG 2030 scenario.

Table 30 Private consumption and food price change in MRG & MWG 2030, compared with BAU 2030

Food items	Private consumption		Food price	
	MRG 2030	MWG 2030	MRG 2030	MWG 2030
Rice	+	+	-	-
Wheat	+	+	-	-
Other Grain products	+	+	-	-
Vegetable and Fruits	+	+	-	-
Oil Seeds	+	+	-	-
Bovine cattle, sheep, and goats, horses	+	+	-	-
Other animal products	+	+	-	-
Fishery products	-	-	+	+
Bovine meat products	+	+	-	-
Other meat products	+	+	-	-
Vegetable oils and fats	+	+	-	-

Sources: results from the study

Both MRG and MWG scenarios are expected to decrease overall food prices, except for fishery products. Price effects of the MRG scenario are larger than similar effects for the MWG scenario. The study provides estimates of prices that are expected to decline by 16%, 21% and around 30% for vegetables, oilseeds and livestock products, respectively in the MRG scenario. The MWG scenario is expected to have a moderate influence on food prices with the prices of rice and other grain products are expected to decline by

0.65% and 0.96%, respectively. The price for oilseeds and vegetable oils and fats are expected to increase by 1.05% and 1.54%, respectively. For meat and livestock sectors, beef cattle, sheep, goats, and horses (5.2%) and the other animal sector (9.27%) are expected to experience a larger price reduction than the beef meat (1.64%) and other meat sectors (8.1%).

The consumption volume and price changes for fishery products appear to be of the opposite direction to the other agricultural sectors. In both the MRG and MWG scenarios, private consumption of fishery products is expected to decrease while the prices for fishery products are predicted to increase by 2030, compared with the BAU 2030 scenario.

V. GDP implication

The effects on China's GDP of all the simulations are presented in Table 31. Tariff reduction and free trade agreements are expected to have moderately positive implications for China's GDP growth. If the government attempts to improve grain self-sufficiency rates by imposing high grain tariffs, China's GDP is estimated to be lower than it is in the BAU 2030 scenario. Agricultural productivity improvement is expected to improve China's GDP significantly. Machinery and fertilizer subsidies are expected to increase GDP slightly. Rice mandated growth rate is likely to increase GDP growth by 13%, compared with the BAU 2030 scenario. Compared with the MRG 2030 scenario, a mandated wheat growth rate is expected to bring moderate impacts on China's GDP, which is only 1.15% higher than it is in the BAU 2030 scenario.

Table 31 China's GDP changes of difference simulations in 2030, compared with BAU 2030

	GDP 2030
MTR (Meat tariff reduction)	+
GTR (Grain tariff reduction)	+
GTI (Grain tariff increases by 50%)	-
CAM (China-Australia free meat agreement)	+
CKM (China-Korea free meat agreement)	+
Ag TFP (Ag TFP increases by 2.05%)	+

IMS (Increase machinery subsidy)	+
IFS (increase fertilizer subsidy)	+
MRG (Mandated rice growth rate)	+
MWG (Mandated wheat growth rate)	+

Sources: results from the study

VI. Welfare implication

In the GTAP model, each region's representative agent aims to maximize the level of utility. When a policy is changed, the agent calculates a change in income level. The changed income level affects the scale of savings and consumption for each commodity so that the marginal utility of consumption is the same across all commodities. In this case, agents use prices to clear the market in the decision-making process. In free trade experiments, the welfare level of agents in one region would improve, while the welfare level of a trading partner would likely decrease. The welfare changes for China under different scenarios are presented in Table 32.

In the MTR scenario, for China and its major meat trade partners, the gains and losses are not spread evenly. China is expected to face a considerable decline in total welfare while Australia and New Zealand (a meat exporter to China) and Japan (meat importer from China) are expected to experience a welfare increase. Canada, Russia, and Korea are expected to obtain benefits in this case.

In the cases of the GTR and GTI scenarios, China's welfare will not experience significant changes (Table 38). China appears to gain slightly if the government increases the grain tariff. If the grain tariff is removed, then the opposite result is expected to result.

Increasing fertilizer and machinery subsidies are expected to lead to a significant loss of total welfare for China. For two free trade meat agreement scenarios, compared with welfare in the same period for the BAU scenario, China is expected to experience a welfare loss in 2030 if it removes the meat import tariff for Australia and New Zealand. On the other hand, Australia and New Zealand's welfare are expected to improve by 2030, compared to the same period under the BAU scenario. It is worth mentioning, that this free trade meat agreement is expected to generate positive welfare effects for

China in 2050. The CKM scenario welfare change indicates that China is expected to gain throughout the projection period, resulting from Korea removing all meat import tariffs for China's animal and meat products. Results for this scenario showed that this free trade meat agreement results in a win-win situation for both China and Korea.

Table 32 China's welfare implications of difference scenarios, compared with BAU

	Welfare effects
MTR (Meat tariff reduction)	-
GTR (Grain tariff reduction)	-
GTI (Grain tariff increases by 50%)	+
CAM (China-Australia free meat agreement)	+
CKM (China-Korea free meat agreement)	+
Ag TFP (Ag TFP increases by 2.05%)	+
IMS (Increase machinery subsidy)	-
IFS (increase fertilizer subsidy)	-
MRG (Mandated rice growth rate)	+
MWG (Mandated wheat growth rate)	+

Sources: results from the study

Increasing agricultural TFP is expected to bring significant welfare gains for China. In the case of rice and wheat mandated growth rates, China is also likely to experience considerable welfare gains. Overall, for scenarios of agricultural TFP improvement, free trade meat agreements with both Australia and Korea and grain mandated growth rates, China gains welfare from these policy interventions. In the cases of the meat tariff reduction, grain tariff reduction, fertilizer subsidy and machinery subsidy, China's welfare is seen to decline.

VII. Poverty implication

Table 33 Poverty implication (percentage change)

Poverty implication 2030				
	Unskilled labor wage	GDP growth rate	U	Y
Meat tariff reduction	0.16	-0.096	-0.017	-0.11
Grain tariff reduction	0.00083	-0.00028	-0.00004	-0.00031
Ag TFP increase by 50%	74.95	20.73	25.28	22.02
Grain tariff increase by 50%	-0.0004	0.00012	0.00001	0.00013
Increase machinery subsidy	-0.44	-0.18	-0.075	-0.19
Increase fertilizer subsidy	-1.55	-0.94	-0.333	-0.98
Rice to mandate growth rate for 2.04% per year	33.78	15.25	15.43	16.41
Wheat to mandate growth rate for 2.04% per year	2.48	1.42	1.44	1.56
China-Australia and New Zealand meat free trade	0.0075	-0.0033	-0.00052	-0.0035
China- Korea meat free trade	-0.00081	0.00106	0.00033	0.0012

Sources: results from the study

An attempt has also been made to capture the poverty implications from the study (Table 33). U and Y define the per capita utility of aggregate household expenditures and regional household income respectively. In the agricultural TFP, MRG, MWG and CKM scenarios, both U and Y are positive for China. This implies that China's household expenditures and incomes have increased. Moreover, in the case of the agricultural TFP and MRG scenarios, U and Y have improved considerably. While for the experiments of the MTR, GTR, IMS, IFS and CAM scenarios, Y and U are insignificant negative numbers. The impacts on unskilled labor are further analyzed to investigate the poverty aspects of the analysis. The results for the scenarios of MTR, GTR, agricultural TFP, RMG, WMG and CAM indicate that the unskilled labor return is higher than the GDP growth rate for China in 2030. This reflects a reduction in poverty. But for the scenarios of IMS and IFS, both unskilled labor's wage and GDP have negative growth rates and the unskilled labor's wage is the lower of the two. In the case of the CKM and GTI scenarios,

household expenditures and incomes improved in China, with the improvement making a significant impact on the poorer section of the population. Thus, both CKM and GTI scenarios are helpful for poverty alleviation in China.

In summary, without any policy interventions, China's grain self-sufficiency rate is projected to be far below the government's targets. China is expected to experience a huge agricultural trade deficit in 2030 and agricultural commodity consumption rates that more and more rely on international markets. The ranking of the most important agricultural export and import commodities are relative stable throughout the projection periods.

Under the current agricultural productivity level, the current quantity of arable land is not enough to secure the government's target for grain self-sufficiency (95%) in 2030. The "Red Line" policy for arable land is not enough to meet government's grain security target in 2030; moreover, limited land resources are available for China to reclaim. To safeguard national food security given this situation, government policy interventions appear necessary.

According to projected results from this study, improving agricultural productivity (agricultural TFP) is beneficial for China's food security because it increases economic growth, all agricultural sectors' outputs, agricultural product exports, grain self-sufficiency rates, China's total welfare and domestic food consumption. Meanwhile, it is also helpful for poverty alleviation. Agricultural productivity improvement is expected to decrease domestic food prices and agricultural product imports. Overall, China's national food security is expected to improve significantly under the agricultural TFP 2030 scenario. A meat import tariff reduction scenario is likely to improve grain self-sufficiency rates, as well as domestic food consumption resulting in a decrease in food prices. Even though China's welfare is expected to decrease under the MTR scenario, meat tariff reduction still helps China's government to achieve its grain security target and enhance domestic food consumption. Lower food prices in the MTR 2030 scenario leads to food being more accessible to the poorer residents. Grain tariff adjustments are expected to have little effect on China's welfare. Grain tariff reductions are helpful in improving food accessibility, but they are not helpful in improving grain's self-

sufficiency rates. On the contrary, an increasing grain tariff policy is expected to meet the government's grain self-sufficiency targets, but the domestic food consumption will decrease and food prices will increase. Therefore, if the government aims to safeguard grain self-sufficiency by increasing grain import tariffs, it is not helpful to improve national food security. Compared with a free trade meat agreement with Korea (CKM), a reduced meat import tariff for Australia is expected to bring more benefits to China's food security. China is predicted to increase the majority of its agricultural commodities' output levels, improve grain self-sufficiency rates, gain welfare, decrease food prices and increase private food consumption levels with the CAM scenario. In addition, the CAM scenario is helpful for poverty alleviation in China. Conversely, the China-Korea free trade meat agreement is not expected to benefit China's food security, even though China's meat exports will be simulated. Opposite to expectations, machinery and fertilizer subsidies do not improve returns to unskilled labor. The two subsidies improve grain self-sufficiency rates but at the expense of a considerable total welfare loss. Mandated grain growth rates are expected to have significant positive impacts on important food security indicators. In addition, the policies are beneficial for poverty alleviation, as well as farmers' income and national welfare, which are expected to improve for both MRG and MWG scenarios.

Chapter 7 Summary and Conclusion

Ensuring that food security is a focus for all the countries in the world a major development strategy for China is to promote economic development, maintain social stability and achieve a national self-sufficiency rate for basic food ingredients (Zhou 2010). With rapid economic development and growing urbanization, an increasing amount of cultivated land is becoming occupied by construction for urban development and transportation infrastructure (Deng et al. 2006). China's food production capacity is constrained by the limited availability of land and water resources (Zhou 2010). China's agricultural productivity is 46% of the average world productivity value. However, rapid income growth and a large population base lead to a substantial level of domestic demand for agricultural commodities. In addition, China's agricultural trade deficit has been rising for some years now. This is particularly true for grain products, as China became a net importer of grain in 2010, and this trend is expected to continue for the foreseeable future. Thus it puts pressure on China's food security target of 95% for rice and wheat self-sufficiency rates. Given China's large population size, the attainment of food security has become both a national and global issue. Population growth and the increase in meat consumption that comes with economic development will rapidly increase demand, while natural disasters, resource availability, technology growth, and policy can all affect supply. The stability of food security therefore presents a great challenge, with a need to consider many complex factors simultaneously. In this backdrop, the current study objective is to investigate China's food security situation in 2030 and investigate the impacts of alternative policies on food security.

In this study, the GTAP framework and the version 8 database are used to provide estimated impacts of different policy interventions designed to address China's food security situation. The GTAP model contains 129 regions and 57 commodity sectors. For the purposes of the current study, the 57 commodity sectors and 129 regions are aggregated into 36 sectors and 16 regions. A recursive process is employed to project the model's results to the year 2030. The current study addresses various scenarios to estimate the impact of food security policies in China. A number of scenarios are based on agricultural tariff adjustments; agricultural subsidy supports, agricultural productivity improvements, and mandated grain production growth rates. Effects of

these policies on the nation's food security are measured using nine indicators, including agricultural outputs, agricultural imports and exports, grain self-sufficiency rates, food prices, private household food consumption figures, as well as China's economic growth rate, values for national welfare change, poverty implications, and factor returns to unskilled labor.

The results from this study suggest that China is expected to achieve a grain self-sufficiency level of a little above 90% by the year 2030, but less than 90% by the year 2050. Without any policy intervention in the Business as Usual (BAU) scenario the self-sufficiency rate for rice is expected to be 82.25% and for wheat the rate will be 84.97% by 2050. The total value of agricultural imports and exports are expected to increase substantially. In addition, the current "Red Line" arable land protection policy (1,800 million mu) is determined to be insufficient to allow for the production of enough grain by the year 2030 to meet the desired 95% self-sufficiency rate. Moreover, it is not enough to meet 90% (2,727.495 million mu) and 95% (2,879.022 million mu) self-sufficiency rates by the year 2050. Study results indicate that arable land should be strictly protected for food production against pressure from industrialization and urbanization. However, it is only part of the food security solution. Therefore, policy interventions are required to ensure that China's food security targets are met.

Agricultural and trade policy impacts on the Chinese economy were estimated for this study. The MTR (meat tariff reduction) has a greater impact on China's food security than the GTR (grain tariff reduction). With respect to the MTR, outputs of rice and wheat are expected to increase substantially, thus the grain self-sufficiency rates are expected to improve by 2030 and to be above 90% in 2050. The GTR scenario produces few positive effects on grain self-sufficiency rates and agricultural trade values while there is a marginal negative impact on society welfare. Compared with the GTR, a GTI (grain tariff increase) is expected to raise the grain self-sufficiency rates considerably for both 2030 and 2050. In 2030, with the GTI policy, the rice and wheat self-sufficiency rates are expected to increase to 98.8% and 97.2% in 2030, respectively. All the grain product self-sufficiency rates are estimated to be over 95% in 2050. However, national food prices are expected to increase and private food consumption is expected to decline. The poor food buyers will be mostly affected, since the food is unaffordable,

resulting in larger malnourished population.

In this study we have captured the impact of two recent free trade agreements signed by China. The CAM (China-Australia meat free trade agreement) results in greater positive effects on China's food security than the CKM (China-Korea meat free trade agreement). CAM results indicate an increase in private consumption and a decrease in food prices; while the CKM appears to present the opposite results. The results of the various subsidy scenarios indicate a mix of impacts on China's food security. The IMS (increasing machinery subsidy) has a much greater impact on China's food security than the IFS (increasing fertilizer subsidy). In the case of the IMS, major grain product (rice and wheat) self-sufficiency rates are expected to improve by 3.5% by 2030 and by 18.5% by 2050. On the other hand, the IFS policy results in only a marginal increase (0.14% increase) by 2030 and (0.2% increase) by 2050. However, China's total welfare and factor returns to unskilled labor are expected to decrease notably for both IMS and IFS. In the case of a mandated rate of growth for rice (MRG) and a mandated rate for wheat (MWG), it appears that these are effective in encouraging an improvement in the self-sufficiency rates of the grain target policy. These policies also reveal a substantial increment in output levels. Wages of unskilled labor and national welfare under both policies are likely to increase. Under the agricultural total factor productivity scenario (Ag-TFP), the agricultural sectors are expected to have a considerable increase in output levels. Imports of agricultural commodities are expected to decrease while exports of agricultural commodities are expected to increase. These impacts will also help to reduce food prices and stimulate food consumption. Factor returns to unskilled labor are also expected to increase considerably.

Policy recommendations

A couple of strategic options were found to ensure grain security in China based on the current study.

To attain China's grain security target in 2030 and 2050, China must preserve and even increase its grain production areas. The government should restrict the conversion of arable land for other purposes. Even though the Chinese government has developed a series of arable land protection policies, such as the "Red Line" policy, current farmland

reserves seem incapable of maintaining grain self-sufficiency rates at the target level by 2030 and 2050. In addition to keeping arable land in agriculture rather than allowing it to be diverted for other uses, the government should encourage the reclamation of abandoned residential areas so that the land can once again be used for food production. Rural governments should strictly define and enforce land use rights. Well-defined land use rights will result in a sound land market, as well as promoting a rational allocation of land resources. It is worth noting that the minimum rice and wheat areas required to meet the 95% and 90% self-sufficiency rates in 2050 under current levels of productivity are 2,879.022 mu and 2,729.495 mu respectively.

Since China's agricultural production and thus supply are subject to limited natural resources, it is widely accepted that imports of foods from the international market will be unavoidable. Since China has joined the WTO, China's food market has become more integrated into the world market²⁹. Since grain products are all exempted in all free trade agreements with China³⁰, it has been argued that China should decrease its grain import tariff to better meet domestic demand. The results of this study indicate that grain tariff adjustments are in fact not to a good policy option. Feed grains compete for resources with food grain, therefore a free trade in meat policy is likely to release more available production resources into the food grain sectors than other policies. Instead of reducing grain tariffs, governments should focus on this meat trade policy as a meat tariff reduction is more effective in enhancing China's food security than tariff adjustments for grain. Australia and New Zealand are expected to become important meat and livestock suppliers of China thus a China-Australia free trade agreement is under negotiation.

In recent years, the government of China has made great efforts to increase budget contributions to support machinery and fertilizer subsidies³¹. This study concludes that the government might be better to adjust both machinery subsidy and fertilizer subsidy investments to moderate growth rates in the near term. It could shift its budget to agricultural technology and research development (R&D), which contributes substantial

²⁹ For more details, please see Chapter three.

³⁰ For more details trade policies, please see chapter two.

³¹ For more details agricultural subsidy and support programs, please see chapter two

agricultural TFP improvement.

If the central government aims to minimize their dependence on international markets, domestic agricultural production capacity expansion has to rely on increasing yield per unit area, given the shrinking arable land base. Several studies suggest that returns from agricultural R&D is promising (Fan et al. 2002; Zhang and Fan 2004). Moreover, R&D plays an important role in countering soil erosion, and soil loss due to degradation and natural disasters (Li and Li 2014). For a long period, agricultural research and technology investment in China has been underfunded. In many cases, farmers have had limited access to new agricultural technology. China's agricultural productivity can be increased considerably if conventional technologies are widely applied. Therefore, the government should make an effort to promote the application and extension of existing technologies. The government also could try to transfer new agricultural technologies from the developed world to help domestic farmers to improve their productivity. In summary, improving investment in agricultural technology and research development is a crucial step to take to improve food security in the face of limited and declining agricultural resources. Meanwhile, the quality of farmer training programs should be improved. This program also contributes to a substantially increase in agricultural TFP. These programs include farm equipment use and maintenance; use of straw and organic manures; integrated pest management; field leveling; deep plowing; transplanting techniques; and crop marketing.

Since farmers make up a large proportion of China's population, protecting farmers' incomes should be taken into consideration when the government implements new policies. To encourage domestic farmers to produce more food, farmers incomes must be improved and strongly protected (Chen 2009). At the same time, rising food prices are likely to affect the food intake of the lower income groups. A mandated grain growth rate strategy such as offered in this study might be beneficial in increasing farmers' incomes and thus in reducing grain prices. This intervention is a strategic option in extraordinary circumstances. To ensure the achievement of the target of self-sufficiency rates, an increase in farmers' incomes and a reduction in grain prices, the government could set a mandated growth rate to target grain crops in the short run.

Limitations and further consideration

Based on these results, there are few areas of further research that could be pursued. The current study applies a multiregional CGE, while future research could apply single country CGE models with SAM to generate more comprehensive information about the poverty implications of chosen policies. In the single country CGE model, households could be further classified by income level. This allows for an analysis to examine the interrelationships between food consumption and income levels. Another future study could be undertaken using a dynamic CGE model to determine if there was a difference in results as compared to the present study. The current study has not included environmental impacts associated with policy alternatives. It is well known that livestock and crop production activities generate a lot of GHG (greenhouse gas) emission. Thus, future research might also integrate an assessment of environmental impacts for several policy scenarios.

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Appendix Appendix 1

The share of China's top five markets on fishery products (2002-2013)

	Top five export markets	Total exports	% of top five markets of total
2002	4,013,990,398	4,480,132,667	90%
2003	4,411,405,923	5,236,829,866	84%
2004	5,324,650,795	6,631,302,206	80%
2005	5,735,149,345	7,511,297,583	76%
2006	6,541,401,218	8,949,361,320	73%
2007	6,480,974,320	9,230,099,673	70%
2008	6,726,099,274	10,088,078,714	67%
2009	6,625,954,097	10,222,517,272	65%
2010	8,225,257,328	13,198,079,977	62%
2011	10,150,283,166	16,969,048,505	60%
2012	10,692,041,315	18,122,340,989	59%
2013	10,930,006,679	19,433,091,016	56%

Source: UN Comtrade 2013 (Unit: \$ US)

Appendix 2

57 sectors in GTAP 8 database and sectoral aggregation

Original sector #	Original Sectors	Aggregated Sector #	Aggregated Sectors
1	Paddy rice	1	Paddy rice
2	Wheat	2	Wheat
3	Cereal grains nec	3	Cereal grains nec
4	Vegetables, fruit, nuts	4	Vegetables, fruit, nuts
5	Oil seeds	5	Oil seeds
6	Sugar cane, sugar beet	6	Sugar cane, sugar beet
7	Plant-based fibers	7	Plant-based fibers
8	Crops nec	8	Crops nec
9	Bovine cattle, sheep and goats, horses	9	Bovine cattle, sheep and goats, horses
10	Animal products nec	10	Animal products nec
11	Raw milk	11	Raw milk
12	Wool, silk-worm cocoons	12	Wool, silk-worm cocoons
13	Forestry	13	Forestry
14	Fishing	14	Fishing
15	Coal	15	Mining sectors
16	Oil		
17	Gas		
18	Minerals nec	16	Minerals nec
19	Bovine meat products	17	Bovine meat products
20	Meat products nec	18	Meat products nec
21	Vegetable oils and	19	Vegetable oils and fats

	fats		
22	Dairy products	20	Dairy products
23	Processed rice	21	Processed rice
24	Sugar	22	Sugar
25	Food products nec	23	Food products nec
26	Beverages and tobacco products	24	Beverages and tobacco products
27	Textiles	25	Light Manufactory
28	Wearing apparel		
29	Leather products		
30	Wood products		
31	Paper products, publishing		
32	Petroleum, coal products	26	Petroleum, coal products
33	Chemical, rubber, plastic products	27	Chemical, rubber, plastic products
34	Mineral products nec	28	Other heavy industries
35	Ferrous metals		
36	Metals nec		
37	Metal products		
38	Motor vehicles and parts		
39	Transport equipment nec		
40	Electronic equipment		
41	Machinery and equipment nec	29	Machinery and equipment nec
42	Manufactures nec	30	Manufactures nec
43	Electricity	31	Electricity
44	Gas manufacture, distribution	32	Gas manufacture, distribution
45	Water	33	Water
46	Construction	34	Construction
47	Trade	35	Transportation & Communication
48	Transport nec		
49	Water transport		
50	Air transport		
51	Communication		
52	Financial services nec	36	Other services
53	Insurance		
54	Business services nec		
55	Recreational and other services		
56	Public Administration, Defense, Education, Health		
57	Dwellings		

The original GTAP database is from Narayanan G et al. (2012)

https://www.gtap.agecon.purdue.edu/databases/v8/v8_sectors.asp

Appendix 3

129 countries and regions in GTAP 8 database and regional aggregation

Number	Original regions	Aggregated regions
1	Australia	Australia & New Zealand
2	New Zealand	Australia & New Zealand
3	View/Hide Rest of Oceania	Rest of World
4	China	China
5	Hong Kong	Hong Kong
6	Japan	Japan
7	Korea Republic of	Korea Republic of
8	Mongolia	Rest of Asia
9	Taiwan	Rest of Asia
10	View/Hide Rest of East Asia	Rest of Asia
11	Cambodia	Rest of Asia
12	Indonesia	Indonesia
13	Lao People's Democratic Republic	Rest of Asia
14	Malaysia	Rest of Asia
15	Philippines	Rest of Asia
16	Singapore	Rest of Asia
17	Thailand	Thailand
18	Viet Nam	Viet Nam
19	View/Hide Rest of Southeast Asia	Rest of Asia
20	Bangladesh	Rest of Asia
21	India	Rest of Asia
22	Nepal	Rest of Asia
23	Pakistan	Rest of Asia
24	Sri Lanka	Rest of Asia
25	View/Hide Rest of South Asia	Rest of Asia
26	Canada	Canada
27	United States of America	USA
28	Mexico	Rest of OECD

29	View/Hide Rest of North America	Rest of World
30	Argentina	Rest of World
31	Bolivia, Plurinational Republic of	Rest of World
32	Brazil	Rest of World
33	Chile	Rest of OECD
34	Colombia	Rest of World
35	Ecuador	Rest of World
36	Paraguay	Rest of World
37	Peru	Rest of World
38	Uruguay	Rest of World
39	Venezuela	Rest of World
40	View/Hide Rest of South America	Rest of World
41	Costa Rica	Rest of World
42	Guatemala	Rest of World
43	Honduras	Rest of World
44	Nicaragua	Rest of World
45	Panama	Rest of World
46	El Salvador	Rest of World
47	View/Hide Rest of Central America	Rest of World
48	View/Hide Caribbean	Rest of World
49	Austria	Rest of OECD
50	Belgium	Rest of OECD
51	Cyprus	Rest of World
52	Czech Republic	Rest of OECD
53	Denmark	Rest of OECD
54	Estonia	Rest of OECD
55	Finland	Rest of OECD
56	View/Hide France	Rest of OECD
57	Germany	Germany
58	Greece	Rest of OECD
59	Hungary	Rest of OECD

60	Ireland	Rest of OECD
61	Italy	Rest of OECD
62	Latvia	Rest of World
63	Lithuania	Rest of World
64	Luxembourg	Rest of OECD
65	Malta	Rest of World
66	Netherlands	Rest of OECD
67	Poland	Rest of OECD
68	Portugal	Rest of OECD
69	Slovakia	Rest of OECD
70	Slovenia	Rest of OECD
71	Spain	Rest of OECD
72	Sweden	Rest of OECD
73	United Kingdom	UK
74	Switzerland	Rest of OECD
75	View/Hide Norway	Rest of OECD
76	View/Hide Rest of EFTA	Rest of World
77	Albania	Rest of World
78	Bulgaria	Rest of World
79	Belarus	Rest of World
80	Croatia	Rest of World
81	Romania	Rest of World
82	Russian Federation	Russia
83	Ukraine	Rest of World
84	View/Hide Rest of Eastern Europe	Rest of World
85	View/Hide Rest of Europe	Rest of World
86	Kazakhstan	Rest of World
87	Kyrgyzstan	Rest of World
88	View/Hide Rest of Former Soviet Union	Rest of World
89	Armenia	Rest of World
90	Azerbaijan	Rest of World

91	Georgia	Rest of World
92	Bahrain	Rest of World
93	Iran Islamic Republic of	Rest of World
94	Israel	Rest of World
95	Kuwait	Rest of World
96	Oman	Rest of World
97	Qatar	Rest of World
98	Saudi Arabia	Rest of World
99	Turkey	Rest of OECD
100	United Arab Emirates	Rest of World
101	View/Hide Rest of Western Asia	Rest of World
102	Egypt	Rest of World
103	Morocco	Rest of World
104	Tunisia	Rest of World
105	View/Hide Rest of North Africa	Rest of World
106	Cameroon	Rest of World
107	Cote d'Ivoire	Rest of World
108	Ghana	Rest of World
109	Nigeria	Rest of World
110	Senegal	Rest of World
111	View/Hide Rest of Western Africa	Rest of World
112	View/Hide Central Africa	Rest of World
113	View/Hide South Central Africa	Rest of World
114	Ethiopia	Rest of World
115	Kenya	Rest of World
116	Madagascar	Rest of World
117	Malawi	Rest of World
118	Mauritius	Rest of World
119	Mozambique	Rest of World
120	Tanzania United Republic of	Rest of World
121	Uganda	Rest of World

122	Zambia	Rest of World
123	Zimbabwe	Rest of World
124	View/Hide Rest of Eastern Africa	Rest of World
125	Botswana	Rest of World
126	Namibia	Rest of World
127	South Africa	Rest of World
128	View/Hide Rest of South African Customs Union	Rest of World
129	View/Hide Rest of the World	Rest of World

The original GTAP database is from Narayanan G et al. (2012)

<https://www.gtap.agecon.purdue.edu/databases/regions.asp?Version=8.211>

Appendix 4

Table 1

Grain production and consumption in 2013 (1000 ton)

	Production	Consumption
Rice	142965	145055
Wheat	120580	124281
Other Grain	208190	213141
Total	471735	482477

Sources: China's NBS (2014)

Table 2

BAU					
Year	China (000ton&%)	Rice	Wheat	Other Grain	Total
2020	Production	204,403.59	167,658.39	301,333.69	673,395.67
	Consumption	207,283.60	173,203.16	312,391.09	692,877.84
	Self-sufficiency rate	98.61%	96.80%	96.46%	NA
2030	Production	290,479.99	231,450.69	437,235.18	959,165.86
	Consumption	305,598.20	246,693.26	474,771.97	1,027,063.44
	Self-sufficiency rate	95.05%	93.82%	92.09%	NA
2050	Production	407,717.72	305,792.66	670,019.19	1,383,529.56
	Consumption	495,680.29	359,876.13	838,637.22	1,694,193.63
	Self-sufficiency rate	82.25%	84.97%	79.89%	NA

Sources: results from the study

Table 3

Other countries welfare changes in MTR			
Country	2020	2030	2050
Meat exporters			
Australia & New Zealand	65.38	233.69	610.88
Canada	64.2	190.6	87.87
USA	588.95	1302.87	-8381.91
Russia	12.1	475.35	4.35
Meat importers			
Hong Kong China	-4	-25.42	-5.1
Japan	-69.69	-312.55	4756.45
Korea	-42.34	-183.99	229.35

Sources: results from the study

Table 4

Australia's welfare change in China-Australia meat free trade			
Welfare	2020	2030	2050
Australia & New Zealand	89.73	138.6	-113.98

Sources: results from the study

Table 5

Korea's welfare change in China-Korea meat free trade			
Welfare	2020	2030	2050
Korea	15.14	13.74	31.74

Sources: results from the study