Economic Analysis of China's Agricultural Policies: A Case Study on Policy Reforms of Corn

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(Degree)
博士（学術）

(Date of Degree)
2021-09-25

(Date of Publication)
2022-09-01

(Resource Type)
doctoral thesis

(Report Number)
甲第8169号

(URL)
https://hdl.handle.net/20.500.14094/D1008169

Doctoral Dissertation

Economic Analysis of China's Agricultural Policies: A Case Study on Policy Reforms of Corn

中国の農業政策に関する経済分析：トウモロコシの政策の事例を中心に

July, 2021

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Acknowledgements

This dissertation is the culmination of three years' work during my doctoral study at Kobe University. Completing this dissertation, I am deeply indebted to many people for their inspirations, supports, and encouragement during my postgraduate years.

With sincere gratitude, I would like to express my most profound appreciation to my supervisor: Professor Atsushi Koike, for providing the necessary information and the direction of this dissertation. It is also deeply acknowledged that he gave me the golden opportunity to take this wonderful Ph.D. project and steered out this project successfully by his insightful leadership and the profundity of his knowledge, and he provided me with kind endless help and support from its start to the end.

I would also like to show my deepest acknowledgments to Professor Masato Yamazaki, faculty of Nagoya University, for his encouragement, creative and comprehensive advice until this work came into existence. From the inception of my Ph.D. project to its completion, he devoted so much to my study when I felt difficulty moving forward sometimes during the writing of my papers and this dissertation because of certain immature ideas. I will always remember those enjoyable and thought-provoking discussions with him, which brought him many trips from Nagoya/Kyoto to Kobe and always turned out to be several hours long, and which led me to the completion of some papers and this dissertation.

The project was also greatly assisted by the contributions made by Professor Yueying Mu, faculty of China Agricultural University, to whom I would like to express my deep thanks for her generous advice on not only the writing of this dissertation but also my life in Japan. Professor Mu was also my promoter, who encouraged me to take this Ph.D. project and embrace various experiences overseas.

I would also like to underscore the contributions of specific knowledge preparation made by Professor Toshimori Otazawa and Professor Hajime Seya, and of valuable suggestions proposed by Professor Shunsuke Segi, to the writing of this dissertation. In addition, I would like to thank my family, friends, lab members, and lab assistant: Mrs. Akiko Yoshikawa, who also helped bring the dissertation into form.

Last but not least, financial support from the China Scholarship Council is gratefully acknowledged.

"What's past is prologue" (William Shakespeare). Meeting them during my doctoral period was a treasure that fate bestowed. All their inspirations and supports will always encourage me to explore, challenge, and overcome in my future life.

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Rokkodai, Kobe

Summer 2021

Abstract

Sufficient agricultural supply is at the basis of the development of the national economy in China. Supply shocks like African Swine Fever (ASF) may cause insufficient agricultural supply in China. The agricultural sectors of China are standing at the crossroad of reform. Chinese officials have been launching a supply-side structural reform. Agricultural policies are powerful tools to continuously deepen the reform of the supply-side structural reform in agriculture. In this dissertation, the topic is research on the economic effects of agricultural policies on the agricultural sectors, corresponding downstream sectors, and China's economy by taking corn as an example. Under this topic, feasible agricultural policies for further reform in the future are explored. The policies are analyzed, simulated, and evaluated to quantify their effects on the agricultural sectors, corresponding downstream sectors, and the economy of China by taking corn as an example.

The dissertation with seven chapters is set out as follows. In Chapter 1, the backgrounds and significance of the research program are analyzed as preparation before this research to explore the reasons of doing this research and explore what significance the research shows. Additionally, some concepts concerning agriculture are redefined for clear understandings. After these preparations, the evaluation and future scenarios of agricultural policy under WTO rules are introduced in China in Chapter 2. This chapter is to show the main historical and current policies applied to agriculture, the WTO rules and disputes on agriculture, and possible future scenarios in agriculture of China. This chapter also shows a discussion on scenarios of agricultural policies under WTO rules when the insufficient domestic supply of some agricultural products appears in China. After the discussion in Chapter 2, agricultural supplies, divided into the domestic supply and the foreign supply (or import), are analyzed. This analysis provides the understanding of conditions of agricultural supply in China, which to some extent determines whether some policies should be applied to support domestic agricultural production or agricultural imports in China. Chapter 3 analyzes the domestic supply by discussing the agricultural classification in Chinese and investigating its movement and agricultural sufficiency under agricultural policies. Chapter 4 analyzes the agricultural import, including the analyses of the development of agricultural imports in China, the substitution between domestic goods and imports, and the export of China’s partner countries of trade. Additionally, this chapter contains an introduction to the methodology of panel data analysis to support the practice of our model in this chapter. When agricultural products suffer shortages, importing may be a feasible choice. Because an agricultural price widely affects agricultural sectors and even the economy, it makes sense to measure the impact of import prices on domestic prices. Chapter 5 investigates the volatility of agricultural prices under its policies to explore the relationships between domestic and import markets of China. In this chapter, the general conceptual framework of price volatility and its transmission between domestic and import markets of China are introduced, and then how the price theory of rational expectations works in our framework is introduced as well. Then, a statistical method is applied to analyze the price movements and volatility of agricultural products in China. Furthermore, empirical analyses are applied to quantify the volatility and its transmission between the import price and domestic one. Additionally, this chapter includes an introduction of the methodology of multivariate time series analysis for price volatility to support the practice of our model in this chapter. After the analysis of agricultural prices, a CGE (Computable general equilibrium) analysis is constructed to make some simulations on future scenarios of agricultural policies in China that I investigate in the above chapters to compare their economic effects on the agricultural sectors, corresponding downstream sectors, and the economy. In this chapter, I construct a SAM (Social accounting matrix) for China and a CGE model to simulate these policies. Then, the parameters for this study are introduced. On the basis of the above works, I

get the simulation results from the model and make a sensitivity analysis to check the robustness of the results. Finally, Chapter 7 summarizes the findings of this research and highlights policy implications according to the findings.

By the analysis in these chapters, the conclusions have been drawn as below. Firstly, the evaluation of China's agricultural policy reflects its process of reform for agricultural marketization and trade liberalization. However, China is still complained of violating WTO rules by implementing excessive agricultural support by the U.S. In this context, when the domestic supply of some agricultural products is not sufficient to support their demand, relaxation of imports to increase imports may be an optional way. Secondly, even with the support of agricultural policies, China's domestic supply of some agricultural products like corn has made significant progress; however, their domestic supply may still be insufficient to support their demand. Thirdly, by taking the example of corn, I find China's agricultural import has gradually increased to reach its quota, which implies increasing its imports means relaxation in its import policies. In addition, imported corn has a larger substitution for China's corn, which can promote imports. Countries mainly import corn from 6 countries, including Argentina, Brazil, Canada, the USA, Ukraine, and Russia, and China mainly imports from the USA and Ukraine; however, some countries, including the USA maybe not the origin with sufficient corn for China. Fourthly, by taking the example of corn, I find the volatility has a larger amplitude in import price than domestic price of corn, and after the change from stockpiling policy to subsidy policy, it gets larger in domestic corn price. In addition, before the change, the volatility in import price affects domestic prices; however, after the change, it shows significant effects of the volatility in domestic price on import price. Fifthly, for China, increasing corn imports by tariff reductions or quota level increases have a wide economic impact on China's industries, corn and its downstream industries in particular. In addition, increasing corn imports does not necessarily lead to welfare growth, and regarding welfare growth, it is a more feasible way to increase corn imports by quota level expansion.

According to these results, I suggest: firstly, it is recommended to avoid further strong support or stimulus policies to expand domestic agricultural production, and focus on the maintenance of current agricultural resources and insuring agricultural supply by promotion of productivity and by imports; secondly, it is necessary to diversify sources of agricultural imports for sufficient agricultural supply, optionally by the considerable measures: construction of a global agricultural supply information system, cooperation with potential partner countries, development of overseas agriculture, and promotion of WTO agreements on agricultural export restrictions; thirdly, when suffering potential shortages in domestic supply of some agricultural varieties, increasing import by expanding import quotas is a more feasible way.

Key words: Agricultural policies, Economic effects, Armington model, VAR-BEKK-GARCH, CGE

Abstract in Japanese

適切な農業供給は、中国における国民経済発展の基盤である。アフリカ豚コレラ（ASF）のような供給ショックは、中国で不十分な農業供給を引き起こす可能性がある。中国の農業部門は改革の岐路に立って、中国当局は供給側の構造改革を開始している。農業政策は、農業における供給側の構造改革の改革を継続的に深めるための強力なツールである。本稿では、トウモロコシを例として、農業部門、対応する下流部門、および中国経済に対する農業政策の経済的影響に関する研究がトピックになっている。このトピックの下で、私は将来のさらなる改革のために実行可能な農業政策を探求したいと思っている。トウモロコシにとると、政策は分析、シミュレーション、評価、農業部門、対応する下流部門、および中国経済への影響が定量化されている。上記の分析により、結論を導き出し、いくつかを提案した。

本研究は、7章から構成されている。第一章では、この調査の前の準備としての調査プログラムの背景と重要性を分析し、調査を行う理由と、調査が示す重要性を論じている。その次、農業に関する概念を明確に再定義されている。第二章では、中国がWTO規則に基づく農業政策の評価と将来のシナリオを紹介する。農業に適用されて主な歴史的および現在の政策、農業に関するWTO規則と紛争と将来の可能性を示す。そして、中国で一部の農産物の国内供給が不適切である場合のWTO規則に基づく農業政策のシナリオについて説明する。その次、国内供給と海外供給（または輸入）に分けられた農業供給を分析されている。この分析は、中国における農業供給の状況を理解し、中国の国内農業生産または農業輸入を支援するための政策を適用すべきかどうかをある程度に決定されている。第三章では、中国における農業分類について議論し、農業政策の下で、その動きと農業の適切性を調査することにより、国内供給を分析する。第四章では、中国における農業輸入の発展、国内財と輸入の代わりに、および中国の貿易相手国の輸出の分析を含む農業輸入を分析する。また、モデルの実践をサポートするためのパネルデータ分析の方法論の概要が含まれている。農産物が不足している場合で、輸入は実行可能な選択かもしれないことを説明する。農業価格は農業部門や経済にさえも大きく影響するため、輸入価格が国内価格に与える影響を測定することは理由となっている。第五章では、中国の国内市場と海外市場の関係を調査し、その政策の下で、農業価格の変動性を調査にする。具体的には、価格ボラティリティの一般的な概念フレームワークと、中国の国内市場と海外市場の間の伝達を紹介し、また合理的な期待の価格理論が私たちのフレームワークでどのように機能するかについても紹介する。その次に、統計的手法

を適用して、中国の農産物の価格変動とボラティリティを分析する。また、経験的分析を適用して、輸入価格と国内価格の間のボラティリティとその伝達を定量化されている。本章のモデルの実践をサポートするために、価格ボラティリティの多変量時系列分析の方法論の紹介が含まれている。農業価格を分析した後、第六章では、CGE 分析によって調査した中国の農業政策の将来のシナリオについていくつかのシミュレーションを行い、農業部門、対応する下流部門、および経済に対する経済効果を比較しようとしている。中国の SAM (社会会計マトリックス) と CGE (計算可能一般均衡) モデルを構築して、これらの政策をシミュレートする。第六章では、本研究のパラメータを紹介する。上記の作業に基づいて、モデルからシミュレーション結果を取得し、感度分析を行って結果の口バスト性を確認されている。第七章では、本研究の調査結果を要約し、その結果に応じたポリシーへの影響を強調してする。

以上のような分析により、次のように結論を導き出す。第一に、中国の農業政策の評価は、農業の市場化と貿易自由化のための改革のプロセスを反映している。しかし、中国は依然として米国による過度の農業支援を実施することで WTO 規則に違反していると不満を漏らしている。この文脈において、一部の農産物の国内供給が需要を支えるのに十分でない場合で、輸入を緩和して輸入を増やすことはオプションの方法かもしれない。第二に、農業政策の支援があっても、トウモロコシのような農産物が中国の国内供給において大きな進歩を遂げたことである。しかし、彼らの国内供給は依然としてその需要を支えるには不十分かもしれない。第三に、トウモロコシにとると、中国の農業輸入は徐々に増加して割当量に達していることがわかっている。つまり、輸入の増加は輸入政策の緩和を意味する。さらに、輸入トウモロコシは中国のトウモロコシの代わりになり、輸入を促進する可能性がある。国としては主にアルゼンチン、ブラジル、カナダ、米国、ウクライナ、ロシアを含む 6 か国からトウモロコシを輸入し、中国は主に米国とウクライナから輸入している。ただし、米国を含む一部の国では、中国にとって適切なトウモロコシの産地ではない可能性がある。第四に、トウモロコシによって国内価格よりも輸入価格の方がボラティリティの振幅が大きく、備蓄政策から補助金政策への変更後、国内トウモロコシ価格の変動が大きくなっていることがわかる。さらに、変更前は、輸入価格の変動が国内価格に影響を及ぼしている。ただし、変更した後は、国内価格の変動が輸入価格に大きな影響を及ぼしている。第五に、中国にとって関税引き下げまたは割当レベルの引き上げによるトウモロコシ輸入の増加は、中国の産業、特にトウモロコシとその下流産業に幅広い経済的影響を及ぼしている。さらに、トウモロコシ

の輸入を増やすことは必ずしも福祉の成長につながるわけではなく、福祉の成長に関しては、割当レベルの拡大によってトウモロコシの輸入を増やすことがより実現可能な方法になっている。

上記の結果によると、次のことを提案する。まず、国内の農業生産を拡大するためのさらなる強力な支援や刺激策を避け、生産性の促進と輸入による現在の農業資源の維持と農業供給の確保に焦点を当てることをお勧めである。次、適切な農業供給のために農業輸入の供給源を多様化する必要があり、場合によっては、グローバルな農業供給情報システムの構築、潜在的なパートナー国との協力、海外農業の開発と農業輸出に関するWTO協定の促進などのかなりの措置を講じる必要がある。最後は、一部の農種の国内供給が潜在的に不足している場合に、輸入割当を拡大して輸入を増やすことがより現実的な方法である。

キーワード: 農業政策、経済効果、アーミントンモデル、VAR-BEKK-GARCH、CGE

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Abbreviations

Abbreviations of general terms

ASF	African Swine Fever
AMS	Aggregate Measurement of Support
AAP	Applied Administered Price
ASEAN	Association of Southeast Asian Nations
ARCH	Autoregressive Conditional Heteroscedasticity
CGE	Computable General Equilibrium
CES	Constant Elasticity of Substitution
CET	Constant Elasticity of Transformation
CIF	Cost Insurance and Freight (insert named port of destination)
DDGS	Distiller's Dried Grains with Solubles
EP	Eligible Production
EUR	European Currency
E.U.	European Union
FGLS	Feasible Generalized Least Squares
FE	Fixed Effects
FERP	Fixed External Reference Price
FAO	Food and Agriculture Organization of the United Nations
FOB	Free on Board
GARCH	Generalized Autoregressive Conditional Heteroscedasticity
GDP	Gross Domestic Production
GTAP	Global Trade Analysis Project
HS	Harmonized System
HK	Hongkong
IO	Input-output
JPY	Japanese Yen
MO	Macao
MPS	Market Price Support
Mt	Million tons
MARA	Ministry of Agriculture and Rural Affairs, PRC
ME	Mixed Effects
MFN	Most Favored Nations
MVAR	Multivariate Vector Autoregression
NBSC	National Bureau of Statistics of China, PRC
NDRC	National Development and Reform Commission
OLS	Ordinary Least Squares
OECD	Organization for Economic Cooperation and Development
PRC	People's Republic of China
VOP	Product's Value of Production
RE	Random Effects
RMB	Ren Min Bi (Chinese Yuan)
SAM	Social Accounting Matrix
SC	State Council, PRC
SCTG	Standard Classification of Transported Goods
SIC	Standard Industrial Classification
UNCTD	United Nations Conference on Trade and Development
USD	United States Department of Agriculture

U.S.(A)	United States of America
USTR	United States Trade Representative
USD	US Dollar
VAR	Multivariate Vector Autoregression
WTO	World Trade Organization

Abbreviations in social accounting matrices

ASE	Agricultural Service
ALC	Alcohol
CAP	Capital
CON	Condiment
COR	Corn
EXT	External Sector
FEE	Feed
FIS	Fishery
FOR	Forestry
GOV	Government
HOH	Household
HUS	Husbandry
INV	Investment
LAB	Labor
OAG	Other Agriculture
OFO	Other food
IDT	Other Indirect Tax
OMA	Other Manufacture
OSE	Other services
SUG	Sugar
TQR	Tariff Quota Rent
TRQ	Tariff Rate Quota

Chapter 1 Introduction

1.1 Background and significance of the research program

1.1.1 Background

1.1.1.1 Sufficient agricultural supply is at the basis of the development of the national economy in China

The Chinese officials have repeatedly emphasized the importance of agriculture to the economy in China. The three following statements are examples. The prime minister reported that only when the Chinese people are free from food availability and eliminate food supply worries can they concentrate on and support the current economic reforms, thus ensuring a sustained, rapid, and steady development of the economy (the State Council, 1996). The issues about agriculture, farmer, and rural areas are fundamental issues related to the national economy and people's welfare, and the party will always treat these issues as top priorities, reported by China's Chairman Xi Jinping (2017). It was emphasized that agriculture is the foundation of the national economy, and the rural economy is an important part of the modern economic system in a report in 2018 (the State Council, 2018).

China is a largely agricultural country, and reliable agriculture with sufficient supply leads to extensive social stability, which offers a foundation for economic development. NBSC (2020) reported the population of China was about 1.4 billion in 2019. In particular, the population in rural areas was 0.55 billion that took up about 39.3%. In addition, 0.77 billion people are employed persons in 2019 in China, and 0.19 billion people are employed in the primary sector[1] reported by NBSC (2020). For the huge population living in rural areas and working in the primary sector in China, sufficient agricultural supply is the guarantee for their lives, work, and subsequently social stability, especially in China where incomes in agriculture are relatively lower than those in other industries.

1.1.1.2 Supply shocks may cause insufficient agricultural supply in China

Supply shocks may lead to insufficient agricultural supply in China. For example, ASF broke out in China from August 2018 and has caused decreased production to China's hog industry and a reduction to its pork stocks in 2018 and 2019. As feed grain, corn and soybean are estimated to contribute to around 20% and 75% respectively for Chinese pig rations (Pitts and Whitnall, 2019). Subsequently, soybean imports decreased in 2018; but, corn was still imported more by China in 2018 and 2019 than before. With pork being the dominant meat in the Chinese diet, China's governments actively controlled the sources of ASF infection and guided its hog industrial recovery since ASF spreads. The recovery would further aggravate the supply pressure on these agricultural products. Concerning imports, the quantity of soybean imports in 2018 was 8.25 Mt; however, it increased to 10 Mt in 2020. As for corn, its import quantities were 4.46 Mt in 2018 and 7 Mt in 2020. Corn imports in China has almost reached to its quota level, which implies increasing imports under current quota and tariff policies in China implies more costs of importers in China and which also leads to pressure on domestic supply of corn.

1.1.1.3 The agricultural sectors of China are standing at the crossroad of reform

[1] Activities associated with primary sector in China mainly include agriculture, forestry, grazing, hunting, gathering, and fishing.

China is moving on the way to reform its agricultural sectors. The problems in agriculture force the Chinese government to reform the agricultural sector in China (Ministry of Agriculture and Rural Affairs, PRC, 2016). For example, these problems are reflected by a "strange phenomenon" that the production, imports, and stocks of some agricultural varieties increased simultaneously in China before 2016 for some reasons. Firstly, the supply of agricultural products cannot effectively meet its demand. The demand for soybean increased significantly, and its domestic supply was insufficient; however, its production even declined. In contrast, corn production has been doubled in recent 15 years until 2016; however, it was over-supplied in the recent decade until 2020. In addition, some agricultural products with high quality were in short supply, but those with low quality were in oversupply. Secondly, the comparative advantage of China in agricultural products deteriorated because of higher prices than world prices, caused by factors like high input costs and agricultural supports by policies. The prices of domestic agricultural products were generally higher than the world prices, and the prices of some varieties were even higher than the CIF prices within quotas. High prices benefited farmers, but farmers' gains did not offset the losses of, for example, the Chinese government and consumers. They were barriers to related industries' development because downstream industries suffer losses due to higher costs. Thirdly, most agricultural products were overproduced. Some policies like stockpiling policy supported the production of some agricultural products, for example, rice, wheat, and corn. However, they also brought a heavy financial burden to the government for managing ever-increasing stocks and subsidies to compensate for some losses of production in downstream industries. However, some of these problems are not completely solved, and new problems may appear with the development of the agricultural sectors in China. It is still being explored which path should be taken for the agricultural sectors in China or which kind of reform can be carried out for these sectors. Therefore, the agricultural sectors of China are still standing at the crossroad of reform.

1.1.1.4 Chinese officials have been launching a supply-side structural reform

The supply-side structural reform began in November 2015 in China, which formally includes five elements: eliminating excess capacity, reducing excess housing stocks, deleveraging, reducing costs, and strengthening weak points. In the approach of eliminating excess capacity, the central government offers modest subsidies to promote the closure of production capacity. Conceptually reducing stocks can eliminate any kind of surplus, particularly for reducing excess housing stocks in this practice. Deleveraging is to restructure debt to manage risks. Reducing costs is to help firms reduce costs and increase competitiveness, referring to tax reductions, reductions in burdensome regulation, and, perhaps, reductions in social security contributions. In the approach of strengthening weak points, the government emphasizes the development of weak points of China, like agriculture and some technologies.

At the same time, a supply-side structural reform in agriculture started, which includes three elements reported by the Ministry of Agriculture and Rural Affairs, PRC (2016). They are reducing excess stocks, reducing costs, and strengthening weak points. Reducing excess stocks means facilitating the consumption of excessive agricultural product stocks and facilitating grain processing, mainly referring to food crops and economic crops, such as rice, corn, wheat and soybeans, cotton, red dates, apples, and other agricultural products, which are over accumulated in granaries. The cost reduction means to reduce production costs and improve agricultural efficiency and competitiveness through the development of appropriate scale operations, reduction of unreasonable use of fertilizers and pesticides, and development of social services. Strengthening weak points is to strengthen the weak points of agricultural supply such as agricultural infrastructure and increase the production of agricultural products that are in short supply in the market.

1.1.2 Significance

Agricultural policies are powerful tools to continuously deepen the supply-side structural reform in agriculture. In this dissertation, the topic is research on the economic effects of agricultural policies on the agricultural sectors, corresponding downstream sectors, and the economy of China by taking corn as an example. In detail, I try to explore feasible agricultural policies for further reform in the future, and the policies are analyzed, simulated, and evaluated to quantify their effects on the agricultural sectors, corresponding downstream sectors, and the economy of China by taking corn as an example. This research program shows great significance for the further supply-side reforms on agriculture.

The research shows significance in policy development for the further supply-side reforms on agriculture. This research program is dedicated to prescribing feasible policies by comparing their effects on the agricultural sectors, corresponding downstream sectors, and the economy. Those economic effects about the distribution of the resulting benefits and costs in each economic agent are most essential for understanding why particular policies are chosen, and it is also useful, in some settings, for prescribing policies. In addition, welfare is an essential index for policy implementation, and this research also offers the welfare changes resulted from agricultural policy changes to get welfare information for the development of agricultural policies in China.

This research shows significance in more feasible agriculture-resource allocation for the further supply-side reforms on agriculture. In China, agriculture resources like labor in agricultural sectors and capital are limited, even scarce for the huge population. Optimizing the inputs of the agricultural resources on agriculture is crucial. The method in this dissertation can systematically evaluate the effects of a series of agricultural policies at both micro and macro levels on the agricultural sectors, corresponding downstream sectors, and an economy. The research results can provide evidence to guide an economy to select optimized sectoral inputs of agricultural resources.

This research shows significance in providing evidence of possible policies for further supply-side reforms on agriculture. The effect of policies often deviates from the original intention of policymakers in formulating policies, leading to many distortions (Powell 2005). Therefore, for formulating policies in an effective manner, policymakers require a wide range of information, for example, information that contains not only historical information but also predictable information showing possible changes in the future caused by these policies. This research gives an overview of the economy about a target agricultural product in China by historical data and simulates and evaluates its policies to forecast the effects of these policies before they are implemented, which is valuable for avoiding some of the possible economic distortions. For agriculture, one goal of agricultural policies may go against other goals. For example, price support policy helps ensure farmers' income contributing to the goal of anti-poverty in China; however, it makes consumers suffer losses. Therefore, before the implication of a policy, some trade-offs to balance the benefits of all agents in an economy should be taken into consideration. The simulations and evaluations of policies in this dissertation can offer quantified effects of agricultural policies on the agricultural sectors, corresponding downstream sectors, and the economy. Thus, the dissertation can provide some evidence for future policy implementation in advance.

1.2 Related concepts in context

1.2.1 Definition of agricultural policies

Agricultural policy describes a set of laws relating to domestic agriculture and imports of foreign agricultural products, which concerns the relations between agriculture, economics, and society, and is usually implemented as a tool by governments to achieve a specific outcome in the domestic agricultural product markets.

1.2.2 Definition of agricultural support policies

The agricultural support policy is defined as the policy in relation to the annual monetary value of gross transfers to agriculture from consumers and taxpayers to support agriculture, regardless of their objectives and economic impacts.

The concept of agricultural support policy cannot fully cover all elements of agriculture policy. For example, the agricultural policy, agricultural tax policy applied in China from 1958 to 2006, is not an agricultural support policy. However, agricultural support policies are generally implemented by countries all over the world, and they are the main policy tools by governments on agriculture. Therefore, the agricultural policies analyzed in this study mainly include agricultural support policy, in particular agricultural price policy and international trade policy of agricultural products.

1.2.2.1 Definition of agricultural price policies

Agricultural price policy refers to policies of the government whereby it acts to influence or determine the prices of agricultural outputs and inputs, including the policies of price control, price intervention, agricultural tax, subsidy, and stockpiling, etc.

- Price control means direct control on market prices that aim to maintain the affordability of staple foods to prevent price gouging during shortage (FAO). Price control policies are including, i.e., price ceiling (a maximum price that can be changed), price floor (a minimum price that can be changed), and fixed price (determined price that can be changed) measures.
- Price intervention on staple commodities is government interventions on minimum, maximum, or fixed price of key staple food commodities to support (or decrease) supply.
- Agricultural tax is the policies to taxing agricultural inputs or outputs. In China, the policy was mainly to tax agricultural outputs according to production quantity.
- Subsidy refers to direct or indirect payment to individuals or firms, usually in the form of a cash payment from the government or a targeted tax cut. Agricultural subsidies can be divided into subsidies for consumers like food subsidies and subsidies for producers like production subsidies (FAO). Food subsidy aims to make food available to consumers and to maintain adequate levels of food consumption. Production subsidy is based on agricultural production output to support farm income and boost production (FAO). In China, the main current subsidy policies aim to support farm income and boost production; therefore, subsidies for consumers are not analyzed in this study.
- Stockpiling is a measure by releasing a given food or graining stock to help stabilize food domestic prices to restore confidence in markets by guaranteeing adequate food availability or to provide readily available food and safety net reserves targeted at the most vulnerable. Food reserves held to stabilize food prices are called buffer stocks. It can rightfully be considered as falling under the social protection domain as a risk management measure in place to buffer against shocks, decreasing people's vulnerability, especially the poor (FAO). In China, the stockpiling measure in agriculture often corporates price intervention, which means governments stockpile an

agricultural good with a price intervention measure. Thus, in this dissertation, the stockpiling policy on corn[2] means the combination of stockpiling and price intervention measures, and the abolishing of stockpiling policy of corn stands that the price intervention measure in the stockpiling policies is eliminated.

1.2.2.2 Definition of international trade policies

International trade policies are policy decisions aimed at supporting consumers or producers using measures such as food import changes, export restrictions, imposition of technical barriers on trade, or implementation of a bilateral or multilateral free trade agreement (FAO). In this study, I discuss the following trade policies. In particular, the two main measures, import tariff and tariff-rate quota measures, on trade for agricultural products are analyzed.

- Trade control means direct control on imports or exports by governments for some reasons like supporting domestic production and maintaining food security.
- Trade intervention means a direct intervention on imports or exports by governments for the sake of supporting domestic production and food security.
- Import tariffs are *ad valorem* or specific tariffs on imported goods.
- Tariff-rate quota combines tariff and quota, under which imports within the quota enter the country at a lower (in-quota) tariff rate and imports out of the quota enter the country at a higher (out of quota) tariff rate.

1.2.3 Definitions concerning goods

In an open economy, suppose that domestic good perfectly substitutes the imported good, such that the economy would not export and import the good simultaneously. However, an economy often reports both imports and exports of a good. Thus, I apply the Armington assumption in this dissertation under which domestically produced and domestically consumed goods, imported goods, and exported goods are supposed to substitute for each other imperfectly. In addition, I assume that a virtual factory inputs domestically produced goods and imported goods to produce Armington composite goods consumed by consumers or as intermediate inputs. It should be noted that the goods directly supplied to or demanded by consumers are Armington composite goods rather than domestically produced goods and imported goods.

Thus, I distinguish a good in this dissertation by domestic good, exported good (exports), imported goods (imports), and Armington composite good (composite good). The domestic good is the domestically produced and domestically used good. The concepts in relation to domestic goods include domestic market, domestic supply, domestic demand, domestic price, domestic consumption, and domestic input/output as well. The export good is the domestically produced and exported good. The concepts in relation to exported goods include the supply of an exported good, the demand of an exported good, the price of an exported good, and the output of an exported good as well. The imported good is the goods imported from foreign countries. The concepts in relation to imported goods include the import market, the supply of an imported good, the demand of an imported good, the price of an imported, and the input of an imported good as well. The Armington composite good is the good that is combined by domestic good and imported good; for example, Armington composite corn is made by domestic corn and imported corn. The concepts in relation to Armington composite good include the supply of an Armington composite good, the demand of an Armington composite

[2] "玉米临储政策" in Chinese

good, the price of an Armington composite good, the output of an Armington composite good, the intermediate input/demand/supply of a good (an Armington composite good) as well.

1.3 Contents and structure of the dissertation

This dissertation is based on a simple supply and demand framework with a section to analyze prices and sections to analyze supplies, but not including a section to analyze demands because most agricultural policies in China are in close relation to the supply-side rather than the demand-side of agricultural products. The analysis framework of the dissertation in detail is presented in
Figure *1-1*.

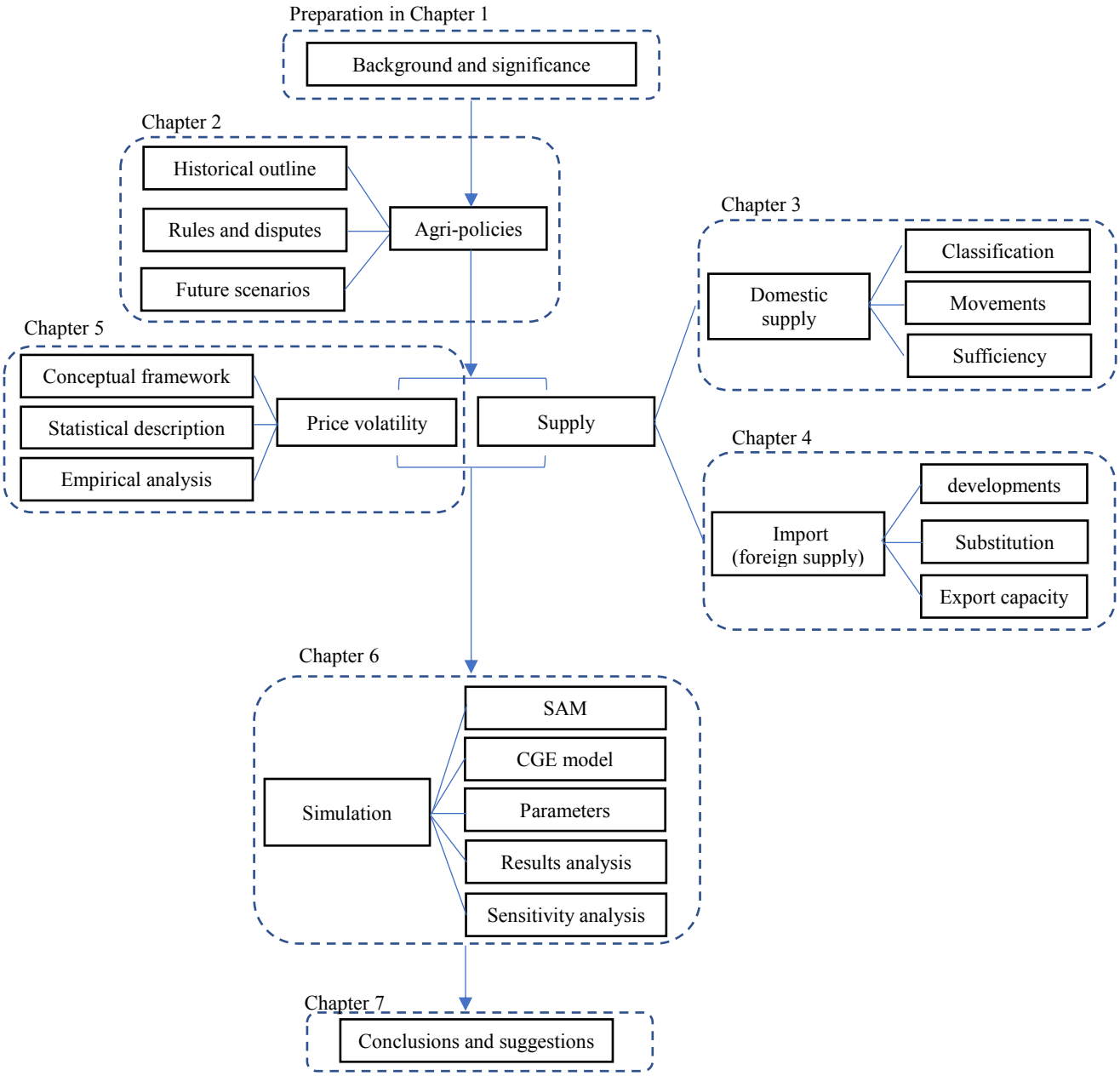


Figure 1-1 The analysis framework of the dissertation

This dissertation seeks to analyze and simulate the economic effects of possible agricultural policies for the further supply-side structural reform stated in 2015 by taking corn as an example. The dissertation has seven chapters. As shown in Figure 1-1, in Chapter 1, I analyze the backgrounds and significance of the research program as preparation before this research to explore the reasons why I do this research and explore what significance the research shows. Additionally, some concepts in relation to agriculture are redefined for clear understandings. After these preparations, I introduce the evaluation and explore possible future scenarios of agricultural policy in China under WTO rules in Chapter 2. By this chapter, I show the main historical and current policies applied to agriculture, the WTO rules and disputes on agriculture, and possible future scenarios in agriculture of China. This chapter shows a discussion on scenarios of agricultural policies under WTO rules when the insufficient domestic supply of some agricultural products appears in China. After the discussion in Chapter 2, agricultural supplies, which are divided into the domestic supply and the foreign supply (or import), are analyzed. This analysis provides the understanding of conditions of agricultural supply in China, which to some extent determines whether some policies should be applied to support domestic agricultural production or agricultural imports in China. Chapter 3 analyzes the domestic supply by discussing the agricultural classification in Chinese and investigating its movement and agricultural sufficiency under agricultural policies. Chapter 4 analyzes the agricultural import, including the analyses of the development of agricultural imports in China, the substitution between domestic goods and imports, and the export of China's partner countries of trade. Additionally, this chapter contains an introduction to the methodology of panel data analysis to support the practice of our model in this chapter. When agricultural products suffer shortages, importing may be a feasible choice. Because an agricultural price widely affects agricultural sectors and even the economy, it makes sense to measure the impact of import prices on domestic prices. Chapter 5 investigates the volatility of agricultural prices under its policies to explore the relationships between domestic and import markets of China. In this chapter, the general conceptual framework of price volatility and its transmission between domestic and import markets of China are introduced, and then how the price theory of rational expectations works in our framework are introduced as well. Then, I apply the statistical method to analyze the price movements and volatility of agricultural products in China. Furthermore, empirical analyses are applied to quantify the volatility and its transmission between the import price and domestic one. Additionally, this chapter includes an introduction of the methodology of multivariate time series analysis for price volatility to support the practice of our model in this chapter. After the analysis of agricultural prices, I try to make some simulations on future scenarios of agricultural policies in China, which I investigate in the above chapters by a CGE analysis to compare their economic effects on the agricultural sectors, corresponding downstream sectors, and the economy. In this chapter, I construct a SAM for China and a CGE model to simulate these policies. Then, the parameters for this study are introduced. On the basis of the above works, I get the simulation results from the model and make a sensitivity analysis to check the robustness of the results. Finally, Chapter 7 summarizes the findings of this research and highlights policy implications according to the findings.

1.4 Possible new points

One, this dissertation extends the analysis framework of agricultural policy. Under the traditional analysis framework, most studies firstly analyze the current situation about agricultural fields and secondly explore agricultural policies about the agricultural fields. In this dissertation, I analyze the current situation, explore agricultural policies, and additionally simulate the economic effects of the agricultural policies. In addition, most studies only analyze

domestic supply or import to explore agricultural policies, while this dissertation analyzes both domestic supply and import. Under the analysis framework in this dissertation, the analysis results can provide more comprehensive information for exploring agricultural policies.

Two, this dissertation develops a CGE method to incorporate a quota module to meet China's situations of agricultural import. The CGE model in this dissertation includes a quota module to analyze the quota policies in China by incorporating some assumptions about the tariff rate quota policies of China. This provides a new method to analyze agricultural policies, agricultural trade policies in particular.

Three, this dissertation offers comprehensive results about the economic effects of agricultural policies of an example variety. By taking corn as an example, this dissertation provides analysis results for most sectors in China in relation to corn. The sectors consist of not only a corn sector but all downstream sectors of corn in China, and they constitute a complete system of corn production and corn processing industries in China. Thus, by providing the analysis results about these sectors, this dissertation can construct a comprehensive economic analysis on agricultural policies of the example variety.

Chapter 2 The evolution and possible future scenarios of China's agricultural policies under WTO rules

Countries widely apply agricultural support policies for some reasons. As for agricultural markets, from both demand and supply perspectives, prices of agricultural products have the trance to continue declining. The demand for some food products reaches its peak soon. As necessity goods, food products have smaller income elasticities of demand that are between 0 to 1 in common. Smaller income elasticity of demand implies that the increase/decrease in food demand is not as significant as the increase/decrease in consumer income. According to Engel's law which describes how household expenditure on a particular good or service varies with household income, the poorer a family is, the larger the budget share it spends on nourishment. Witt (2001) stated that as household income rises, some motivations in household expenditure become more prominent because the more basic wants that dominate consumption patterns at low-income levels, such as hunger, eventually become satiated at higher income levels. As household income rises, the demand for food products at higher income levels like meats and vegetables substitutes the demand for food products at low-income levels like rice and wheat. Therefore, with the development of the economy, the demand for some food products like rice and wheat reaches its peak soon, even decreases as household income continues to increase. In addition, some reasons like technological progress and the increase of public investment in agricultural sectors contribute to agricultural production. Increasing production has a negative effect on price. In recent years, prices of food products like rice and wheat have been continually declining, and decreasing world price leads agricultural resources to transfer from the agricultural sector to industrial sectors. Protection and support on agriculture offer support to farmers to avoid the effects caused by the price decline of agricultural products, and these measures can, for example, improve the domestic supply of food products and prevent food security problems caused by resource transfer in a country. As for politics, farmers are sensitive to agricultural policies, which leads policymakers to launch protection and support policies to get their votes. As society develops, farmers' political unities are organized to improve their benefits, which prompts policymakers to introduce support and protection policies. In addition, the people of a country are often tolerant of their country's agricultural policies that benefit famers but may make consumers suffer losses. Because agriculture is a disadvantaged sector, and it seems natural to support disadvantaged sectors, and consumers just need to pay a low cost per capita for keeping those policies. These policies may have some positive effects like increasing production and ensuring food security in a country, but they also go against the international division of labor and the fundamental purpose of global coordinated development, which causes the waste of resources.

From 1949 when the People's Republic of China (PRC) was established, the Chinese government has repeatedly emphasized the importance of agriculture to the development of China. A series of appropriate policies is a prerequisite to support the development of agriculture. Appropriate policies in agriculture need to meet the requirements of their effects to improve the efficiency of resource allocation, coordinate the distribution of interests between different economic agents, and conducive to the use of related information (Liu, 2020). The government has designed and launched different agricultural policies at different stages of development in China. During the more than 70 years' development of the PRC, these agricultural policies have played an irreplaceable role in the development of agriculture in China. In the process of development in agriculture, agricultural policies contribute much to guiding and regulating the development, especially at the macro level. However, they also led to some problems, such as overproduction (Jiang, 2016) and production misleading (Jiang and Du, 2017), excess storage (Ma, 2016), agricultural smuggling (Hu, 2017), and import dependence (Cheng, 2016). Studying policy evolution shows significance for understanding

why particular policies are chosen in the stages of China and what prescribing policies are possibly applied in the future.

In this chapter, I try to introduce and analyze the evaluation of China's agricultural policies and the WTO rules, and the U.S.-China disputes on agriculture and explore the possible future scenarios of agricultural policies in China with four sections. Firstly, the history of agricultural policy in China is outlined in Section 2.1. Secondly, Section 2.2 is to introduce the WTO rules and the U.S.-China disputes on agriculture. Thirdly, Section 2.3 aims at analyzing possible policies of corn in future scenarios in China. The last section is a summary of the above three sections. This chapter mainly analyzes the agricultural policies by the example of corn with comparisons of wheat, and rice, because they are the three staple food agricultural products classified by China, and the agricultural policy tools are used intensively on the three products. In addition, they are also the target agricultural products in U.S.-China disputes on agriculture.

2.1 A historical outline of agricultural policies in China

In this section, the history of agricultural policy is outlined. About the history of agricultural policy in China, some researchers have introduced it and divided it into some periods. For example, Cai and Wang (2017) divided agricultural development in China into three stages where it has overall completed two stages that aim to solve the food supply problem and income problem of farmers, respectively, and entered a new stage aiming at the build of China's model of agricultural production by reference to the general categorization of economic development stages of China and international experiences of agricultural development. The history of agricultural policies was also divided in this way. Studies to dividing it in a similar way also include Yang (2006), Lu (2007), Cheng (2012), etc. The division of stages is different because of the evidence and basis that scholars referenced. For example, Geng (2018) divided it into four periods. In this study, history is not divided, and the agricultural policies are separated from each other by their start and end times.

The agricultural policy mainly includes agricultural price policies and international trade policies. In detail, agricultural policies are divided into price control, price intervention, agricultural tax, agricultural subsidies for producers, and stockpiling policies.

2.1.1 A historical outline of agricultural price policies in China

China's governments launched a series of agricultural price policies from the year 1949 since the PRC was established. In this section, I try to outline the main agricultural price policies in China, including the policies of price control, price intervention, agricultural taxes, agricultural subsidies for producers, and stockpiling.

2.1.1.1 Price control

In the 1950s, at the start period of PRC, agricultural productivity was low, and food supply was insufficient in China. To stabilize food prices and prevent private grain merchants from driving up food prices, China implemented the policy of state monopoly of purchasing and marketing for corn, wheat, rice, and other some other agricultural products, that is, a planned economic policy by which only the state had rights to purchase and sale the products and they are transacted at the prices determined by the national plans. The policy had greatly eliminated market speculation, stabilized food prices, eased the food crisis, ensured the needs of the country's economic construction and people's lives. In addition, it had realized that the rational allocation of resources in the case of resource shortages provided primitive capital accumulation for the development of China's industry and had positive effects on the progress

of China's industrialization. But, under the policy, a highly monopoly operation and management system about these products has been formed, which were against market mechanism, made it unable to play a role in price adjustment and resource allocation. Low prices negatively affected farmers' enthusiasm for production, which in turn, took disadvantages of food production and hindered the development of the agriculture economy in China. Furthermore, it widened the economic gap between urban and rural areas in China. From 1978, this policy was gradually being replaced.

2.1.1.1 Price intervention

To marketize agricultural markets and encourage farmers for production, China had gradually increased the government-determined price of corn, wheat, rice, and other grains since 1978. From the year, private sectors had access to grain markets after the government had already carried out purchase plans, which had significantly increased the output of grains but also caused problems such as the insufficient purchasing capacity of the government and higher prices for purchase than sale prices. In this context, the price control policy was abolished and replaced by a "double-track pricing system" in which the government ordered and purchased corn, rice, wheat, and soybean at the government-determined prices, and the left after the orders can be traded freely at market prices. However, the system also led to problems that two different prices of one product often caused friction and conflicts and caused chaos and disorder in the grain market. From 1993, the government had no longer absolutely determined a price of any agricultural product, rather, keep the original state-purchase quantities of grain and purchased at market prices when market prices did not lower/higher than minimum prices/maximum prices that the government determines to stabilize market prices of related grain products. If the price exceeded the limitation, the government purchased at minimum price when the market price was lower and at maximum price when the price was higher. Because the price was often lower, the government purchased at a minimum price that was still higher than the market price, over-supply problems and excessive financial burden had gradually become prominent. From 2004, as for wheat, the government set minimum prices in major provinces[3] for stockpiling quantity. From 2006, the same policies applied for rice. As for corn, from 2004 to 2007, corn price was determined by the corn market, and the government had no intervention in the pricing of corn. In 2008, the corn stockpiling policy was launched under which the government set a target price for corn stockpiling in the four aforementioned provinces.

2.1.1.2 Agricultural taxes

In 1958, the government launched "Agricultural tax regulations" under which farmers needed to pay 15.5% in average of their production as agricultural tax. Although agricultural taxes had supported urbanization and industrialization to some extent in China, with development, the tax had no necessity and did not meet the requirements of the market economy. The tax was unreasonable because it seemed to land rent and taxed all the income of farmers, including them, for basic living activities like food and education. It was unfair because there was no threshold and exemption for agricultural tax for farmers; however, income tax for the non-agricultural population had them. In addition, the tax was much higher, thus, decease the

[3] Major provinces refer main areas to produce staple grains. In China, they are Heilongjiang, Jilin, Liaoning and Inner Mongolia for corn production, Hebei, Jiangsu, Anhui, Shandong, Henan and Hubei for wheat production, and Hunan, Sichuan, Hubei, Jiangsu, Guangdong, Guangxi, Anhui, Zhejiang, Jiangxi and Heilongjiang for rice production.

international competitiveness of Chinese agricultural products. From 2003, the measure was changed to 7% in maximum as agricultural tax rate, and additionally, plus 20% of the tax as agricultural surcharge to support the operation of rural organizations and the poor. From 2000, the government tried to eliminate agricultural tax in some pilot provinces, and in 2006, the tax was eliminated in China.

Regarding the history of the agricultural tax in China, an important background is the dual urban-rural economic structure. Boeke (1953) created a concept - dual economy, which describes that two separate economic sectors exist within one country, caused by different levels of development, technology, and different patterns of demand. In China, about agriculture, the dual urban-rural economy is a basic economic structure in which the urban economy is characterized by socialized production and the rural economy characterized by smallholder production coexist. In et al. (2010) pointed out that treating the dual urban-rural economic structure as a long-term characteristic of China is a prerequisite for studying the development of agricultural policies. In this context, as the changes of roles of urban and rural areas in China's urbanization and industrialization processes, agricultural policies have also changed accordingly. In these processes, a reversal from taxing to subsidizing agriculture occurred in the application of agricultural policies in 2004. The reversal is in a general application or universal acceptance (e.g., Ma et al., 2005). Referring to the evolution of agricultural policy in developed countries, they have also experienced this kind of reversal (e.g., Liang, 2007).

2.1.1.3 Agricultural subsidies for producers

Agricultural subsidy policies started being introduced in 2004 after the government began to abolish the agricultural tax. The government introduced four kinds of subsidies to support grain[4] production and farmers' income who produce grain. Targets of subsidy policies are not all grain but including corn, rice, and wheat for most of the subsidy policies.

The government has successively introduced some subsidies to support grain production. One, the subsidy for agricultural support and protection: in 2004, the government proposed to use part of the grain risk fund to directly subsidize the farmers who produce grain and establish agricultural machinery subsidies and seed subsidies. In 2006, the government set up subsidies for corresponding inputs for agricultural production based on the consideration of the impact of rising prices of production inputs such as diesel, chemical fertilizers, and pesticides on growing grain. In 2016, the government classified the above three kinds of subsidy as the subsidy for agricultural support and protection (also called "three subsidies"). Two, the subsidy for corn producers: in 2016, the stockpiling policy was abolished, while the subsidy for corn producers was introduced in the same provinces. Three, the subsidy on agricultural insurance: in 2007, the government began to support the establishment of the agricultural insurance system and introduced insurance subsidies for agricultural products, including corn. For insurance fees, the central finance and provincial finance each bear 25% of it, and the rest are paid by farmers themselves. In addition, a subsidy for agricultural services was launched.

2.1.1.4 Stockpiling

[4] The grain is "Liangshi" that, in Chinese definition, is a category of agricultural food products for people including cereals and some of beans and potatoes. In 1950, corn is listed as "liangshi" that also includes wheat, rice, millet, soybean, sorghum, and other coarse cereals and, subsequently, the potatoes.

For wheat and rice, similar stockpiling measures were applied in 2004 and 2006, respectively. The government set minimum prices for the under-stockpiling part of them in major provinces. These policies are still applying for them.

As for corn, in 2008, the government launched the stockpiling policy under which the government set target prices that were up to 50% above market prices when stockpiling in major provinces. The government set a target price, and if the market price was lower than this target price, the government would buy corn at the target price in these four provinces to push the market price up and keep it not lower than the target price. This policy was conducive to increasing corn production and farmers' income, but it led to some problems like over-stock and fiscal burden. The stockpiling policy with price intervention for corn was abolished in 2016; thus, the government purchase and store corn at market price after the abolish.

2.1.2 A historical outline of international trade policies in China

The trade-oriented policies of corn of China developed with the change from a planned economy to a market economy in China. From 1949 when the PRC was established to 1978, when an economic reform named "Economic reform and open up" began, China was developing in a planned economy in which the supply and demand of most products in China were based on plans by Chinese governments. In this background, the governments exercised a high degree of control over corn production and sales, and state-owned enterprises had almost monopolized corn import-exports of China where quantities of corn trade were decided by the plans from Chinese governments. Since the reform started, the policy for the corn trade has also changed. In the 1980s, the import licensing system had been being implemented for corn import, in which the Chinese government issues quota licenses to some companies that also can be private companies. For a long period, the government mainly applied a quota policy to manage corn import.

According to the agreements between China and other members of WTO, the period from 2002 to 2004 was a transition period partly for China to modify its trade policies to meet the rules in the agreements. In this period, the import quota increased to 7.2 Mt of corn, 9.636 Mt of wheat, and 5.32 Mt of rice in 2021; their import tariff rates in quota were set as 1%, and the import tariff rates out of quota were set as 65%. Since 2014, these policies on corn import have no changes. As for the policies for corn export, China eliminated all agricultural export subsidies in 1995, and from 2007, the exported quantity of corn reduced to be almost negligible.

Table 2-1 lists the main import measures of policy on cereals in China in 2021, including quotas and tariff rates. This suggests corn, wheat, and rice are subject to some strict import policies, and they are more liberal for other cereals.

Table 2-1 Quotas and tariff rates of cereals of China in 2021

	Quota	In-quota tariff rate	Out-of-quota tariff rate (MFN)	Out-of-quota tariff rate	Tariff rate for ASEAN	Tariff rate for HK and MO
Corn	7.2 Mt	1%	65%	180%	50%	0
Wheat	9.636 Mt	1%	65%	180%	5%	0
Rice	5.32 Mt	1%	65%	180%	50%	0
Rye	-	-	3%	8%	0	0
Barley	-	-	3%	160%	0	0
Oats	-	-	2%	8%	0	0
Sorghum	-	-	2%	8%	0	0
Other cereals	-	-	2%	8%	0	0

Notes: The HS (Harmonized System) codes of corn, wheat, rice, rye, barley, sorghum, and other cereals are 1005.9000, 1001.9900, 1006.1029, 1002.9000, 1003.9000, 1007.9000, and 1008.1000, respectively, in the Customs of Import and Export Tariff of the People's Republic of China (2020). MFN: Most Favored Nations; ASEAN: Association of Southeast Asian Nations; HK: Hongkong; MO: Macao

2.1.3 Summary of agricultural policies in China

About the history outline of agricultural price policies and international trade policies, Figure 2-1, Figure 2-2, and Figure 2-3 outline the policies as time. From 1949 to 1977, the government almost controlled the price of corn, wheat, and rice, absolutely, and then, from 1978 to 2004, it relaxed some price controls and changed it to price intervention. In 2004, it tried to abolish price intervention policy, but so as to support corn, wheat, and rice, stockpiling policies were gradually launched under which market prices of them were still under intervention by the government. Along with changes in price intervention policies, the government also changed the policies from taxing to subsidizing agriculture. About trade policies, the history of agricultural support policy can be divided into two periods: one before 2014 with trade control and trade intervention by administrative measures and the other one after 2014 with on trade intervention by administrative measures.

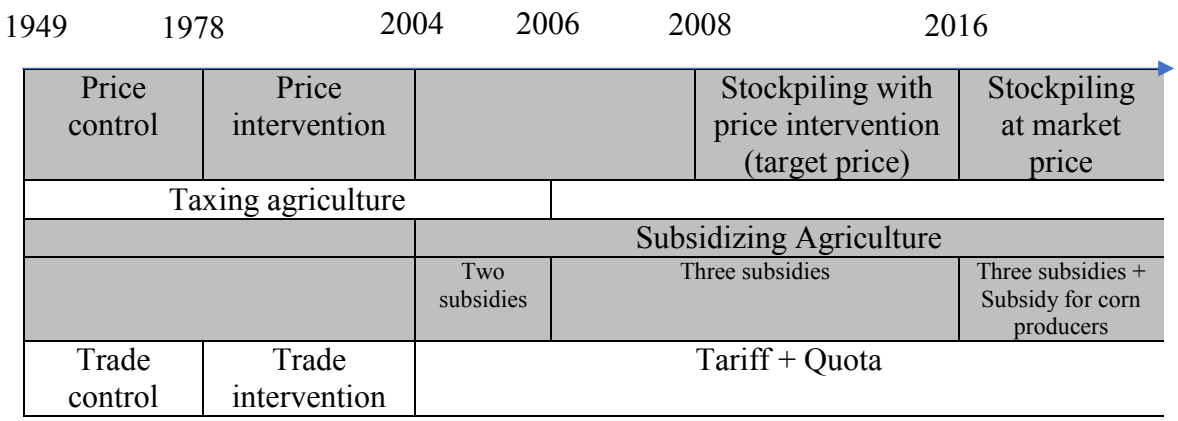


Figure 2-1 Main corn policies of China in timeline

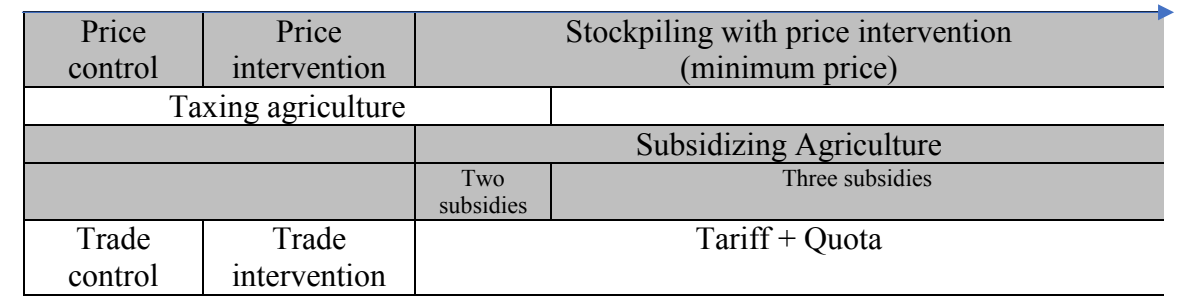
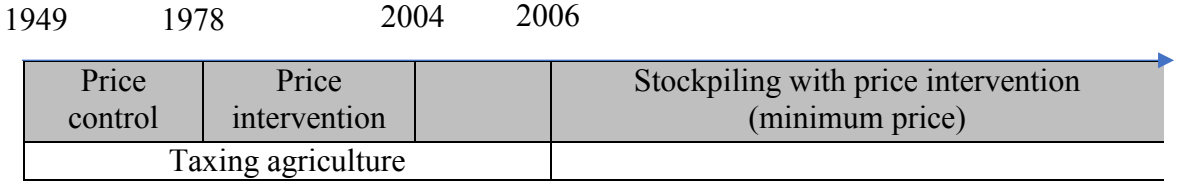


Figure 2-2 Main rice policies of China in timeline



		Subsidizing Agriculture	
		Two subsidies	Three subsidies
Trade control	Trade intervention	Tariff + Quota	

Figure 2-3 Main wheat policies of China in timeline

One difference between corn and wheat and rice is that the current corn market price is more marketized with no intervention under current corn policies, while market prices of wheat and rice are still under intervention by minimum price policies. The history of corn support policy can be divided into two periods: one with price intervention and the other one with on price intervention. China gradually marketized its corn market. During the period from 1949 to 2016, when the stockpiling policy was abolished, agricultural support and protection policy in China was evaluated with price intervention. The support policy in the period after 2016 was evaluated with on price intervention by the government. In the year, the government abolished the target price measures when stockpiling and changed to apply a subsidy to support corn producers.

2.2 WTO rules and the U.S.-China disputes on agriculture

As for dealing with the global rules of trade, WTO is the only international organization mainly to ensure that trade flows as smoothly, predictably, and freely as possible (WTO). The important objectives of WTO are: to improve the standard of living of people in the member countries, to ensure full employment and broad increase in effective demand, to enlarge production and trade of goods, to increase the trade of services, to ensure optimum utilization of world resources, to protect the environment and to accept the concept of sustainable development. It is obvious that not all protection and support measures are subject to the WTO objectives. Based on the WTO objectives, after many negotiations among member countries, the current Agreement on Agriculture was formed. The objective of this agreement is to establish an equitable, market-oriented trade system by reducing domestic support, eliminating export subsidies, and applying special and differential treatment. According to the constraints in this agreement, WTO members need to adjust their agricultural policies, including support and policies to meet WTO rules.

In this part, the WTO rules on agriculture, the U.S.-disputes on agriculture, and China's new corn policies after the reform on corn in 2016 are introduced. In addition, under the current agricultural rules of WTO and the development of the corn sector in China, what policies may be suitable for its future development is discussed.

2.2.1 WTO rules on agriculture

The negotiations until which WTO was funded in 1995 have resulted in the Agreement on Agriculture including four main portions: the Agreement on Agriculture itself; the concessions and commitments on market access, domestic support, and export subsidies to undertake members; the agreement on sanitary and phytosanitary measures; and the ministerial decision about least-developed and net food-importing developing countries (WTO). The agreement consists of three pillars of constraints on agriculture: domestic support, market access, and export subsidies. The WTO divides domestic support into two groups: trade-distorting measures that are nonexempt measures and non-trade-distorting measures (or minimally distorting measures) that are exempt measures. The group of trade-distorting measures comprises measures that raise the domestic price received by producers and paid by consumers

above the world market price, which concerns some border measures such as some forms of import protection and export subsidy. The group of non-trade-distorting measures comprises measures that allow consumers to pay world market prices. In this section, the WTO rules under the three pillars and main disputes between China and the U.S. on agriculture are introduced.

2.2.1.1 Market access rules

Market access defined by the WTO means the conditions, tariff, and non-tariff measures agreed by members for the entry of specific goods into their markets (WTO). Developed country members need to reduce their tariffs by 36% on average of all agricultural products, with a minimum cut of 15% for any product over six years from 1995 to 2004. For developing countries, the cuts are 24% and 10%, respectively, to be implemented over a six-year period beginning in 1995. Least-developed country members were required to bind all agricultural tariffs but not to undertake tariff reductions. As for China, the tariff on average on agricultural products needed to be reduced to 17% in five years ending in 2004. About non-tariff measures, members agreed to convert their non-tariff measures to equivalent bound tariffs. All members have agreed with the prohibition of non-tariff border measures; however, the Agreement contains a "special treatment" clause (Annex 5), under which non-tariff border measures can be applied for rice imports of the Republic of Korea and Philippines and imports of cheese and sheep meat in the case of Israel. Some additional market access is provided through tariff-rate quotas. As for China, it is prohibited for the application of non-tariff measures on some agricultural products like rice, wheat, and sugar, but available to use quota to manage imports.

2.2.1.2 Domestic support rules

The present Agreement on Agriculture is still the Agreement resulted in 1994 because the latest round of trade negotiations among the WTO members, the Doha Round, failed to result in an agreement. Although the Agreement does not identify any boxes or colors, it is universally understood that the set of green, blue, and amber boxes is applied to separate exempt from nonexempt measures. The green box contains fully authorized support by the WTO, which has no, or at most minimal (*de minimis*), trade-distorting effects or effects on production. The blue box contains tolerated support, which includes support that is linked to one product, but that does not increase according to production levels. The amber box contains support to be avoided and reduced, which concerns the domestic support measures considered to distort production and trade.

Figure 2-4 shows the constraints along with the present ones in the Agreement. In the Agreement, the domestic support provisions apply to all "domestic support measures in favor of agricultural producers," with some exceptions (Article 6.1). Domestic support measures in favor of agricultural producers contain green box measures and non-green box measures. Green box measures and part of non-green box measures can be exempt from commitment. Annex 2 in the Agreement defines the green box in which the measures are considered to meet the fundamental requirement on agriculture and exempt from commitment. Non-green box measures include special and differential measures that differentiate some subsidies in developing country members, blue box measures, and non-exempt measures that are calculated to describe a total aggregate measurement of support (AMS). About special and differential measures that are only for developing country members, Article 6.2 in the Agreement defines them: investment subsidies which are generally available to agriculture and agricultural input subsidies generally available to low-income or resource-poor producers. No generally recognized color or box matches them, but they are often considered as development box

measures. Thus, developing country members excluding China can apply those measures subject to Article 6.2 and be exempt from commitment, although the measures tolerate trade and production. China is not exempt from commitment to Article 6.2 measures. About the blue box measures, Article 6.5 defines them as direct payments under production-limiting programs if such payments are based on fixed area and yields, or such payments are made on 85 percent or less of the base level of production, or livestock payments are made on a fixed number of head. These direct payments shall be subject to the exemption from commitment to reduce domestic support. These two kinds of non-green box measures - Article 6.2 support and blue box payments - shall be exempt from domestic support reduction commitments like green box measures.

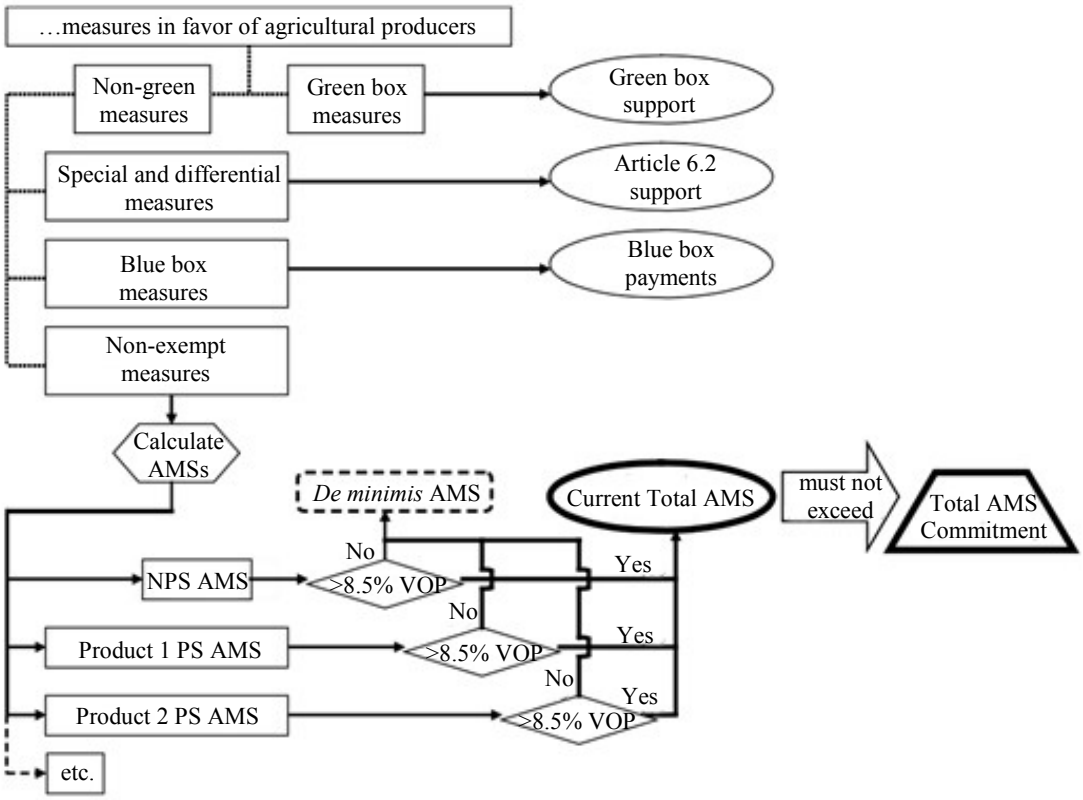


Figure 2-4 Domestic support provisions in the Agreement on Agriculture
Source: Brink, 2009

Figure 2-4 does not describe what measures can be treated as amber box measures. The reason is no distinguishing criteria in the Agreement for amber box measures. But the Agreement shows us what can be distinguished as green box and blue box measures and Article 6.2 measures; the amber box consists of measures that are not included in the three distinct categories. In addition, Annex 3 in the Agreement shows what measures shall be accounted for in total AMS; however, it is not exhaustive and cannot cover all amber box measures (Brink, 2009).

Based on the Agreement, all WTO members need to meet the provisions on ceilings of total AMS that is calculated as a sum in monetary terms of the annual level of support. Total AMS shall not be exempt from exempt. Total AMS levels of each member are reported in their Schedule of Concessions and Commitments. Total AMS levels rely on percentage numbers calculated as showed in Figure 1 (The Agreement seems to count Article 6.2 measures and blue box measures in AMS, however, this does not correspond to practice (Brink, 2009)). AMS is divided into non-product specific (NPS) AMS and product-specific AMS. Thus, the total AMS

of a member is the sum of NPS AMS and product-specific AMSs. However, if an AMS number is small enough and meets the *de minimis* rules, this number shall not be counted into the total AMS. The *de minimis* rules suggest that if an AMS number is small enough and it is no more than 5% (5% is applied for 14 developed members; developing countries (114 members) use 10%, and 8.5% is for China and Kazakhstan) of product's value of production (VOP) or, of the value of total agricultural production for NPS AMS, those AMS measures need to be exempt from commitment. Thus, those non-exempt measures excluded by *de minimis* rules are counted into total AMS, and the current total AMS (total AMS in the latest year) of each member must not exceed their total AMS commitments. About values of total AMS commitments, only about 30 members have total AMS. For these 30 members, developed country members needed to decrease 20% of their total AMS in six years from 1995 to 2000, and developing country members needed to decrease 13% of their total AMS in ten years from 1995 to 2004. Based on the negotiations between the members, China has no total AMS commitments but can provide AMS to agricultural producers up to 8.5% of the value of production. However, although some countries have total AMS commitments to decrease 20% or 13% total AMS because some of them applied large AMS support before the WTO negotiations, these countries still maintain huge total AMS after the reductions on total AMS. For example, the U.S., the E.U., and Japan still have 19.1 billion (USD), 72.3 billion (EUR), and 3972 billion (JPY), respectively, of total AMS as upper limitations in their commitments, which are still much higher than other members' total AMS.

In conclusion, green box measures and blue box measures are exempt from commitment for all members. Art. 6.2 measures can be exempt for developing country members except for China. If total AMS does not exceed 5% of VOP for developed countries, 10% for developing countries except China, and 8.5% for China, they can be treated as *de minimis* measures exempt from commitment. About total AMS commitment, all developed country members who have a total AMS commitment should reduce 20% of total AMS from 1995 to 2000, and all developing country members who have a total AMS commitment should reduce 13% of total AMS from 1995 to 2004. But most members like China do not make total AMS commitments, but they still have other limits on AMS; for example, China only can provide AMS to agricultural producers up to 8.5% of the value of production. These conclusions are summarized in Table 2-2.

Table 2-2 A summary of restraints on agricultural domestic support

	Developed country members	Developing country members	China
Green box measures	Y	Y	Y
Art. 6.2 measures	N	Y	N
Blue box measures	Y	Y	Y
de minimis measures	≤5%	≤10%	≤8.5%
Total AMS commitment	-20% in six years (1995-2000)	-13% in ten years (1995-2004)	N

Notes: "Y"-yes, "N"-no

WTO members have tried to update the Agreement to reach more consensus on agriculture. The latest round of trade negotiations among the WTO members is the Doha Round which aims to achieve major reform of the international trading system through the introduction of lower trade barriers and revised trade rules (WTO). The Doha negotiations follow the three-pillar architecture of market access, export competition, and domestic support and try to result in more detailed constraints on ceilings on overall trade-distorting support and blue box

payments, and product-specific caps (Brink, 2009), but Doha Round failed to result in an agreement because of some disagreements on special safeguard mechanisms[5].

2.2.1.3 Export subsidies rules

The WTO members are committing to reduce subsidized export quantities and the amount of money spent subsidizing exports (WTO), and the WTO prohibits most subsidies directly linked to the volume of exports, including for least-developed country members. About agricultural products, in 2015, the WTO member stated agreement to eliminate export subsidies for agricultural products. Least-developed countries had to eliminate agricultural export subsidies until the end of 2018 (until 1 January 2017 in relation to cotton exports and the end of 2023 in relation to part of export subsidies), while developed nations agreed to eliminate most such subsidies immediately. China had eliminated all its export subsidies on agricultural products in 2001 when China joined WTO.

2.2.2 The U.S.-China agricultural disputes

The United States sued China for violating WTO rules in 2016. As for Agriculture, on 13 September 2016, the United States requested consultations with China regarding certain measures through which China appears to provide domestic support in favor of agricultural producers, in particular, to those producing wheat, Indica rice, Japonica rice, and corn (WT/DS 511). The Office of the United States Trade Representative (USTR) reported in DS511 files that the AMSs on wheat, rice, and corn in China exceeded China's commitments (8.5% for each product in maximum). According to the data from the office on 19 September 2017, the values of AMS in China for wheat, rice, and corn are from 33.3% to 69.0%, which have largely exceeded its commitments, which is respectively reported in Table 2-3, Table 2-4, and Table *2-5* in detail. The reasons why the data lead to excessively over-limit in commitments are that the fixed external reference prices (FERPs) they reported were much low because China's nominal border prices from 1986 to 1988 in average were applied as FERPs, and because under China's programs, all production in identified provinces is fit or entitled to receive the applied administered price, the QEP (quantity of eligible production) is drawn from China's National Bureau of Statistic and Ministry of Agriculture official wheat, rice, and corn production volumes in major provinces[6]. However, under the values of FERPs and QEPs reported by the U.S., China's current total AMSs are impossible without exceeding China's WTO limits (Orden and Brink, 2018).

[5] A tool that would allow developing countries to raise tariffs temporarily to deal with import surges or price falls in the Doha Round.

[6] major areas to produce the products of corn, wheat, and rice

Table 2-3 China's current total AMS on wheat reported by the U.S.[7]

	AAP[8]	FERP[9]	QEP[10]	MPS	VOP	AMS
	RMB/Ton		Mt	Million RMB		%
2012	2040	431.11	94.08	151364.37	262329.93	57.7%
2013	2240	231.11	96.83	175154.82	287139.05	61.0%
2014	2360	431.11	99.98	192850.42	304180.47	63.4%
2015	2360	431.11	102.89	198463.49	302997.69	65.5%

Data source: USTR, 2017

Table 2-4 China's current total AMS on rice reported by the U.S.

	Variety of rice	AAP	FERP	QEP	MPS	VOP	AMS
		RMB/Ton		Mt	Million RMB		%
2012	Early indica	2400	470.83	25.05	28325.71	48753.37	58.1%
	Mid/late indica	2500	470.83	83.43	168725.49	290405.32	
	Japonica	2800	546.62	50.87	114629.44	188225.68	60.9%
2013	Early indica	2640	470.83	25.97	56333.34	85743.29	65.7%
	Mid/late indica	2700	470.83	82.32	183505.27	279307.87	
	Japonica	3000	546.62	51.80	127085.08	188553.53	67.4%
2014	Early indica	2700	470.83	25.85	57624.04	86392.86	66.7%
	Mid/late indica	2760	470.83	84.44	193297.51	289801.36	
	Japonica	3100	546.62	51.77	132193.59	197894.60	66.8%
2015	Early indica	2700	470.83	25.61	57089.04	82978.26	68.8%
	Mid/late indica	2760	470.83	85.96	196777.05	286013.15	
	Japonica	3100	546.62	52.36	133700.08	193768.23	69.0%

Data source: USTR, 2017

Table 2-5 China's current total AMS on corn reported by the U.S.

	Province	AAP	FERP	QEP	MPS	VOP	AMS
		RMB/Ton		Mt	Million RMB		%
2012	Heilongjiang	2100	366.07	28.88	152217.43	457109.40	33.3%
	Jilin	2120		25.79			
	Liaoning	2140		14.24			
	Inner Mongolia	2140		17.84			
2013	Heilongjiang	2220	336.07	32.16	180449.16	474866.21	38.0%

[7] AAP = Applied Administered Price; FERP = Fixed External Reference Price, QEP = Quantity of Eligible Production; VOP = Value of Production; MPS = Market Price Support; MPS = (AAP - FERP) × QEP; AMS = MPS/VOP

[8] The AAP is "the price the Chinese government provides for each of the basic agricultural products and is identified for each product and each year in the Chinese legal instruments implementing the program" (DS511 report).

[9] The FERP is a static reference value defined by the Agreement in Annex 3, which states that "the price 'shall be based on the years 1986 to 1988", "may be adjusted for quality differences as necessary," and it shall "generally be the average FOB unit value for the basic agricultural product concerned in a net exporting country and the average c.i.f. unit value for the basic agricultural product concerned in a net importing country in the base period" (WTO).

[10] Eligible production refers to "production that is "fit or entitled" to be purchased rather than production that was actually purchased." (DS511 report).

	Jilin	2240		27.76			
	Liaoning	2260		15.63			
	Inner Mongolia	2260		20.7			
2014	Heilongjiang	2220	336.07	33.43	176770.62	482979.84	36.6%
	Jilin	2240		27.33			
	Liaoning	2260		11.71			
	Inner Mongolia	2260		21.86			
2015	Heilongjiang	2000	366.07	35.44	163459.99	423471.48	38.6%
	Jilin			28.06			
	Liaoning			14.04			
	Inner Mongolia			22.51			

Data source: USTR, 2017

The disputes mainly resulted in two central elements: FERP and QEP. About FERP, the rule in the Agreement is that "the price shall be based on the years 1986 to 1988", "may be adjusted for quality differences as necessary," and it shall "generally be the average f.o.b. unit value for the basic agricultural product concerned in a net exporting country and the average c.i.f. unit value for the basic agricultural product concerned in a net importing country in the base period" (WTO). But practices of each country vary the understandings of the rule. For example, for the Republic of Korea, FERP of rice is 1.1 times of China's FOB price in 1993 reported by FAO; barley' FERP is Japan's CIF price reported by Japan External Trade Organization based on the years from 1986 to 1988, and it is CIF price of Korea for corn-based on the years from 1986 to 1988. For Japan, FERP of rice is CIF prices of Thailand on average based on the years from 1986 to 1988, and it is sluicegate price in European Common Market for pork. For E.U., FERPs are the same as those applied to estimate producer support, and these price concerns handling charges and commercial margins. The 36 members, including China but excluding Bulgaria, which is now a member of the E.U., that have acceded to the WTO since 1995, used later base years than 1986 to 1988 in AMS calculations, for example, Viet Nam, Ukraine, the Russian Federation, and Kazakhstan. From the above examples, in practice, different countries have different data sources for FERP, and even data for a domestic product come from foreign countries' data for their same product, and the base years are not only the period from 1986 to 1988. In addition, there is a consensus that the U.S. is the price maker of the world prices so that the border (FOB and CIF) prices of other countries are largely based on the U.S. FOB price of each variety of U.S., plus the transport and insurances costs (Jacques, 2016), which may lead to unfairness. About QEPs, three kinds of QEP were applied to calculated China's AMSs, which are the quantities of total China's production applied by OCED (2017), the quantities of production in major provinces by USTR (2017), and the Chinese government-purchased quantities in WTO reports by China officials. The related measures are stockpiling for corn and minimum price measures for rice and wheat in major provinces, which are not applied in all provinces of China.

In China's report, the AMSs of China showed differences with those reported by the U.S. In China reported, the FERPs are much higher because they are calculated by border price based on the years from 1996 to 1998, and the QEPs are much lower because they are the Chinese government-purchased quantities. According to the data from China's reports, the values of AMS in China for wheat and rice are from 0.01% to 5.58%, which are without exceeding China's commitments, which is reported in Table *2-6* and Table *2-7* in detail. As for corn, China reported the total AMS in 2013, 2014, and 2015 on corn exceeded China's commitment (see in Table 2-8), but China modified its price support program for corn in 2016, with the result that the WTO domestic support dispute does not show stress on China's commitment about corn.

Table 2-6 China's current total AMS on wheat reported by China

	AAP	FERP	QEP	MPS	VOP	AMS
	RMB/Ton		Mt	Million RMB		%
2012	2040	1698	23.20	7936	264100	3.00%
2013	2240	1698	8.38	4544	289160	1.57%
2014	2360	1698	25.93	17171	307690	5.58%
2015	2360	1698	29.48	14282	313150	4.56%

Data source: Supporting tables DS:4 and DS:5 in Domestic support: China (WTO)

Table 2-7 China's current total AMS on rice reported by China

	Variety of rice	AAP	FERP	QEP	MPS	VOP	AMS
		RMB/Ton		Mt	Million RMB		%
2012	Indica	3517	2343	0.06	65	571490	0.01%
	Japonica	4000	3291	2.77	1966	203100	0.97%
2013	Indica	1831	2343	13.33	19847	601460	3.30%
	Japonica	4286	3291	9.48	9431	292780	3.22%
2014	Indica	3917	2343	9.75	15340	619300	2.48%
	Japonica	4429	3291	12.75	14507	298470	4.86%
2015	Indica	3923	2343	9.42	14604	612910	2.38%
	Japonica	4429	3291	14.10	16041	306450	5.23%

Data source: Supporting tables DS:4 and DS:5 in Domestic support: China (WTO)

Table 2-8 China's current total AMS on corn reported by China

	AAP	FERP	QEP	MPS	VOP	AMS
	RMB/Ton		Mt	Million RMB		%
2012	2125	1199	2.82	2611	442450	0.59%
2013	2245	1199	43.23	45225	475520	9.51%
2014	2245	1199	64.69	67666	479170	14.12%
2015	2000	1199	125.36	100410	431490	23.27%

Data source: Supporting tables DS:4 and DS:5 in Domestic support: China (WTO)

In the final Panel's report on 28 February 2019, the results supported that China broke the WTO rules about the products of wheat and rice, but corn. About corn, the Panel found that "following the 2015 corn harvest, China had removed an essential element of the challenged corn measure: the AAP" and the MPS measure relating to corn had expired prior to U.S. initiation of the dispute (WTO). Therefore, the Panel ultimately declined to rule on the corn measure. As for the two central elements, in China's case, the FERP should be based on years 1996-1998 reported by China, rather than the years 1986-1988, set out in paragraph 9 of Annex 3 of the Agreement and reported by the U.S. Regarding the QEP, the Panel reported that the QEP for wheat and rice is the entire volume of production in major provinces in the absence of any explicit or implicit limits in China's challenged measures. Based on this dispute settlement, the current total AMSs in 2012-2015 was calculated as shown in Table 2-9 and Table 2-10.

Table 2-9 China's current total AMS on wheat

	AAP	FERP	QEP	MPS	VOP	AMS

	RMB/Ton		Mt	Million RMB		%
2012	2040	1698	94.08	32175.36	264100	12.18%
2013	2240	1698	96.83	52481.86	289160	18.15%
2014	2360	1698	99.98	66186.76	307690	21.51%
2015	2360	1698	102.89	68113.18	313150	21.75%

Data source: Author's calculation according to dispute settlement

Table 2-10 China's current total AMS on rice

	Variety of rice	AAP	FERP	QEP	MPS	VOP	AMS
		RMB/Ton		Mt	Million RMB		%
2012	Indica	3517	2343	108.48	127355.52	571490	22.28%
	Japonica	4000	3291	50.87	36066.83	203100	17.76%
2013	Indica	3831	2343	108.29	161135.52	601460	26.79%
	Japonica	4286	3291	51.8	51541	292780	17.60%
2014	Indica	3917	2343	110.29	173596.46	619300	28.03%
	Japonica	4429	3291	51.77	58914.26	298470	19.74%
2015	Indica	3923	2343	111.57	176280.6	612910	28.76%
	Japonica	4429	3291	52.36	59585.68	306450	19.44%

Data source: Author's calculation according to dispute settlement

About the implementation of adopted reports, China informed the WTO of its compliance in this dispute on 18 June 2020. China stated a Notice on Improving the Wheat Minimum Procurement Price Policy (NDRC, 2019) and a Notice on Improving the Rice Minimum Procurement Price Policy (SC, 2020) were launched to help meet WTO rules. In these notices, the quantity of wheat applicable to AAP is limited to 37 Mt, and the numbers for India and Japonica rice are 20 Mt and 30 Mt, respectively. If these numbers are considered as QEPs, China's AMSs on rice and wheat are *de minimis* supports exempt from commitment. But on 16 July 2020, the U.S. still reported China had failed to bring its measures into compliance with its WTO obligations within a reasonable period of time. Therefore, this U.S.-China's dispute on Agriculture is still in the process of settling.

2.3 Possible future scenarios of agricultural policies in China

Due to agricultural resource limitations and the huge demand for agricultural products in China, it is widely recognized that China cannot be 100% self-sufficient in all its agricultural products. Moreover, with the premise of the global division of labor, it is not economical for China to be 100% self-sufficient since China does not have the competitive advantage of some agricultural products under the small-scale structure of agriculture. In addition, with the development of China's economy, the demand for agricultural products in China has been continually increasing. It can be predicted that the demand for some agricultural products may further increase in China in the future. In these contexts, for China, launching what kind of policies to deal with increasing demands and possible shortages is still under debate. In this section, the possible policies, including policies to increase agricultural supply and decrease agricultural demand, are introduced and discussed.

2.3.1 Launching polices to increase agricultural supply

Possible measures to increase agricultural supply include launching policies to further support and increase domestic production and possibly removing some import restrictions to increase imports. As for launching policies to further support and increase domestic production, although the U.S.-China agricultural dispute is in a process to settle and China may not need to make changes to decrease domestic support on agriculture and consequently to possibly decrease domestic agricultural supply, China has to formulate agricultural support policies under WTO rules. This implies it is impossible for China to launch policies to support domestic agriculture without restrictions, and one of the restrictions is that the total aggregate measurement of support in China on one agricultural product must lower than its commitment, 8.5%. In addition, agricultural resources such as land and water are limited. The possible way to increase domestic production may be to improve agricultural productivity, and China is increasing productivity by improving production technologies. But there is still a long way to go to improve productivity, and it may not be able to solve a shortage problem in the short term. As for removing some import restrictions to increase imports, by considering the economy, importing is a widely accepted solution to shortages and to not sufficient domestic supply of agricultural products. However, by considering food security, importing may have a negative effect on self-sufficiency goal. Huang (2017) argued that the concepts should be changed from "meat imports" to "feed cereal imports"; hence, feed grains such as corn should be imported more. The author, based on his prediction, contended that self-sufficiency in China of food should be over 95%, wheat and rice should be about 100%, and corn can be no less than 85%. According to the concepts of Huang and based on the current import pattern of corn in China, releasing trade restrictions on corn to increase its import should be implemented.

2.3.2 Launching polices to decrease agricultural demand

Possible measures to decrease agricultural demand include launching policies to lead to substitution to the agricultural products in shortage by some agricultural products with sufficiency and relocate the industries demanding for agricultural products in shortage to other countries with sufficient such products and increase imports produced in the industries of the countries. I take corn and husbandry as examples. Regarding substitution, China can launch policies to guide the farmers who produce live stocks to input more, for example, wheat and vegetables to substitute corn as feeds. Regarding relocating industries, China can launch policies to drive husbandry, which consumes more corn to move to other countries with sufficient corn and import more live stocks from these countries. However, the measure of substitution may cause losses in husbandry and wastes of agricultural resources, and the measure of relocating industries may be a huge project with a high cost and bring self-sufficiency stresses on other products. Consequently, researchers rarely explored the policies to decrease agricultural demand, and the measure is not widely accepted.

2.4 Summary

Agricultural support policies are widely applied by countries for some reasons. From 1949 when the People's Republic of China (PRC) was established, the Chinese government has repeatedly emphasized the importance of agriculture to the development of China. In this chapter, I have introduced and analyzed the evaluation of China's agricultural policies and the WTO rules, and the U.S.-China disputes on agriculture and explore the possible future scenarios of agricultural policies in China with three sections by comparing corn policies with the policies of wheat and rice in China. The findings provide:

By outlining the policy history of corn, wheat, and rice in China, we can conclude that China's agricultural policy history reflects gradual marketization and trade liberalization in

agriculture of China. In addition, price policies with direct price intervention have eliminated some agricultural varieties like corn but still work for some varieties like wheat and rice, and about trade policies, the trade of corn, wheat, and rice are governed by quota and tariff policies. Specifically, the Chinese government intervened to market prices from 1949 to 2004 by price control or price intervention of minimum price. China relaxed some price intervention from 2004. For corn, wheat, and rice, the price intervention policy changed to a stockpiling policy with price intervention in major provinces in 2004, 2006, and 2008. The price intervention measures were minimum prices for wheat and rice and target price for corn. However, the intervention policy for corn was abolished in 2016 and replaced by a subsidy for corn producers. Along with changes in price intervention policies, the government also changed the policies from taxing to subsidizing agriculture. About trade policies, their history can be divided into two periods: one before 2014 with trade control and trade intervention and the other one after 2014 with on trade intervention.

Regarding agricultural policies, WTO mainly sets rules on market access, domestic support, and export subsidies. As for China, about market access, it is prohibited for the application of non-tariff measures on some agricultural products like rice, wheat, and sugar, but available to use agreed quota manage imports. Regarding domestic support, China can apply green box measures, blue box measures, and non-exempt measures without exceeding its commitment that declares the non-exempt support (VOP) cannot exceed 8.5% for all agricultural products. Regarding export subsidies, China has eliminated all its export subsidies for agricultural products. In addition, the U.S.-China disputes on agriculture resulted from American's complaints on domestic support on agriculture in China. In detail, the disputes reflect on the values of FERPs and QEPs, and the disputes are still in the process of settling.

It is widely recognized that China cannot be 100% self-sufficient in all its agricultural products, and launching what policies to deal with increasing demands and possible shortages is still under debate. I outline the possible policies as the policies to increase agricultural supply and the policies to decrease agricultural demand and launching policies to expand imports is a widely accepted solution to shortages and to not sufficient domestic supply of agricultural products by considering economic effects.

Chapter 3 Analysis of the domestic supply of corn and its sufficiency under its policies in China

As for the domestic supply of agriculture in China, most researchers considered that China would face a shortage in domestic agricultural supply to meet its domestic demand. For example, Brown (1996) expressed a sensational trepidation, "who will feed China," because he considered that China would not produce enough food for Chinese people in the next several decades from 1995. In addition, some other researchers like Huang and Li (2003) and Chen et al. (2010) forecasted the shortage as well. As stated by Chen and Han (2016), the growth of domestic supply capacity of agriculture in China was restricted by some factors that on the one hand, China's resources for agriculture are scarce for low per capita arable land, low prolificacy of arable land and insufficient reserve arable land, and on the other hand agricultural resources in China are threatened by pollution for extensive uses of fertilizers and pesticides and pollution caused by urbanization.

Although it is well recognized by researchers that the domestic supply of agriculture may not totally meet its demand in China, this pattern would not appear in any agricultural products of China, and it has several policies to adjust agricultural production to maintain sufficient domestic supply of some agricultural products. In this chapter, I investigate the domestic supply of agricultural sectors in China by the example of corn under its policies. Firstly, in Section 3.1, I have a discussion on the classification of corn in Chinese that has an effect on the attitude to corn about food security and subsequently affects domestic corn supply and its policy development. Secondly, I analyze the domestic supply of corn by the movement of domestic supply with policy changes in Section 3.2. Last but not least, the sufficiency of corn in China is analyzed in Section 3.3. In addition, Section 3.4 summarizes the analysis results in the above three sections.

3.1 The classification of corn in Chinese

China has its system to classify agricultural products. Their classifications always imply the usages of them and attitudes to them about food securities and subsequently imply certain policies for them. For example, rice and wheat are two main edible cereals for Chinese people; therefore, several support policies and strict import restrictions are applied on them for food security. By contrast, soybean is not a main edible cereal in China, and thus it meets liberal policies on its import, and over 80% share of soybean markets in China was taken by its imports in the recent decade.

In this section, I have a discussion on the classification of corn in China. In Subsection 3.1.1, the inputs (consumption) of corn over time in China are analyzed. In Subsection 3.1.2, I show the debate on corn's classification in Chinese to express the debate on corn's policies about food security in China.

3.1.1 Inputs (consumption) of food corn and feed corn

The inputs of corn in China, especially the input as feed, have increased significantly since the economic reforms started in 1978. Figure 3-1 shows the inputs of corn as food and feed in China. It represents the inputs of both feed and food, and others have increased significantly, and the input as feed in 2019 was 190 Mt which was more than 7 times that with 27.1 Mt in 1980, while the input as food and others was 87 Mt, about 2.5 times of 34.7 Mt in 1980. In particular, the share of feed consumption increased to 68.98% of the total corn input in 2019 from 43.9% in 1980. Lohmar (2015) illustrated a supply and demand framework for meat and

feed ingredients, revealing that China still has scope for expansion in animal products and the input of corn as feed.

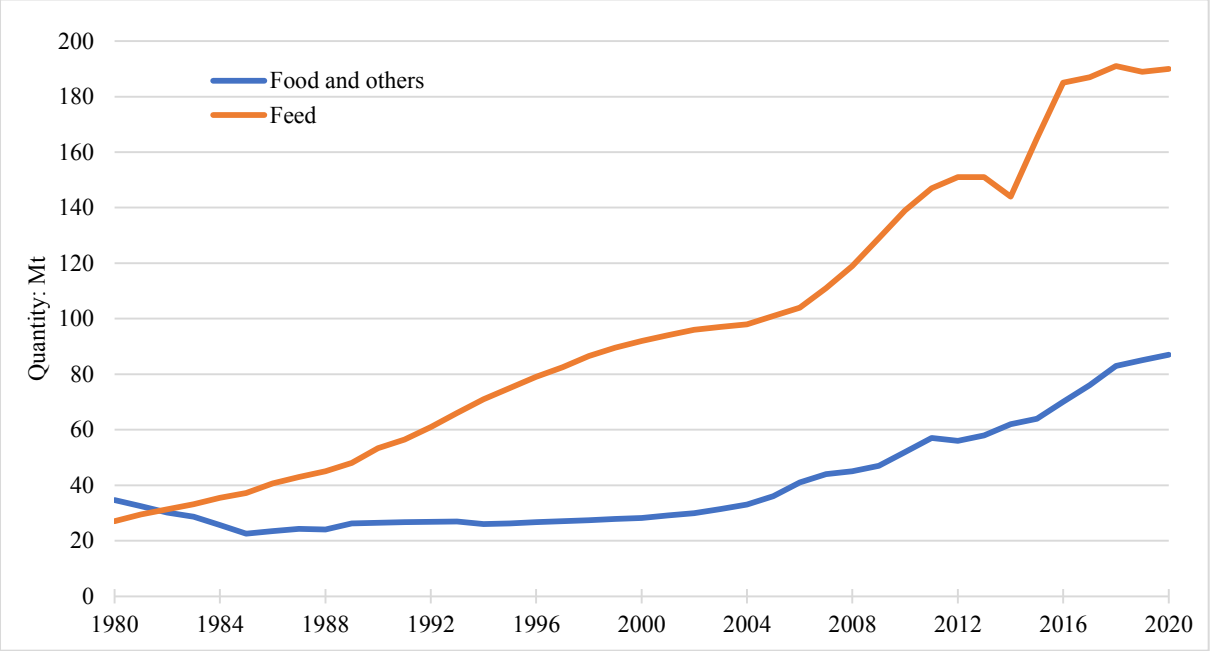


Figure 3-1 Inputs of corn in China
Data source: USDA

3.1.2 The debate on corn's classification in Chinese

The classification of corn stands at the crossroad of changes in China: whether corn should be classified as one of the edible cereals or one of the feed cereals for animals or others. China has its own concept concerning corn as one of "liangshi." In 1950, corn was listed as "liangshi" that also included wheat, rice, millet, soybean, sorghum, and other coarse cereals, and subsequently, potatoes. In 1996, Brown (1996) expressed a trepidation, "who will feed China," because he considered that China would not produce enough food for Chinese people in the next several decades from 1995. From 1996, China began to implement the strategy in which "liangshi" should be no less than 95% self-sufficient to maintain "liangshi" security (a part of food security) and dispel such kinds of trepidations like the one expressed by Brown. After the 18th national congress of China in 2012, the edible cereals for Chinese people were divided from 'liangshi,' which highlighted the importance of edible cereals for "liangshi" security. Subsequently, among all agricultural commodities, China's officials were particularly concerned about cereals, and the national "liangshi" security strategy was then decided, under which "liangshi" should be principally self-sufficient, and edible cereals should maintain absolute self-sufficiency. However, there was no official self-sufficiency rate for principal self-sufficiency (95% as a referenceable rate by scholars) and absolute self-sufficiency (100% as a reference). After the 19th national congress of China in 2017, the "liangshi" security strategy was converted to highlight the security of edible cereals. However, Chinese officials offer no clarity on whether corn belongs to the category of edible cereals. Based on a consistent classification or traditional Chinese framework of "liangshi," corn is listed as one of the edible

cereals that consists of wheat, and rice, as well. Figure 3-2 can help understand the relationships about corn's classification in China, thereby understanding the contents of this paragraph.[11]

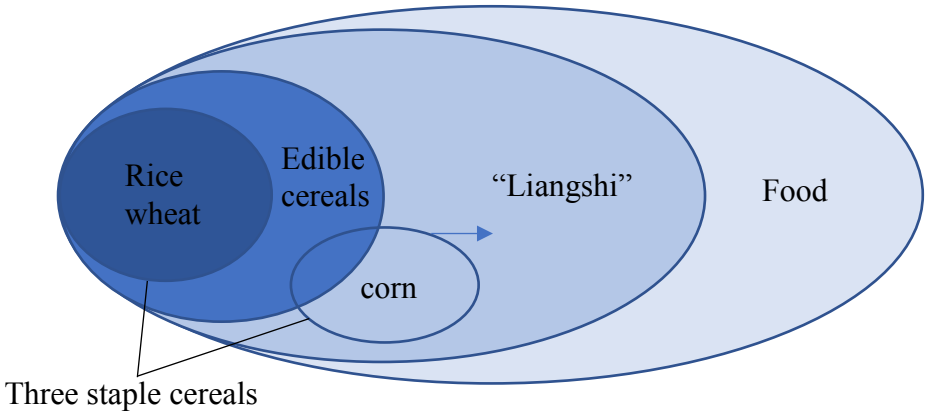


Figure 3-2 The corn's classification in China
Note: The arrow implies that the proportion of corn for food gradually decreased in China.

Whether a product is subjected to strict or liberal policies is referenced by its classification. Before 2016, Chinese governments implemented the stockpiling policy (target price) intervening to corn price directly and used the minimum price policies to intervene to domestic prices of wheat and rice. After 2016, the stockpiling policy was abolished. In addition, corn shared nearly the same protectionist policies that were targeted for rice and wheat in the category of edible cereals. At the same time, China has no such price intervention policies as the stockpiling policy on corn and the minimum price policies on wheat and rice implemented on other cereals. Table 2-1 shows the quotas, tariff rates of cereals of China, revealing that corn still share the strict import policy restrictions. However, corn is more a feed cereal rather than an edible cereal for food of Chinese people, as illustrated in Figure 3-2. Thus, what is the "role" of corn for "liangshi" security, as one of three staple cereals to keep 95% self-sufficiency rate, as one of the edible cereals to keep strict import policies like them on wheat and rice, as one of the feed cereals to share more liberal policies and possibly lower its self-sufficiency rate, or as a specific cereal to meet specific policies and specific self-sufficiency rate? What policies about "liangshi" security and self-sufficiency goal of corn are feasible for corn in China are still under debate.

3.2 The movement of domestic supply of corn in China

Corn policies impact the developments in the corn sector, which, in turn, affect the launch of possible policies. With the development of China's economy, some changes and trends have emerged in corn, which can offer clues that lead to feasible corn policies. This section explores domestic production, the domestic supply, and export, and ending stocks of corn in China, respectively, in Subsection 3.2.1, Subsection 3.2.2, and Subsection 3.2.3.

3.2.1 The domestic production of corn in China

Figure 3-3 illustrates domestic corn production of China. It shows that China has made remarkable progress of the production from 59.2 Mt in 1980 to 260 Mt in 2020, for the reasons

[11] The "three staple cereals" and "edible cereals" correspond with "三大主粮" and "口粮" in Chinese, respectively.

of increases in area harvested and yield of corn (see in Figure 3-4) caused by agriculture mechanization, price support, subsidy, import restraints, etc. However, the situation changed, especially since 2016 when a policy reform from stockpiling policy to a subsidy policy to corn producers was implemented on a pilot basis in aforementioned four provinces. The figure shows that domestic production of corn in China did not continue its upward trend from 2015.

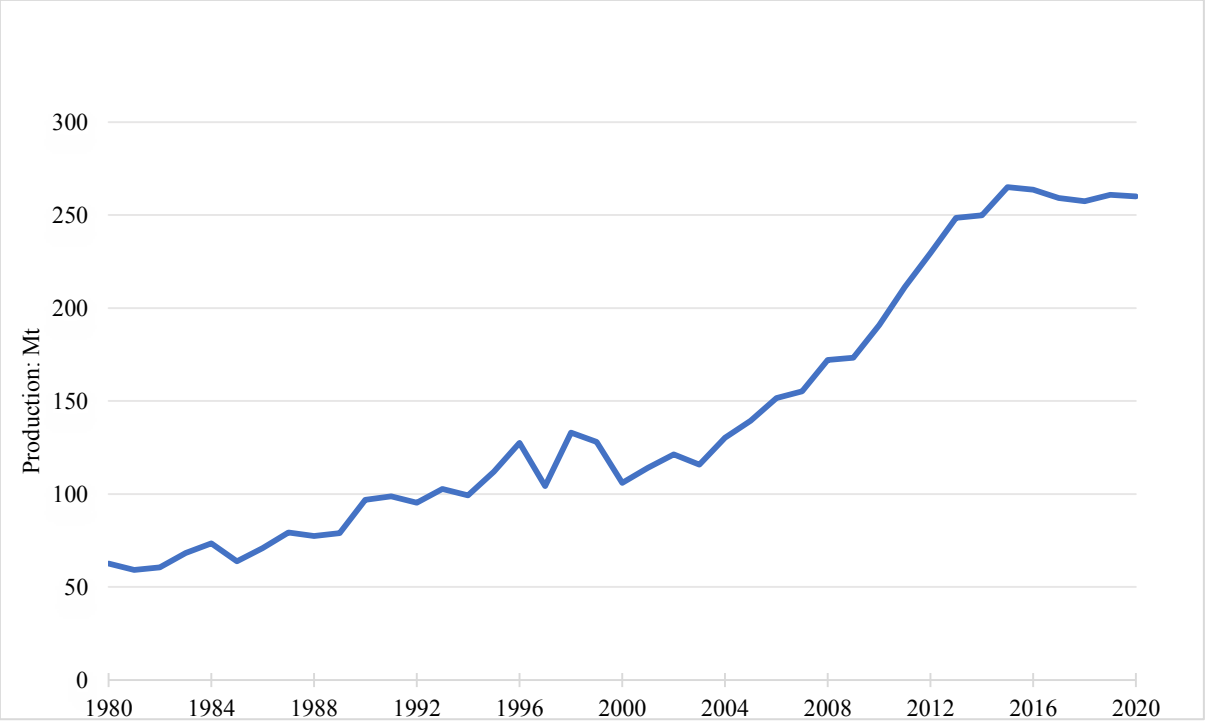


Figure 3-3 The domestic production of corn in China
Data source: USDA

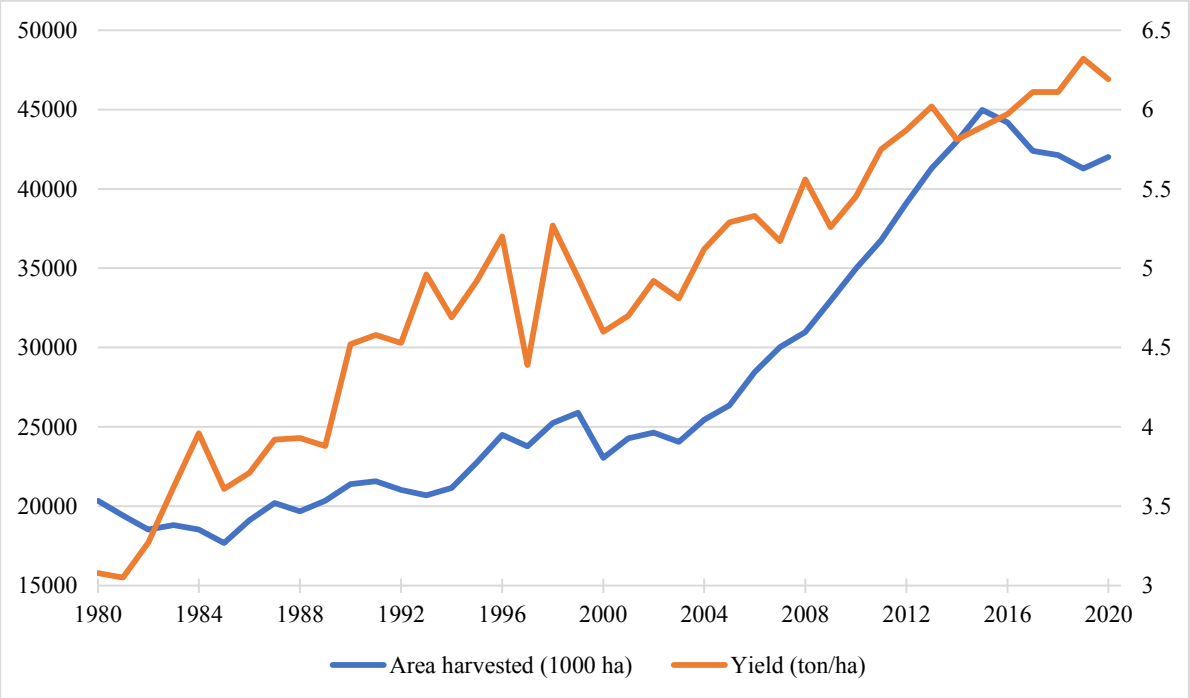


Figure 3-4 The area harvested and yield of corn in China
Data source: USDA

Corn production in China is primarily contributed through family farming, which is not as cost-effective as the large-scale mode of farm production. As the economy develops, the costs of labor, fertilizer and some other means for production gradually increase. MARA (Ministry of Agriculture and Rural Affairs, China) reported in 2015, the average price of second-class corn was 2380 RMB/ton in China's north-eastern area and 1602 RMB/ton by CIF from the U.S. to China. The gap was 778 RMB/ton. Although the comparative advantage of China in corn deteriorated, domestic production and sales of domestic corn did not decline until 2016 partly because of policy support, which also contributed to the difference between domestic and imported corn prices. To overcome farmers' poverty and ensure domestic supply for food security, China has been applying support and protection policies such as subsidies, price support, and tariffs on corn to guarantee farmers' income and maintain food security.

3.2.2 The domestic supply and export of corn in China

Figure 3-5 illustrates the domestic supply and export of corn in China.

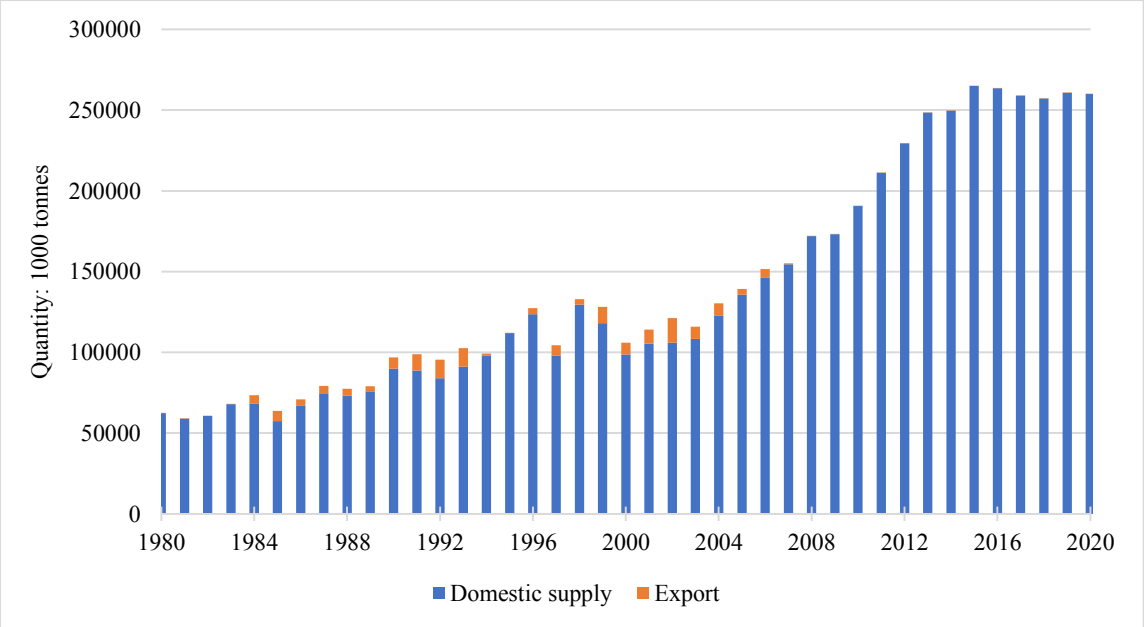


Figure 3-5 The domestic supply and export of corn in China
Note: The domestic production of corn equals its domestic supply plus its export.
Data source: USDA

As for the domestic supply of corn, similar to the domestic production of corn, its domestic supply has also made remarkable progress. The quantity of domestic corn supply has increased from 62.475 Mt in 1980 to 259.98 Mt in 2020. In addition, similarly, the upward situation has changed, especially since 2016 when the policy reform from stockpiling policy to a subsidy policy to corn producers was implemented on a pilot basis in the aforementioned four provinces. The domestic supply of corn in China did not continue its upward trend from 2016.

As for corn export of China, it has not increased with the increase in domestic corn production while the quantity of corn exported reduced from positive numbers before 2006 to almost negligible since 2007. The reason is that most corn production is consumed to meet the domestic demand for corn under the condition of import constraints limited by quotas and tariffs.

3.2.3 Ending Stocks of corn in China

Figure *3-6* shows ending stocks of corn in China. From 1980 to 1999, corn ending stocks gradually increased with the increases in domestic corn production and domestic supply. A sharp drop occurred in ending stocks from 2000 to 2004, and the production and domestic supply relatively decreased in this period as well. In 2013, the ending stocks approximately returned to their level in 1999. However, it continued to significantly increase, spanning the periods from 2014 to 2016, because in this period, the gaps between domestic price and import price got larger and larger (Figure 3-7), and the government continued to enlarge corn stocks to support domestic price of corn.

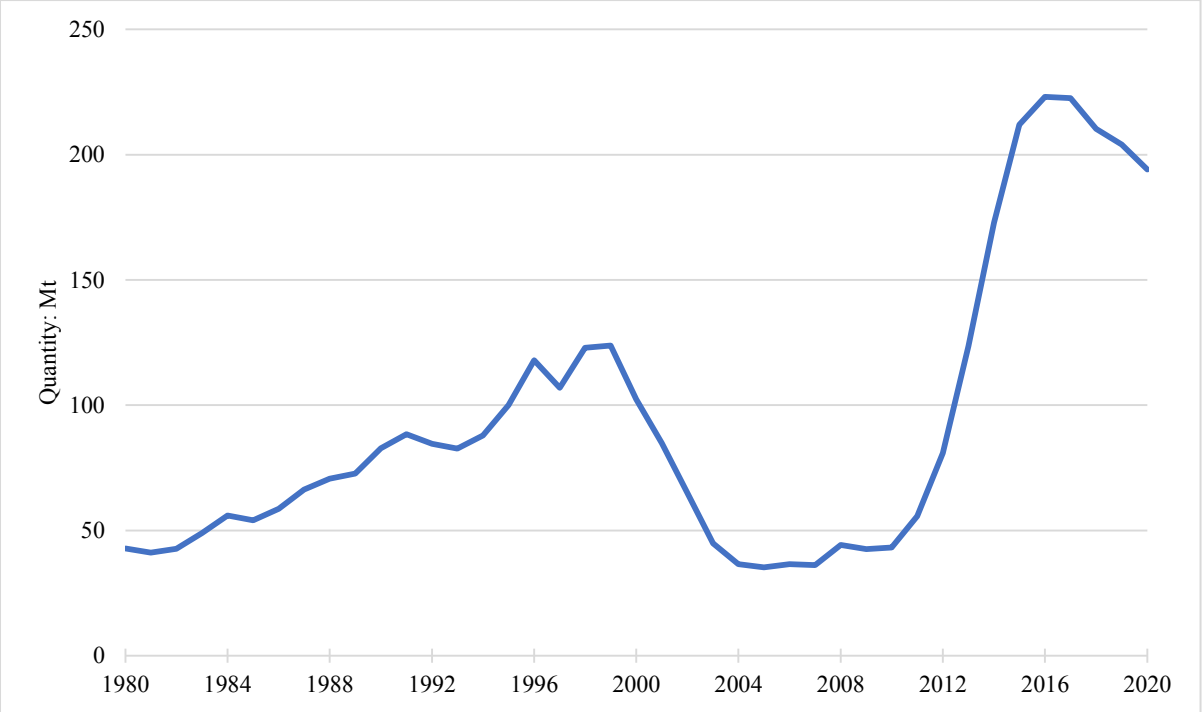


Figure 3-6 Ending stocks of corn in China
Data source: USDA

Figure 3-7 Price gaps between domestic and imported corn of China
Note: Price gaps equal to domestic price minus import price.
Data source: USDA

In addition, because in 2016, the stockpiling policy that can support the domestic price of corn was abolished, and the government was committed to decreasing corn stocks for the reasons of financial budgets, corn ending stocks continually decrease from this year. Consequently, the gaps between the domestic price of corn gradually decrease (Figure 3-7).

From 2016 to the end of 2019, the reduction of corn stocks had exceeded expectations, and the domestic supply of corn was expected to be insufficient to meet corn consumption in the next year (MARA, 2020).

3.3 The sufficiency of corn under its policy in China

In this section, I analyze the sufficiency of corn under its policy in China. The sufficiency of corn in China and its self-sufficiency are analyzed in Subsection 3.3.1 and Subsection 3.3.2.

3.3.1 The sufficiency of corn in China

Figure 3-8 describes corn consumption, production, and imports of China. It shows that from 2010 to 2016, domestic production can meet the consumption of corn in China by 100%; meanwhile, the left out of domestic production increased the corn stocks (also because of negligible exports). At the end of 2015, the government proposed the plan to reduce corn stocks for financial reasons, and the price support policy - stockpiling policy was abolished in 2016. Consequently, the domestic price of corn dropped, and corn production reduced despite the subsidy for corn producers. From the year 2017, corn production had been being no longer enough to meet corn consumption in China.

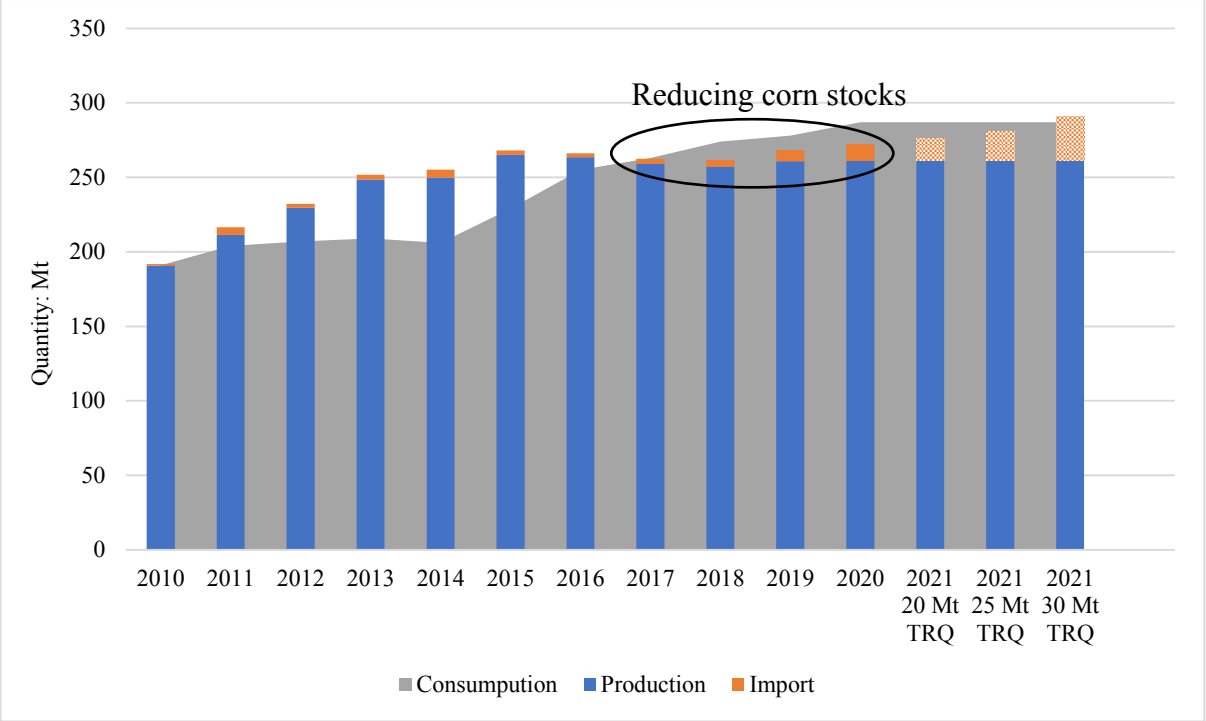


Figure 3-8 The corn consumption, production, and imports of China

Data sources: USDA, NBSC, the General Administration of Customs of China

Notes: The consumption equals the input quantity of domestic corn and imported corn plus ending stocks. The production data for 2020 is changed from 260.67 Mt projected by USDA to 261 Mt reported by NBSC and the import data for 2020 is changed from 17.5 Mt projected by USDA to 11.3 Mt reported by the General Administration of Customs of China. The data of consumption and production for 2021 are projections estimated by the rule: equality with the data in 2020. TRQ: tariff rate quota

It can be expected that if China's government does not reduce corn stocks in 2021, domestic corn will be in short supply to meet corn consumption. In addition, as shown in Figure 3-8, the 7.2 Mt import quota of corn will not be enough to meet the shortage by projections.

3.3.2 The self-sufficiency of corn in China

Figure 3-9 describes the movements of self-sufficiency rate of corn of China. In most years, from 1980 to 2020, the self-sufficiency rate of corn is above 95%, which meets the target of the self-sufficiency rate of China well. The domestic production of corn in China significantly increased since 2000 (Figure 3-3 or Figure 3-10) and this pushed the self-sufficiency rate up sharply (Figure 3-9). However, the upward trend changed in 2014, and the self-sufficiency rate dropped dramatically from 121.2% in 2014 to 93.9% in 2020; meanwhile, domestic production of corn changed its increase trend from 2015.

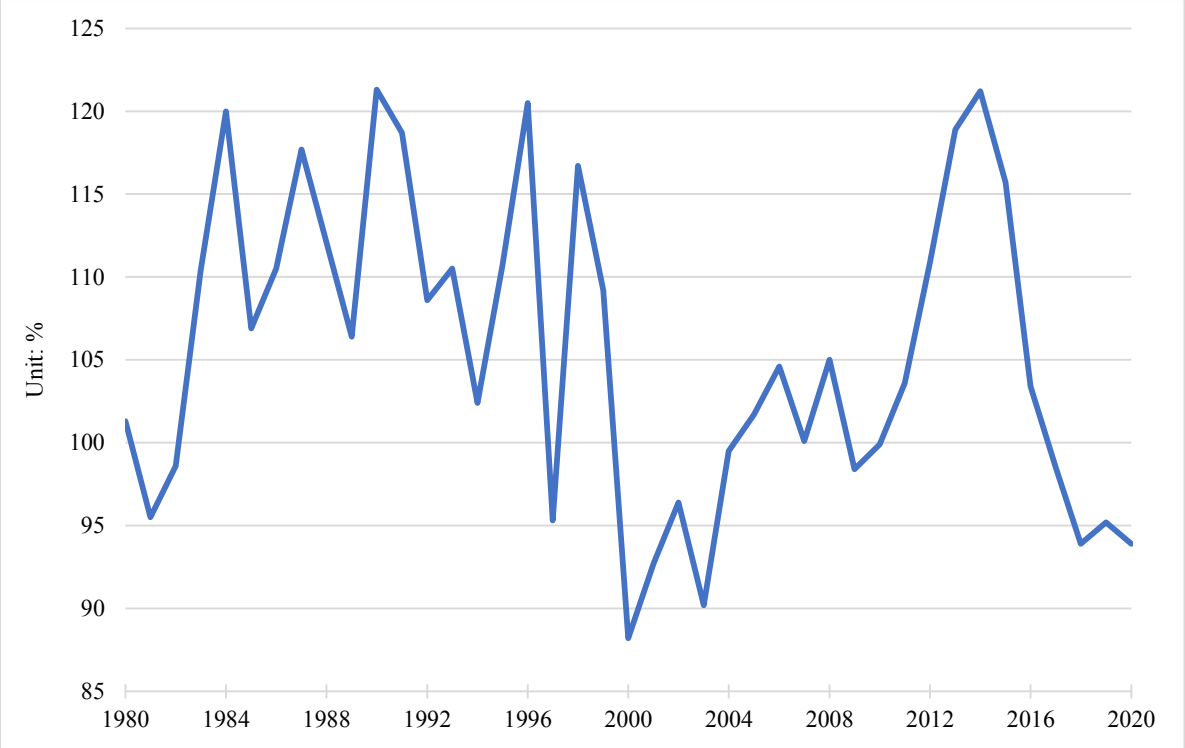


Figure 3-9 Movements of the self-sufficiency rate of corn in China

Data source: USDA

Note: The self-sufficiency rate equals values of domestic production divided by values of consumption of China.

Figure 3-10 is a quadrantal diagram of the production-self-sufficiency rate of corn in China, which shows in most of the years from 1980, with the increases of domestic production, the self-sufficiency rate increased as well. However, in recent years from 2016, with the decreases in domestic production, the self-sufficiency rate decreased as well. In addition, from 2017, the self-sufficiency rate has become lower than 100%, which suggests the domestic supply of corn is not sufficient to meet corn demand, and it has appeared lower rates than the target rate of 95% from 2018. Whether the target rate of corn should be 95% for the future or not is still under debate by researchers and policymakers.

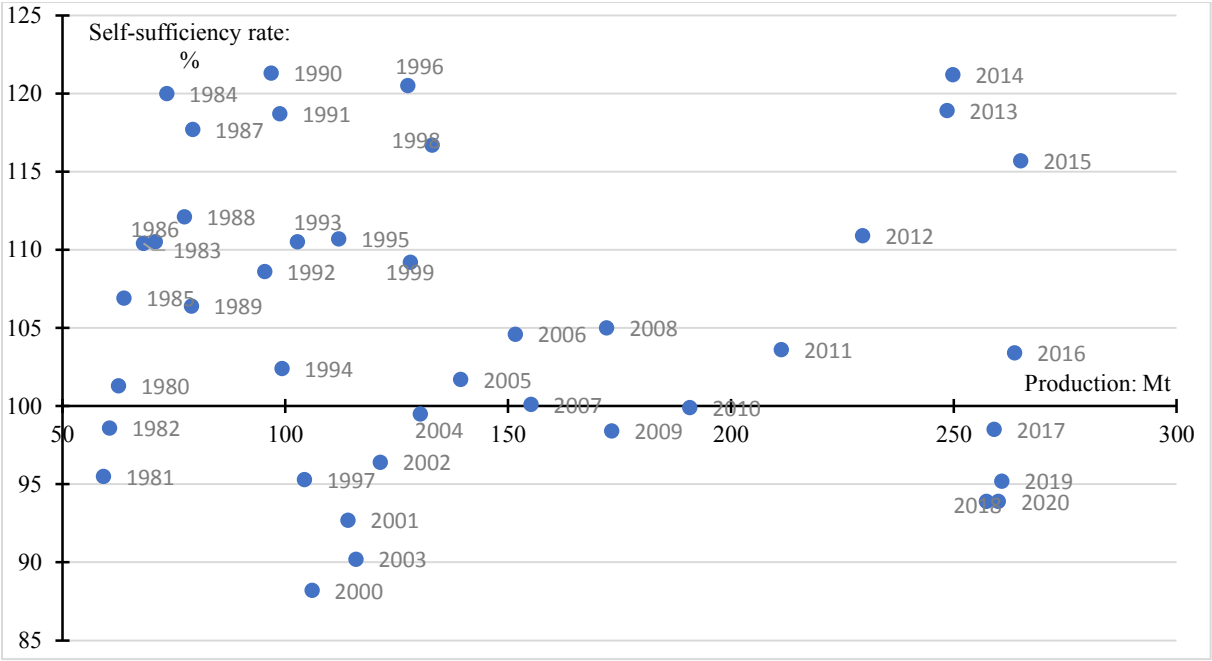


Figure 3-10 A quadrantal diagram of the production-self-sufficiency rate of corn in China
Data source: USDA

3.4 Summary

Although it is well recognized by researchers that the domestic supply of agriculture may not totally meet its demand in China, this pattern would not appear in any agricultural products of China, and it has several policies to adjust agricultural production to maintain sufficient domestic supply of some agricultural products. In this chapter, I have investigated the domestic supply of agricultural sectors in China by the example of corn under its policies with a discussion on the classification of corn in Chinese, an analysis of the domestic supply of corn by the movement of domestic supply with policy changes, and an analysis of the sufficiency of corn in China. The findings provide:

Corn input (consumption) in China has witnessed a sharp upward trend since 1980, mainly for animal feed, and China still has scope for expansion in animal products and the input of corn as feed. In this context, what policies about "liangshi" security and self-sufficiency goal of corn are feasible for corn in China are still under debate, and this debate is reflected in the debate on corn's classification in Chinese.

About the factors in relation to the movement of domestic supply of corn, China had made remarkable progress of the production from 59.2 Mt in 1980 to 260 Mt in 2020, and similarly, its domestic supply has also made remarkable progress with the quantity increase from 62.475 Mt in 1980 to 259.98 Mt in 2020. However, the domestic supply of corn in China did not continue its upward trend from 2016. In addition, the quantity of corn exported reduced from positive numbers before 2006 to almost negligible since 2007. What's more, corn ending stocks changed significantly from 1980 to 2020. Recently, it continued to significantly increase spanning the periods from 2014 to 2016, because in this period, the gaps between domestic price and import price got larger and larger, and the government continued to enlarge corn stocks to support the domestic price of corn.

About sufficiency of corn in China, from 2010 to 2016, domestic production can meet the consumption of corn in China in 100% and from the year 2017, corn production had been being no longer enough to meet corn consumption in China partly because of the elimination of the stockpiling policy with price support. In addition, in most years from 1980 to 2020, the self-

sufficiency rate of corn is above 95%, which meets the target of self-sufficiency rate of China well; however, the self-sufficiency rate dropped dramatically from 121.2% in 2014 to 93.9% in 2020.

Chapter 4 Study on corn imports and substitution under import policies of China and export capacity of corn origins

In Chapter 3, I have analyzed the domestic supply of agricultural sectors of China under its agricultural policies by an example - corn. I draw the conclusion that the domestic supply of corn may not be sufficient to meet its domestic demand in China. Subsequently, importing more corn is a possible choice for China. In General, more imports of agricultural products are possible choices in the period of shortage. As for corn, it is widely supported by researchers that the domestic supply of corn cannot meet its growing demand in China, and importing more corn is necessary. Based on the recent situation and possible trends of supply and demand, it is widely accepted that corn self-sufficiency of 95% is difficult to achieve. Huang et al. (2017) predicted that the overall food self-sufficiency of China is likely to fall from 94.5% in 2015 to around 91% by 2025, and imports of corn are likely to increase substantially. Their study projects net imports of 20.2 Mt in 2025, about 4.3 times the number in 2015 reported by the National Bureau of Statistics of China (NBSC 2016). The organization for Economic Co-operation and Development and FAO (OECD-FAO 2016) predicted that the number would be 6.1 times, while the United States Department of Agriculture (USDA 2016) projected it as 6.2 times for the year 2025. All these numbers imply more imports of corn in 2025 than in 2016. After the policy changes in 2016 mentioned above, the sufficiency rate declined from 115.7% in 2015 to 95.2% in 2019. This may continue to decline because of the rapid growth in the demand for corn. By analyzing the demand, supply, and trends of animal products in China, Lohmar (2015) contended that China is likely to procure sufficient feed grains, including corn, from global markets to meet the growing demand as feed grain consumption is expected to grow faster than corn production.

For some agricultural products, more imports may be inevitable in China; however, given that imports may not perfectly substitute domestic products, it is necessary to quantify how much imports can substitute to domestic ones. Researchers have found fruitful results on elasticities of substitution to quantify the substitution between imports and domestic ones of agricultural products. Shiells et al. (1986) estimated the elasticity for some industries in the U.S. with annual data from 1962 to 1978 at the Standard Industrial Classification (SIC) 3-digit goods level and reported a value of elasticity of 1.421 for grains. Gallaway et al. (2003) also estimated the elasticity for some U.S. industries using monthly data over the 1989-1995 period at the SIC 4-digit goods level and distinguished between long-run and short-run elasticity. According to Gallaway's definition, all the elasticities in this study are long-run elasticity. Turner et al. (2012) added some explanatory variables in their model to capture effects such as market size and distinguished between distance and weighted distance by population and employment weights, and they obtained 0.919 relating with distance variable and 0.645 relating with weighted distance variable for "agriculture, forestry, fishing and hunting" in the Standard Classification of Transported Goods (SCTG) of Illinois. Kapuscinski and Warr (1999) reported the elasticity for the Philippines using annual data spanning the period from the mid-1970s through the late 1980s, and different models found different values of elasticity for corn (3.692 to 4.916). Ogundeji et al. (2010) performed estimates for South Africa using quarterly data from the first quarter of 1995 to the third quarter of 2006 at the 4-digit goods level in the Harmonized System (H.S.), and they obtained 2.75 for corn and 1.91 for wheat and meslin. For the same country, Gibson (2003) found an elasticity value of 1.273 for "agriculture, forestry, and fishing (SIC)" at a 2-digit goods level using annual data from 1970 through 2001. Other researchers used panel data for their estimations. Németh et al. (2011) estimated the elasticity for all European Union countries (E.U.), the first 14 European Union countries (E.U.14), and the new European Union countries (NEU) (those joining the E.U. after the original 14 countries) using annual data from 1995 to 2005. They pointed out that the elasticity of agriculture is 3.6

for the E.U., 3.07 for the E.U.14, and 4.47 for the NEU. The GTAP (Global Trade Analysis Project) database provides the elasticities for agents of all regions, reporting 4.45 for corn, 5.05 for paddy rice, and 1.3 for other grains. From the above studies, we can see that the elasticity varies by country/region and classification of products. However, the study on the agricultural products with the subdivided classification of China is scarce.

In addition, quantifying how much imports from different origins can substitute to each other is also necessary because it is possible that not all partner countries of a country can stably supply agricultural products to the country for some reasons like the occurrence of some natural disasters and finding their substitutes is an important way to ensure the sufficient supply. The elasticity of substitution between goods from partner countries of a country is widely applied to quantify the substitution between goods from foreign origins. However, very few researchers estimated this elasticity by historical data. In some general equilibrium studies, they calculated the elasticity by a so-called rule - the "rule of two" under which the elasticity of goods from foreign sources is twice as much as the elasticity between domestically produced and imported goods. However, Feenstra et al. (2018) denied the accuracy of the "rule of two" and found no significant difference between the two elasticities for most of their sample goods. Additionally, it is obvious that historical data may not support the elasticity values calculated under the rule.

Although for some agricultural products, more imports may be inevitable in China, increasing agricultural imports should be based on the export capacities of the world and China's partner countries. In general, researchers analyze exports from the perspective of export countries rather than import countries. For example, Hansen et al. (2017) reported that agricultural exports from the U.S. to China increased rapidly by comparing the exports to China, Canada, Mexico, and Japan. Sun and Li (2018) analyzed the agricultural exports of China to the Association of Southeast Asian Nations (ASEAN). However, as China is a net import country for some agricultural products like corn, analyzing export from the perspective of import countries shows the significance of ensuring sufficient supply. In the perspective of importers, Zhang and Mu (2016) found that some eastern European countries like Russia and Ukraine have increasing export capacity to supply corn to China, while the export capacity of the U.S. potentially lowers.

In this Chapter, the development of corn import over time are analyzed; how much imports of China can substitute to domestic ones and how much imports of China from different origins can substitute to each other are quantified, and the export capacities of the world and China's partner countries are analyzed. In Section 4.1, the methodology of panel data analysis is introduced as the basis for this study. Section 4.2 explores the development of corn import in China with import policy changes to show the evaluation and trend of corn import in China. In Section 4.3, I quantify how much imports of China can substitute to domestic ones and how much imports of China from different origins can substitute to each other by estimations of elasticities of substitution with an Armington approach. Section 4.4 is to analyzes the export capacity of import-origin countries. In addition, Section 4.5 summarizes the analysis results in the above four sections.

4.1 A methodology of panel data analysis

Panel data and corresponding estimation methods are widely used in analyses. In this sector, I apply a panel data analysis to study the agricultural imports under the import policies of China. The approach in relation to this study is the random coefficient approach. To introduce this approach, I firstly distinguish the basic concepts of mixed effects, fixed effects, and random effects, which are introduced in Subsection 4.1.1. Then, the random coefficient approach is introduced in Subsection 4.1.2.

4.1.1 Mixed effects, fixed effects, and random effects

As an extension of simple linear models, linear mixed models (ME) contain both fixed and random effects and are particularly used when there is non-independence in the data, such as arises from a hierarchical structure. Fixed effects (FE) are constant effects across individuals, and random effects (RE) vary. Under the introduction of Borenstein et al. (2010), in FE models, I assume that there is one true effect size that underlies all the individuals in analysis and that all differences in observed effects are due to sampling error and by contrast, in RE models I allow the true effect sizes to differ, and in other words, it is possible that all individuals share a common effect size, but it is also possible that the effect size varies from individual to individual.

ME models can be expressed as following equation:

$$y_{it} = \boldsymbol{x}'_{\boldsymbol{it}}\boldsymbol{\beta} + \mu + \varepsilon_{it} \tag{4-1}$$

Notions are:

y_{it} dependent variable of individual i at time t,
$\boldsymbol{x}'_{\boldsymbol{it}}$ vector of independent variables of individual i at time t,
$\boldsymbol{\beta}$ coefficient vector,
μ constant term,
ε_{it} error term of individual i at time t.

Under ME structure expressed by the above equation, all individuals share one constant (μ), which implies that there are no individual-variant effects. However, applying the model may omit the individual-variant effects cross individuals.

FE models can be expressed as following equation:

$$y_{it} = \boldsymbol{x}'_{\boldsymbol{it}}\boldsymbol{\beta} + \mu_i + \varepsilon_{it} \tag{4-2}$$

In the equation, μ_i stands for individual effect of individual i. Under FE models expressed by the above equation, it is necessary to test whether there is an individual effect that varies from individual to individual (not all μ_i are equal).

RE models can be expressed as following equation:

$$y_{it} = \boldsymbol{x}'_{\boldsymbol{it}}\boldsymbol{\beta} + \mu_i + \varepsilon_{it} \tag{4-3}$$

We can consider the term, $\mu_i + \varepsilon_{it}$, as the composite error term in RE models. Under RE models expressed by the above equation, it is necessary to test that there is no correlation between the composite error terms ($\mu_i + \varepsilon_{it}$) across different individuals.

4.1.2 A random-coefficient regression approach

Similar with the individual effects in intercept (μ_i), the vector of coefficient ($\boldsymbol{\beta}$) may also show individual effects. I apply a random coefficient approach expressed as below to describe the individual effects in the coefficient.

$$y_{it} = \boldsymbol{x}'_{\boldsymbol{it}}\boldsymbol{\beta}_{\boldsymbol{i}} + \varepsilon_{it} = \boldsymbol{x}'_{\boldsymbol{it}}(\boldsymbol{\beta} + \boldsymbol{\vartheta}_{\boldsymbol{i}}) + \varepsilon_{it} \tag{4-4}$$

where $\boldsymbol{\beta}_{\boldsymbol{i}}$ is the vector of coefficient of individual i, which can be divided into a vector of average coefficient of individuals ($\boldsymbol{\beta}$) and a vector of individual-specific effects ($\boldsymbol{\vartheta}_{\boldsymbol{i}}$). By this approach, we can capture individual effects in both intercepts and coefficients of independent variables. In addition, the FGLS (the feasible generalized least squares) proposed by Swamy (1970) is used to estimate the parameters in the above equation.

4.2 Corn imports of China under its import policy changes

In this section, the corn imports of China with import policy changes are analyzed. Firstly, I analyze the corn imports over time in Subsection 4.2.1. Secondly, I have a discussion on expanding corn imports of China in Subsection 4.2.2.

4.2.1 Corn imports of China over time

Although China has made significant progress in the domestic production of corn, the country changed from a net exporter to a net importer of corn because of the massive domestic corn consumption from 2009 (Figure 4-1). The quantity of corn exported reduced from high positive numbers before 2006 to almost negligible since 2007. By contrast, the quantity of corn imported increased from near zero before 2008 to high positive numbers since 2009 (Figure 4-2).

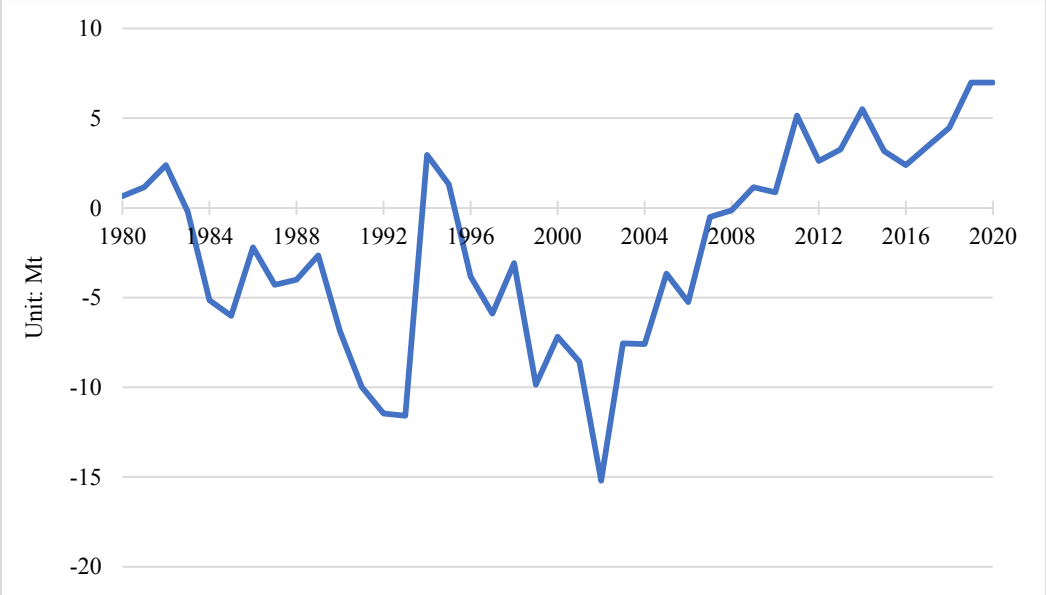


Figure 4-1 Net imports of corn in China
Data source: USDA
Note: The values of net imports are calculated by import quantities minus export quantities.

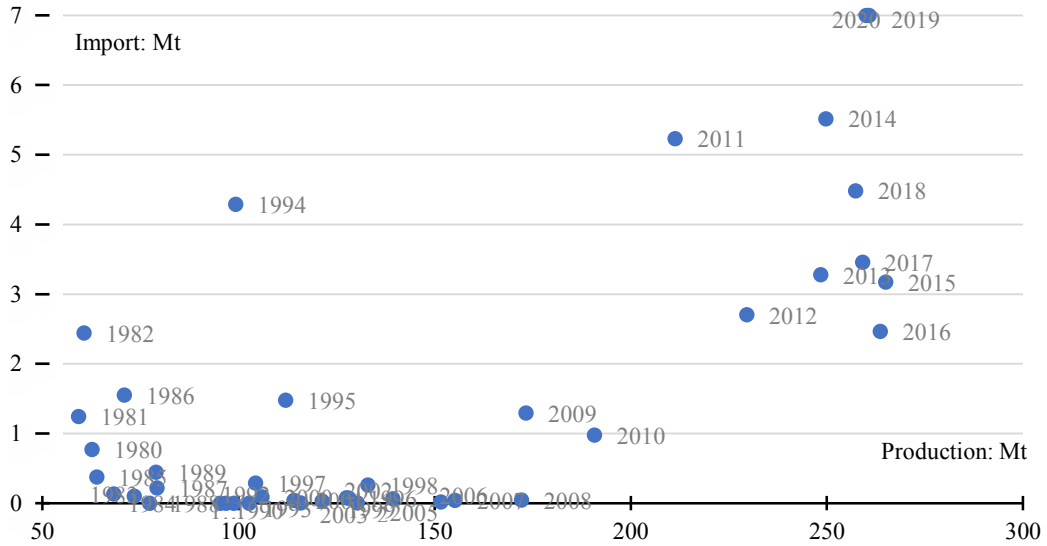


Figure 4-2 A quadrantal diagram of the production-import of corn in China
Data source: USDA

Figure 4-3 shows the movement of the corn import in China. From this figure, we can observe that in recent years from 2008, the imports significantly increased, and they almost reached the top quantity (7.2 Mt) of its import quota from 2019. Given that corn production did not show an upward trend in the last five years, imports of corn have increased consistently to meet the rising domestic demand. However, if corn demand gradually increases in the future, China may face a shortage of domestic corn and import more corn. Thus, expanding its import quota or lowering its above quota import tariff to liberalize its corn market for China are possible future scenarios of corn trade policy in China. The future scenarios would lead to a significant increase in corn imports (Huang et al., 2017). Consequently, increased corn imports in China would not only provide export opportunities for land-rich and water-rich countries but also contribute to global land and water savings (Huang et al., 2017; Ali et al., 2017).

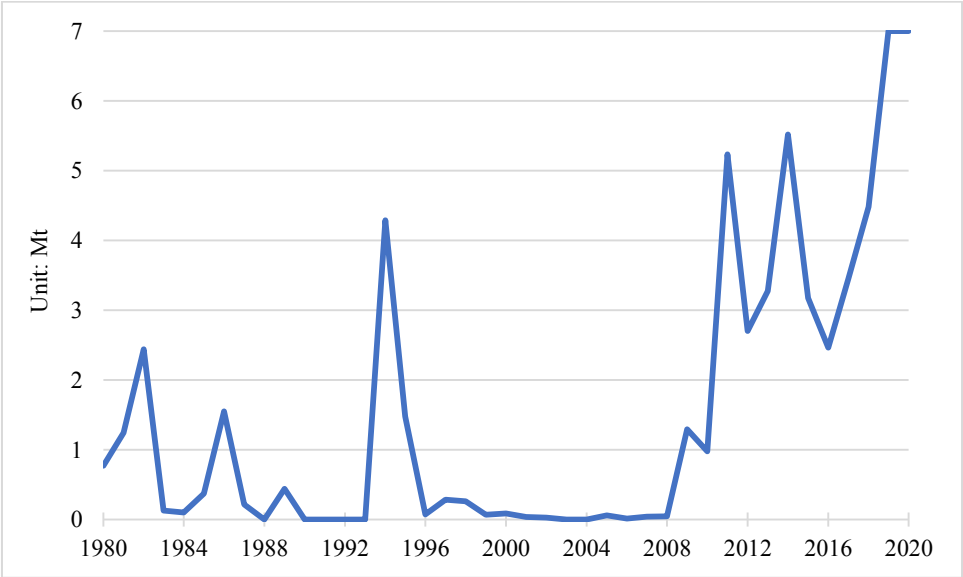


Figure 4-3 The corn import in China
Data source: USDA

4.2.2 A discuss on expanding corn imports of China

As the analysis shown in Subsection 3.3.2 and Subsection 4.2.1, China has been absent from global corn imports, particularly when compared with its consumption rates, in its efforts to bolster food security and maintain self-sufficiency. From 1980 to 2020, China has not exceeded 7.2 Mt corn imports and maintained self-sufficiency of 90% in most of the years. However, Chinese corn prices significantly surged in the recent two years from 2019, which forced China to scoop up large quantities of corn imports. China is on the path to becoming the top importer in the world, particularly after the elimination of the corn stockpiling policy in 2016. As corn imports of China have almost reached the top quantity of its import quota from 2019, in front of increasing demand for corn, will China relax its import policies[12] to expanding corn imports?

As discussed in Section 2.3, China may have several measures to solve shortage problems in agriculture by increasing corn supply by launching policies to further support and increase domestic production and possibly removing some import restrictions to increase corn imports and by decreasing domestic demand for corn with launching policies to lead to substitution to corn by some agricultural products with sufficiency and relocate the industries demanding for corn to other countries with sufficient corn. Which measures more feasible for future scenarios about corn are still under debate. It should be noted that about these measures, importing is a widely supported point of view by researchers; however, importing implies lower self-sufficiency, which may go against the security goal of corn in China.

4.3 The substitution of China's corn and the corn from different origins: estimation of elasticities of substitution

In an open economy, suppose that domestic good perfectly substitutes the imported good, such that the economy would not export and import the good simultaneously. However, an economy often reports both imports and exports of a good. Therefore, it is necessary to consider imperfect substitution between goods in the same category by their origins. In other words, domestic good is assumed to be similar to but slightly different from the imported good. The Armington model incorporating the imperfect substitution assumption is applied in this study.

In this section, I investigate the substitution between domestic corn of China and its imported corn by an Armington approach. In Subsection 4.3.1, the approach is introduced. Subsection 4.3.2 is used to describe the data for this study. Subsection 4.3.3 contains a result analysis.

4.3.1 An Armington approach

Armington (1969) applied an approach in which consumers distinguish goods in the same category by their origins, which is called Armington's consumption. This consumption implies producers combine domestic goods with the corresponding imported goods being "Armington composite goods" consumed by consumers or for intermediate uses. This way to distinguish goods according to their origins is widely accepted and applied in trade-policy analyses. Based on Armington's approach, I applied the assumption in Liu et al. (2020), by which producers have a two-stage procedure to choose the input level of each good in order to achieve maximum profitability and optimize production. In the first stage, they choose input levels of domestically produced and imported goods to maximize profits from composite goods. In the second stage, producers decide input levels of goods imported from different partner countries for maximum

[12] The tariff rates for corn of China are 1% within quota, 65% out of quota for MFN countries, and 50% out of quota for ASEAN countries. Given that the price gap between imported corn and Chinese corn is not as large as 50% difference, to expanding imports of corn largely means relaxing import restrictions by expansions of the corn quota and reductions of out-of-quota tariffs.

profits from composite goods. This two-stage procedure is subjected to their level of production. Production functions are specified in CES (constant elasticity of substitution) style under which the elasticity of substitution can describe the imperfect substitution between goods from various origins. The equations in the model of this study are listed below.

$$\underset{Y^{i,t},\, M^{i,t},\, D^{i,t}}{\text{maximize}}\ \pi^{q,t} = p^{q,t}Q^t - [(1+\tau^{m,t})p^{m,t}M^t + p^{d,t}D^t] \tag{4-5}$$

$$\text{s.t. } Q^t = \gamma_1[\delta m_1 (M^t)^{\frac{\sigma_1-1}{\sigma_1}} + \delta d_1 (D^t)^{\frac{\sigma_1-1}{\sigma_1}}]^{\frac{\sigma_1}{\sigma_1-1}} \tag{4-6}$$

Notions are:

$\pi^{q,t}$	profit of producers to produce Armington composite good[13] (Q^t) at time t,
Q^t	Armington composite good at time t,
$p^{q,t}$	price of Armington composite good at time t,
$\tau^{m,t}$	weighted average import tariff rate[14] at time t,
$p^{m,t}$	price of imported good at time t,
M^t	imported good at time t,
$p^{d,t}$	price of domestic good at time t,
D^t	domestic good at time t,
γ_1	scaling coefficient in the first stage,
$\delta m_1, \delta d_1$	input share coefficients in the Armington composite good in the first stage ($0 \leq \delta m_1 \leq 1$, $0 \leq \delta d_1 \leq 1$, $\delta m_1 + \delta m_1 = 1$),
σ_1	elasticity of substitution between domestic and imported goods.

Equations (4-5) and (4-6) show the procedure of the first stage. Equation (4-5) is the profit function, suggesting that producers maximize the profits of composite goods. The procedure of profit maximization is subject to the production function with constant elasticity of substitution shown in Equation (4-6). I also assume returns-to-scale is constant in time. To solve this maximization problem by the first-order condition of the Lagrangian multiplier technique, I calculate and get Equation (4-7) using Equations (4-5) and (4-6).

$$\frac{M^t}{D^t} = \left(\frac{\delta m_1}{\delta d_1}\right)^{\sigma_1}\left[\frac{p^{d,t}}{(1+\tau^{m,t})p^{m,t}}\right]^{\sigma_1} \tag{4-7}$$

Then, I transfer Equation (4-7) in linear form into Equation (4-8).

$$\ln\left(\frac{M^t}{D^t}\right) = \sigma_1 \ln\left(\frac{\delta m_1}{\delta d_1}\right) + \sigma_1 \ln\left[\frac{p^{d,t}}{(1+\tau^t)p^{m,t}}\right] \tag{4-8}$$

With Equation (4-8), the elasticity between domestically produced and imported goods -σ_1^i- can be estimated by linear regression.

In the second stage, a similar structure is used. Producers maximize the profits from the imported goods, subject to their production, where imported goods from partner countries constitute the composite imported goods.

$$\underset{P^{i,t},\, M_f^{i,t}}{\text{maximize}}\ \pi^t = p^{m,t}Q_m^t - \left(\sum_f \left(1+\tau_f^{m,t}\right)p_f^{m,t}\, M_f^t\right) \tag{4-9}$$

$$\text{s.t. } M^t = \gamma_2\left[\sum_f \delta m_{2,f}\,(M_f^t)^{\frac{\sigma_2^i-1}{\sigma_2^i}}\right]^{\frac{\sigma_2^i}{\sigma_2^i-1}} \tag{4-10}$$

Notions are:

π^t	profit of producers to produce composite good (Q_m^t) at time t,
Q_m^t	composite good at time t,

[13] The "good" in this model is corn.

[14] τ^m approximately equals τ^{m_in} (in-quota tariff rate) plus τ^{m_p} (price premium) that are represented in the CGE model in Chapter 6.

$p^{m,t}$ price of composite good at time t,
$\tau_f^{m,t}$ import tariff rate on imports from country f at time t,
$p_f^{m,t}$ price of imported good from origin country f at time t,
M_f^t imported good from origin country f at time t,
γ_2 scaling coefficient in the second stage,
$\delta m_{2,f}$ input share coefficients in the good from origin country f in the second stage ($0 \leq \delta m_{2,f} \leq 1, \sum_f \delta m_{2,f} = 1$),
σ_2^i elasticities of substitution between goods from foreign origin countries between two China's trade partners.

Equations (4-9) and (4-10) show the procedure in the second stage. The procedure of profit maximization is subject to the production function with constant elasticity of substitution shown in Equation (4-10).

To solve this maximization problem by the first-order condition of the Lagrangian multiplier technique, I calculate and get Equation (4-11). Equation (4-12), a linear equation, originates from Equations (4-9) to Equation (4-11) as a regression model to estimate the elasticity between goods from foreign sources of one country's imports -σ_2^i. In addition, I assume the same import tariff rate is applied for all partners of the analyzed country (China in this study), and returns-to-scale are constant in time.

$$\frac{M_f^t}{M_g^t} = \left(\frac{\delta m_{2,f}}{\delta m_{2,g}}\right)^{\sigma_2^i} \left(\frac{(1+\tau_g^{m,t})p_g^{m,t}}{(1+\tau_f^{m,t})p_f^{m,t}}\right)^{\sigma_2^i} \quad (4\text{-}11)$$

$$\ln\left(\frac{M_f^t}{M_g^t}\right) = \sigma_2^i \ln\left(\frac{\delta m_{2,f}}{\delta m_{2,g}}\right) + \sigma_2^i \ln\left(\frac{p_g^{m,t}}{p_f^{m,t}}\right) \quad (4\text{-}12)$$

4.3.2 The data description

In this study, data for the 10 main import or export countries and regions (10 countries below) for cereals pertain to Argentina, Brazil, Canada, China (mainland of China), E.U.28 (28 countries of the European Union), Japan, Korea (Rep. of Korea), Russia (Russian Federation), the U.S., and Ukraine. In detail, China, Japan, Korea, and E.U.28 are the main import countries, and the left 6 countries in the 10 countries are the main export countries. In addition, I set 2002 as the start of our data because at the end of 2001, China joined the WTO as a member.

Table 4-1 shows the total proportion of corn trade quantity of the 10 countries in world trade quantity. For most of the years from 2002 to 2017, the 10 countries exported corn over 70% in world export quantity; therefore, the 10 countries, especially the 6 net export countries, can be considered as main corn origin countries. In addition, same as China, Japan, Korea, and E.U.28 are net corn import countries; therefore, they are analyzed to make a comparison with China. For most of the years, from 2002 to 2017, the 10 countries import corn over 30% in world import quantity, in particular, China, Japan, Korea, and E.U.28 are the main import countries.

Table 4-1 The total proportion of corn trade quantity of the 10 countries in world trade quantity

	Import	Export
2002	36.95%	82.97%
2003	42.23%	84.01%
2004	42.77%	80.84%
2005	36.19%	78.46%
2006	35.67%	81.43%

2007	38.65%	82.71%
2008	43.89%	79.33%
2009	36.00%	74.28%
2010	32.04%	79.38%
2011	34.26%	75.10%
2012	39.44%	74.37%
2013	34.35%	77.71%
2014	40.34%	76.36%
2015	39.42%	79.83%
2016	38.49%	86.64%
2017	29.48%	64.89%

Data source: Author's calculation by data from UN Comtrade

The model structure is shown in Figure 4-4. The first stage shows that panel data are applied to obtain the country-specific elasticities between domestically produced and imported goods from the world. For the second stage, panel data regarding the import origins for the aggregated group or a given country are used to get the elasticity between goods from partner countries of China. Since some partner countries are not fixed year after year, some countries are aggregated as "others" in the second stage. In detail, China's partners of corn import origin are Argentina, Brazil, Bulgaria, Myanmar, France, Germany, Lao (People's republic), Russia, India, Thailand, Ukraine, the U.S., and others.

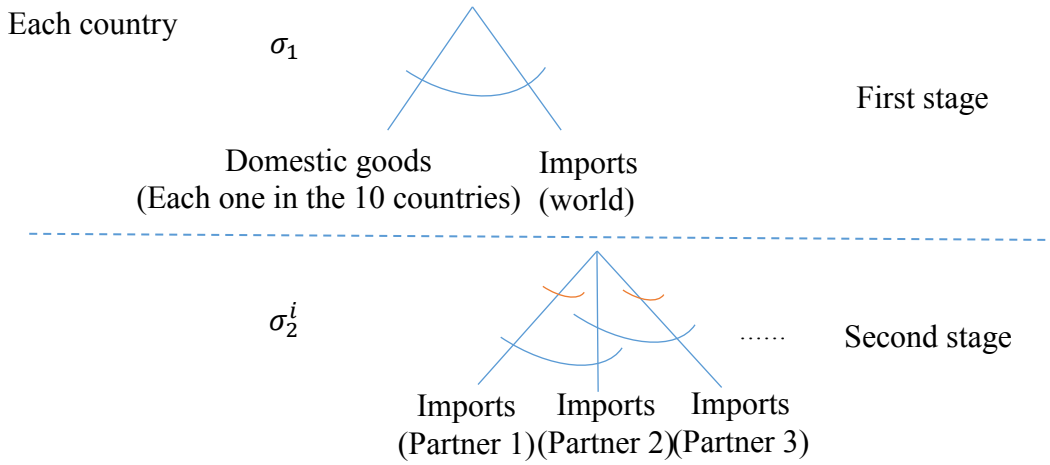


Figure 4-4 The structure of the Armington model

Note: We estimate σ_1 for anyone of the 10 countries and σ_2^i just for China.

The data are originated from the UN Comtrade database, FAO database, and the United Nations Conference on Trade and Development (UNCTAD). Specifically, import quantity (*M*) is taken directly from the UN Comtrade database, and the quantity of domestic supply (*D*) in the FAO goods classification is calculated as the domestically produced quantity minus the export quantity. The domestically produced quantity is from the FAO database, and I get the export quantity according to the HS goods classification from the UN Comtrade database. FAO goods and HS goods classifications are described in Table 4-2. Price information for domestically produced goods and imported goods are calculated using the data sourced from the UN Comtrade database, which reports the approximate prices faced by consumers. The

price of domestically produced goods (*PD*), calculated as the export value divided by the export quantity, is free on board (FOB) price. The price of imported goods (*PM*) is calculated as (import value ÷ import quantity) × (1+tariff rate), the same as the cost, insurance, and freight (CIF) price plus tariffs. The weighted average data from UNCTAD for the tariff rate at the HS 4-digit level are applied. However, data are only available prior to 2014, and I use the same tariff rate data for 2015-2017 as the weighted average tariff rate has little variation year-over-year. More details are shown in Table 4-2.

Table 4-2 Details of the data for the Armington model

Variable	Description (unit)	Calculation	Source	Note
M	Import quantity (kg)	= import quantity	UN Comtrade Database	
D	Quantity of domestic supply (kg)	= domestically produced quantity - export quantity	domestically produced quantity: FAO Database export quantity: UN Comtrade Database	
PD	Price of domestic produced goods (usd/kg)	= export value ÷ export quantity	UN Comtrade Database	FOB price
PM	Price of imported goods (usd/kg)	= (import value ÷ import quantity) × (1 + tariff rate)	UN Comtrade Database	CIF price multiplied by (1+ tariff rate)
	Tariff rate (%)		UNCTAD	2002-2014 data from UNCTAD; 2015-2017 data same as 2014 data

4.3.3 Result analysis

Table 4-3 reports the country-specific elasticity of substitution of 10 countries between domestically produced and imported corn. The elasticities at the 95% confidence level are 1.90 for Argentina, 1.17 for Brazil, 0.90 for Canada, 2.45 for China, 1.56 for E.U.28, 0.61 for Japan, 0.70 for Korea, 1.17 for Russia, 0.93 for the U.S., and 1.75 for Ukraine. The average value of the country-specific elasticity of the countries is 1.32. Comparing with other countries, including Japan, Korea, and E.U.28 which are net corn import countries like China, China has a larger elasticity. This points domestically produced corn in China is more likely to be substituted by corn from other countries when domestic corn price rises or world corn price

falls. In addition, larger elasticity implies that China can increase production to substitute corn imports to a larger extent and to increase its self-sufficiency rate; however, if China strengthens its self-sufficiency rate, it may need to increase support on corn production. Additionally, the results other researchers estimated show 2.75 for corn and 1.91 for wheat in South Africa (Ogundeji, 2010), 3.692 - 4.916 for corn in Philippines (Kapuscinski and Warr, 1999), and 4.45 for corn of the world (GTAP). Comparing with these values, the elasticity of China is not relatively larger. A possible reason is that regardless of integrations of commodity classification, in this study we select the main corn import and export countries and apply their import prices as foreign prices and export prices as domestic prices; however, in these countries exported corn and imported corn may show relatively larger differentiations than them between domestic corn and imported corn. This probably has no effect on us to say that China has a larger elasticity than other 9 countries in this study based on the estimated results.

Table 4-3 The elasticity between domestically produced and imported goods (σ_1^i)

Country	Elasticity	Country	Elasticity
Argentina	1.90 (0.00)	Japan	0.61(0.00)
Brazil	1.17 (0.02)	Korea	0.70 (0.04)
Canada	0.90 (0.00)	Russia	1.17 (0.00)
China	2.45 (0.00)	USA	0.93 (0.03)
E.U.28	1.56 (0.00)	Ukraine	1.75 (0.00)
Average: 1.32 (0.00)			

Notes: p-value in ( ), the average value estimated by regression

Table *4-4* reports the elasticity of substitution between imported corn produced in China's partner countries of trade. The results show that the substitution between corn from different partner countries varies. Lager values mean China imported corn from the two partner countries is more likely to substitute for each other when the cost of importing from one country of the two countries rises or falls. For example, the values are 2.21 between the U.S. and Brazil, 2.59 between the U.S. and Myanmar, 1.84 between the U.S. and France, 2.64 between the U.S. and Germany, 1.69 between the U.S. and Lao, 1.15 between the U.S. and India, 2.22 between the U.S. and Thailand. If corn trade cost rises between China and the U.S., possibly because of the U.S.-China trade frictions, the corn from Brazil, Myanmar, Germany, and Thailand is more likely to substitute the corn from the U.S. than the corn from France and Lao.

Table 4-4 The elasticity of imported corn from partner countries of China (σ_2^i)

Partners	Elasticity	Partners	Elasticity	Partners	Elasticity
Argentina-Brazil	0.68 (0.04)	Argentina-Bulgaria	1.44 (0.05)	Argentina-Myanmar	0.99 (0.02)
Argentina-France	1.06 (0.00)	Argentina-Germany	1.10 (0.00)	Argentina-Lao	1.08 (0.00)
Argentina-Russia	1.69 (0.00)	Argentina-India	0.43 (0.16)	Argentina-Thailand	1.97 (0.02)
Argentina-Ukraine	2.20 (0.00)	Argentina-Others	1.29 (0.00)	Argentina-USA	0.85 (0.12)
Brazil-Bulgaria	2.74 (0.00)	Brazil-Myanmar	2.21 (0.00)	Brazil-France	1.70 (0.00)
Brazil-Germany	1.66 (0.00)	Brazil-Lao	2.18 (0.00)	Brazil-Russia	2.26 (0.00)

Brazil-India	0.78 (0.04)	Brazil-Thailand	1.84 (0.00)	Brazil-Ukraine	2.64 (0.00)
Brazil-Others	2.15 (0.00)	Brazil-USA	2.21 (0.00)	Bulgaria-04	1.56 (0.00)
Bulgaria-France	2.19 (0.00)	Bulgaria-Germany	1.57 (0.00)	Bulgaria-Lao	1.28 (0.00)
Bulgaria-Russia	2.99 (0.00)	Bulgaria-India	1.74 (0.00)	Bulgaria-Thailand	2.18 (0.00)
Bulgaria-Ukraine	1.96 (0.00)	Bulgaria-Others	2.99 (0.00)	Bulgaria-USA	2.79 (0.00)
Myanmar-France	1.49 (0.00)	Myanmar-Germany	0.68 (0.12)	Myanmar-Lao	2.59 (0.00)
Myanmar-Russia	-0.10 (0.93)	Myanmar-India	0.86 (0.03)	Myanmar-Thailand	2.59 (0.00)
Myanmar-Ukraine	1.32 (0.07)	Myanmar-Others	1.32 (0.02)	Myanmar-USA	2.59 (0.00)
France-Germany	1.88 (0.00)	France-Lao	1.52 (0.00)	France-Russia	1.31 (0.00)
France-India	0.55 (0.21)	France-Thailand	2.30 (0.00)	France-Ukraine	2.10 (0.00)
France-Others	1.13 (0.00)	France-USA	1.84 (0.00)	Germany-Lao	0.43 (0.01)
Germany-Russia	0.63 (0.09)	Germany-India	0.79 (0.02)	Germany-Thailand	2.16 (0.00)
Germany-Ukraine	1.82 (0.00)	Germany-Others	1.28 (0.00)	Germany-USA	2.64 (0.00)
Lao-Russia	1.70 (0.00)	Lao-India	0.78 (0.04)	Lao-Thailand	2.27 (0.00)
Lao-Ukraine	1.93 (0.01)	Lao-Others	1.28 (0.00)	Lao-USA	1.69 (0.00)
Russia-India	1.33 (0.00)	Russia-Thailand	2.39 (0.00)	Russia-Ukraine	-2.40 (0.03)
Russia-Others	2.09 (0.00)	Russia-USA	1.29 (0.08)	India-Thailand	1.07 (0.04)
India-Ukraine	1.91 (0.00)	India-Others	0.91 (0.00)	India-USA	1.15 (0.03)
Thailand-Ukraine	2.48 (0.00)	Argentina-Bulgaria	2.33 (0.00)	Thailand-USA	2.22 (0.00)
Ukraine-Others	3.33 (0.00)	Argentina-Germany	1.85 (0.00)	Others-USA	2.36 (0.00)
Average: 1.64 (0.00)					

Notes: p-value in ( ), the average value estimated by regression

4.4 Analysis of export capacity of corn in origin countries of corn imports

Many researchers predict that the demand for corn in China will increase further in the future. However, whether China's trade partners can sufficiently supply enough corn to China and which partners can provide more security to China's corn imports are still needed to investigate. In this section, I analyze the export capacity of import-origin countries of China. Firstly, in

Subsection 4.4.1, I analyze the export capacity of the world to find the corn supply of the world, possibly to China. Secondly, in Subsection 4.4.2, I analyze the export capacity of China's partner countries to find which partner countries can sufficiently supply corn to China to keep the "corn import security" of China.

4.4.1 The corn export capacity of the world

From the supply-side of corn, both world corn production, and corn export show upward trends, which is described in Figure 4-5. In detail, world corn production had increased from 199.58 Mt in 1960 to 1133.89 Mt in 2020, and world corn export quantity had increased from 14.02 Mt in 1960 to 183.63 Mt in 2020. In addition, the upward trend of corn export quantity in recent 10 years is more significant than before. Table 4-5 shows corn export proportion of main corn export countries. From Table 4-5, the corn export increases in Ukraine and Brazil are the main reason why the upward trend got sharper.

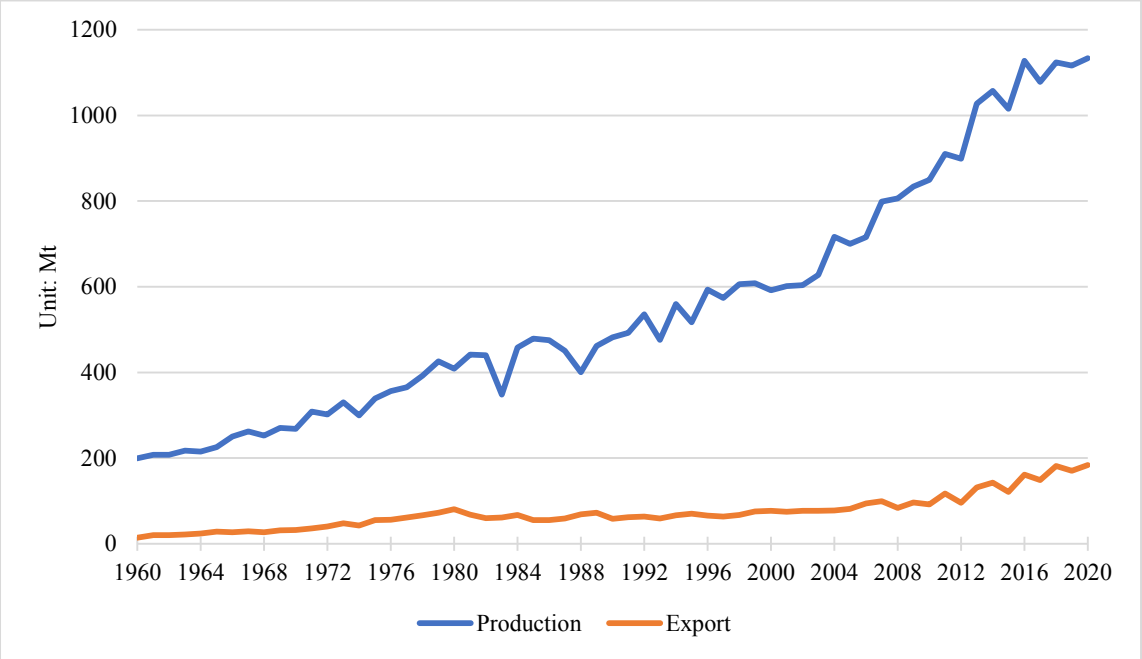


Figure 4-5 The world corn production and export quantities
Data source: USDA

Table 4-5 The corn export proportion of main corn export countries

Year	Argentina	Brazil	Canada	USA	Ukraine	Russia	Total
2010	16.19%	9.98%	0.79%	46.74%	3.74%	0.21%	77.65%
2011	13.83%	8.64%	0.97%	41.70%	7.11%	0.66%	72.91%
2012	14.77%	16.37%	0.58%	26.03%	12.93%	1.82%	72.50%
2013	16.37%	21.72%	1.44%	19.65%	13.65%	2.12%	74.95%
2014	12.48%	16.22%	1.41%	28.09%	13.79%	2.74%	74.73%
2015	11.40%	19.71%	0.40%	30.44%	12.98%	2.52%	77.45%
2016	16.46%	14.69%	1.18%	37.55%	11.60%	3.58%	85.06%
2017	12.14%	11.20%	0.84%	27.17%	9.93%	2.66%	63.94%

Data source: Author's calculation by data from UN Comtrade
Note: values in this table = export quantity of each country in each year/world export quantity in each year

From Table 4-5, we can also realize that the 6 main corn export countries or regions take over 70% of world corn export in most of the years from 2010 to 2017. In addition, the corn export of the U.S. declined, which is partly because increasing bioenergy production in the U.S. consumes corn.

4.4.2 The corn export capacity of China's partner countries

China's corn imports have many origin countries, two of which are the main sources of imports that are the U.S. and Ukraine, as shown in Table 4-6. This shows that China's corn imports are extremely dependent on these two countries' exports of corn. Though these two countries are major corn exporters in the world, which produce a large amount of corn that can be exported, that China's corn imports are concentrated from these two countries causes import dependence of these two countries. This dependence may threaten the sufficiency of corn supply when bilateral trade frictions with China occur, or corn exports decline because, for example, some natural disasters decreasing domestic production.

Table 4-6 China's corn import proportion from main partner countries

Year	Argentina	Brazil	USA	Ukraine	Russia	France	Germany	Total
2010	0.00%	0.00%	95.51%	0.00%	2.67%	1.23%	0.00%	99.41%
2011	0.00%	0.00%	96.16%	0.00%	0.00%	0.00%	0.01%	96.17%
2012	0.00%	0.00%	98.19%	0.00%	0.08%	0.00%	0.01%	98.28%
2013	2.02%	0.02%	90.90%	3.34%	0.15%	0.00%	0.01%	96.44%
2014	0.02%	0.00%	39.53%	37.11%	0.99%	0.00%	0.01%	77.66%
2015	0.00%	0.00%	9.77%	81.44%	1.74%	0.00%	0.00%	92.95%
2016	0.00%	0.00%	7.04%	84.01%	2.06%	0.00%	0.01%	93.13%
2017	0.00%	0.00%	26.78%	64.48%	0.08%	0.00%	0.00%	91.34%

Data source: Author's calculation by data from UN Comtrade

Thus, the sufficient export capacity of corn exporting of China's partner countries is a prerequisite to guarantee the corn imports of China. The export-production elasticity ($\epsilon^{i,t}$) is applied to quantify the capacity, which is also used in their papers by Zhao (2015). The elasticity is described as the ratio of growth of corn export out of the growth of corn production. Its value that is less than 1 means that the increased corn production in the country is more likely to be consumed domestically rather than be exported, while its value that is greater than 1 stands that the increased corn production in the country is more likely to be exported rather than be consumed domestically. The elasticity is symbolized as Equation (4-13).

$$\epsilon^{i,t} = \frac{E^{i,t}/E^{i,2010}}{D^{i,t}/D^{i,2010}} = \frac{E^{i,2010}(1+r_e^{i,t})/E^{i,2010}}{D^{i,2010}(1+r_d^{i,t})/D^{i,2010}} = \frac{1+r_e^{i,t}}{1+r_d^{i,t}} \quad (4\text{-}13)$$

In Equation (4-13), $E^{i,2010}$ and $D^{i,2010}$ respectively present corn export quantity and domestic corn production of country i in the base year 2010. $E^{i,t}$ and $D^{i,t}$ are their quantities in the year t. $r_e^{i,t}$ and $r_d^{i,t}$ stand growth rate of corn export quantity and domestic corn production, respectively, in the year t. Table 4-7 shows the export-production elasticity of China's main partner countries.

Table 4-7 The export-production elasticity of China's main partner countries

Year	Argentina	Brazil	France	Germany	USA	Ukraine	Russia

2010	1	1	1	1	1	1	1
2011	1.26	0.82	1.04	0.96	0.85	1.58	2.42
2012	1.07	0.81	1.51	1.27	0.46	1.45	1.94
2013	1.01	0.75	1.24	1.28	0.94	1.54	3.00
2014	0.98	0.78	0.65	0.70	0.89	1.64	2.36
2015	1.13	1.13	0.74	0.77	0.95	1.69	2.96
2016	0.98	0.93	0.80	0.71	1.03	1.82	3.04
2017	1.08	0.96	0.74	0.72	1.13	1.78	3.48

Data source: Author's calculation by data from FAO

From Table 4-7, the elasticities of Brazil, France, Germany, as well as the U.S. in most of the years are less than 1, which implies these countries may not be the origins with sufficient corn for China. The dependence of China's corn import on these countries, especially on the U.S. as the source country with the largest corn import volume, may threaten the sufficiency of corn supply. In recent years, the elasticities of Ukraine and Russia are greater than 1. Due to improved economy and breeding technology, increased agricultural investment, and sufficient resources like water and lands for agriculture. Corn production in the former Soviet Union countries like Russia and Ukraine is increasing (Wei, 2014). Their increasing corn production will cause more volume of corn export; therefore, these countries should be corn sources of imports, from which China may expand its corn imports.

4.5 Summary

More imports of agricultural products are possible choices in the period of shortage. For some agricultural products, more imports may be inevitable in China; however, given that imports may not perfectly substitute domestic products, it is necessary to quantify how much imports can substitute to domestic ones. In addition, quantifying how much imports from different origins can substitute to each other is also necessary because it is possible that not all partner countries of a country can stably supply agricultural products to the country for some reasons like the occurrence of some natural disasters and finding their substitutes is an important way to ensure the sufficient supply. Although for some agricultural products, more imports may be inevitable in China, increasing agricultural imports should be based on the export capacities of the world and China's partner countries. This chapter is used to analyze the agricultural imports of China by the example of corn. In this chapter, the development of corn import over time are analyzed; how much imports of China can substitute to domestic ones and how much imports of China from different origins can substitute to each other are quantified, and the export capacities of the world and China's partner countries are analyzed. The findings provide:

About the development of corn import of China, although China has made significant progress in the domestic production of corn, the country changed from a net exporter to a net importer of corn because of the massive domestic corn consumption from 2009. In addition, in recent years from 2008, the imports significantly increased, and they almost reached the top quantity (7.2 Mt) of its import quota from 2019. Thus, if corn demand gradually increases in the future, China may face a shortage of corn supply, and expanding its import quota or lowering its above quota import tariff to liberalize its corn market for China are possible future scenarios of corn trade policy in China. However, importing implies lower self-sufficiency, which may go against the security goal of corn in China.

About the substitution, comparing with other countries including Japan, Korea, and E.U.28 which are net corn import countries (or regions) like China, China has a larger elasticity of substitution between domestic and imported corn, which points domestically produced corn in

China is more likely to be substituted by corn from other countries when domestic corn price rises or world corn price falls. In addition, the substitution between corn from different partner countries varies, and larger values mean China imported corn from the two partner countries is more likely to substitute to each other when the cost of importing from one country of the two countries rises or falls.

Regarding the export capacity of import origin countries of China, both world corn production and corn export show upward trends. In detail, world corn production increased from 199.58 Mt in 1960 to 1133.89 Mt in 2020, and world corn export quantity increased from 14.02 Mt in 1960 to 183.63 Mt in 2020. In addition, the upward trend of corn export quantity in recent 10 years is more significant than before. Countries mainly import corn from 6 countries, including Argentina, Brazil, Canada, the USA, Ukraine, and Russia, and the 6 corn export countries take over 70% of world corn export in most of the years from 2010 to 2017. China's corn imports are extremely dependent on two countries' exports of corn, including Ukraine and the USA. However, some countries, including Brazil, France, Germany, as well as the USA, may not be the origins with sufficient corn for China. The dependence of China's corn import on these countries, especially on the U.S. as the source country with the largest corn import volume, may threaten the sufficiency of corn supply

Chapter 5 Volatility of agricultural prices under its policies: relationships between domestic and import markets of China

Prices of agricultural products have a wide effect on an economy, people's livelihood, anti-poverty, etc.; thus, managing price volatility risks in agricultural markets is always a vital priority of the development vision in China and China' governments are paying much attention to agricultural price volatilities. Agriculture is a highly important sector responsible for food security, poverty alleviation, and even ensuring societal stability in China. Stable prices of agricultural products help prevent poor farmers and consumers from falling into poverty traps, promote farm-level investment, and encourage investment throughout the economy by reducing the "noise" in prices of other goods and by promoting social and political stability (Dawe and Timmer, 2012). So long as the influence of some market shocks, like the Covid-19 pandemic, ASF pandemic, and the frictions between China and the U.S., continues to expand its effects, affected by these market shocks, price volatility risks of agricultural products in international markets have been drastic. In addition, volatility transmission across exchanges for agricultural commodities in China and other countries exists (e.g., Arnade et al. (2017) and Hernandez et al. (2014)). It is vital to investigate the impact of import prices of agricultural goods on their domestic prices in China under China's policies affecting domestic prices of agricultural products.

Price volatility and the volatility relationships of agricultural prices between China's and international markets have long been a topic of interest for agricultural economists, but empirical findings vary. Most researchers focused on future markets of China and other countries. For example, Fung et al. (2003) explored the price volatilities of soybeans and wheat futures and their transmissions between the U.S. and Chinese futures markets, and Liu and An (2011) and Liu and Mu (2017) addressed soybeans. They both found there is a bidirectional relationship in terms of price and volatility transmission between U.S. and Chinese markets, with a dominant way of transmission from the U.S. to Chinese markets than the other way around. Some researchers focused on the commodity markets of China and other countries. For example, Imai et al. (2008) analyzed wheat, corn, rice, fruit, and vegetable markets, and they found while most of the domestic commodity prices co-move with global prices, the transmission is in general incomplete, presumably due to distortionary government policies, such as subsidies for domestic agricultural commodities and failure to exploit spatial arbitrage. Wang and Lu (2011) explored corn markets, suggesting that a bidirectional relationship exists in terms of price and volatility transmission between international and Chinese markets, with significant effects from international markets to Chinese markets than the other way around. Wang and Xie (2012) addressed corn, rice, and soybean, and they showed international agricultural prices have a significant impact on domestic prices.

None of these past price volatility and transmission studies concerned the relationships between domestic and import markets of China. The relationships between domestic and import markets of China vary with the relationships between world markets, markets of some countries, and import markets of China. An obvious reason is that China's import price of a good is always different from the world price and the price in some countries of the good because of different transportation fees, differentiation in quality, and brands between the good imported by China and it imported by other countries, etc. The existing studies ignored that import prices are the direct contributors to volatility transmissions between a country and its external markets. Import markets of China rather than world markets or markets of some countries are the markets to directly supply goods to China, thereby affecting the movements of its domestic prices.

Thus, I use this study to investigate the agricultural price volatility and its transmission between domestic and import markets of China by the example of corn. In this chapter, Section

5.1 shows a conceptual framework of price volatility and its transmission. In this section, the factors to cause price volatility and the mechanism of international volatility transmission are introduced. In Section 5.2, I introduce the theory of rational expectations and the practice framework in this study. Section 5.3 illustrates a methodology of price volatility by multivariate time series for this study. The first subsection is an introduction to the theory. In the second subsection, I introduce the practice of the theory in this study in detail. These sections provide the basis for this study in theory and practice. Section 5.4 shows us the statistical descriptions of corn price movements and volatilities and visual descriptions by figures. I find data and show a data description in the first subsection. The second subsection explores the movement of corn prices, and the third subsection investigates the price volatility of corn. After the initial analyses of corn prices, I apply an empirical analysis of corn price volatility and its transmission in Section 5.5. Subsection 5.5.1 is to test the property of our data for selecting a feasible model framework. After checking the data property, a VAR-BEKK-GARCH model is constructed according to the results of the data property in Subsection 5.5.2. In Subsection 5.5.3, the estimated results from the model are analyzed. In addition, Section 5.6 summarizes the analysis results in the above five sections.

5.1 A conceptual framework of price volatility and its transmission

Figure 5-1 shows a conceptual framework of price volatility of agricultural products and its international transmission. About price volatility, many causes contribute to the volatility. I attempt to distinguish different factors to cause price volatility, and five groups of potential

causes have been singled out: root causes, root shocks conditional shocks, shock amplifiers, and international volatility transmission.

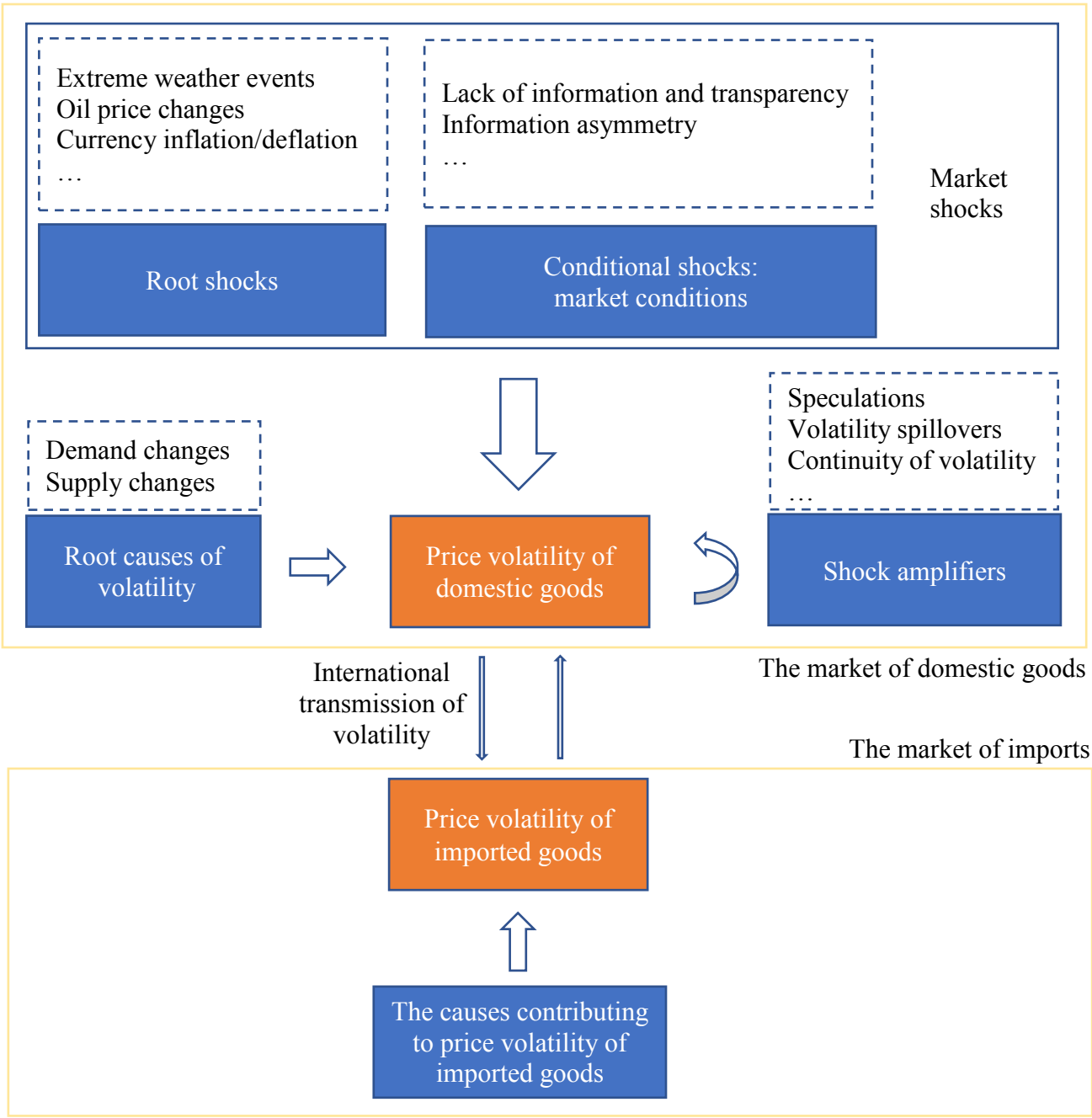


Figure 5-1 A conceptual framework of price volatility of agricultural products and its international transmission

In the market of domestic goods, root causes, including demand and supply changes, are considered as core factors contributing to good price volatility. Root shocks such as extreme weather events, oil price, and currency inflation/deflation are considered as main factors in market shocks affecting good price volatility. In market shocks, conditional shocks are the factors in relation to market conditions, which time-invariant and rather difficult to measure, like the degrees of lack of information and transparency and information asymmetry. The fourth group of factors consists of the factors that are triggered by the dynamic and internal mechanism of price, which are shock amplifiers including, for example, speculations, volatility

spillovers, continuity of volatility. It should be noted that some of the causal factors can be observed and measured, while some are difficult to observe or measure their effects on the price of a domestic good. For example, the supply changes of some goods can be predicted by production plans; however, the shocks of a big earthquake to market price are difficult to predict. In addition, all the cause factors can be considered as the elements in a set of market information.

In the market of imports, the above four groups of factors also contribute to the price volatility of imported goods. Because domestic goods and imported goods can substitute for each other, when international trade occurs, price interactions between domestic and imported goods appear. The interaction is generally defined as a kind of (international) transmission of price volatility.

5.2 A practice of the theory of rational expectations in the framework

We have introduced a general conceptual framework of the price volatility of agricultural products and its international transmission. In this section, I introduce the theory of rational expectations, which explains the price volatility in theory. Then, based on the theory, I show the practice of the theory linking with the general conceptual framework to propose our framework.

5.2.1 The theory of rational expectations

Muth (1961) proposed the theory of rational expectations that describes the many economic situations in which the outcome (e.g., market prices) depends partly on what people expect to happen. The theory to market price can be expressed as following equation:

$$P_t^* = E(P_t|I_{t-1}) = E(P_t) \tag{5-7}$$

Notions are:

P_t^*	the expected price at time t,
P_t	the price at time t,
I_{t-1}	the set of information at time $t-1$,
$E(P_t\|I_{t-1})$	the expected price at time t based on the set of information at time $t-1$,
$E(P_t)$	the expectation of the price at time t.

We can also express the theory as:

$$P_t = E(P_t|I_{t-1}) + \varepsilon_t \tag{5-8}$$

where ε_t stands for the error at time t. According to Equation (5-8), the theory tells us that the price at time t equals the expectation of the price at time t based on the set of information at time $t-1$ plus an error at time t. More generally, this equation shows us that the price at time t equals the expectation of the price at time t based on the set of previous or existing information plus an error at time t. According to this theory, the price is affected by an expectation (mean) based on previous information plus an error. In other words, the price change at time t consists of the change of mean expected under existing information and the other change I cannot predict under the existing information. Given that the information in error at time t (ε_t) are supposed to be included in the information set at time t (I_t), we can consider that ε_t provides with temporary information only appearing at time t. We can also consider that the temporary information affects like a temporary market shock that is a cause to deviate the price away from its expectation based on existing information.

5.2.2 The practice of the theory in the framework

In the framework of this study, price volatilities rather than price movements are analyzed. Thus, I transfer the framework of the theory of rational expectations into a practice framework for this study. The Equation (5-9) can be transferred as:

$$V_t = E(V_t|I_{t-1}) + \varepsilon_t \quad (5\text{-}9)$$

where V_t stands for the price volatility at time t. This equation expresses that the price volatility (V_t) at time t consists of the expectation $[E(V_t|I_{t-1})]$ expected under existing information and a temporary volatility/shock (ε_t) we cannot predict under the existing information. In other word, the change of expectation and an unexpected temporary volatility that can also be considered as a temporary volatility response to temporary shocks) have effects on the volatility of a price.

Based on the above framework, I propose the conceptual framework of price volatility of agricultural products and its international transmission in this study, which are described in Figure *5-2*.

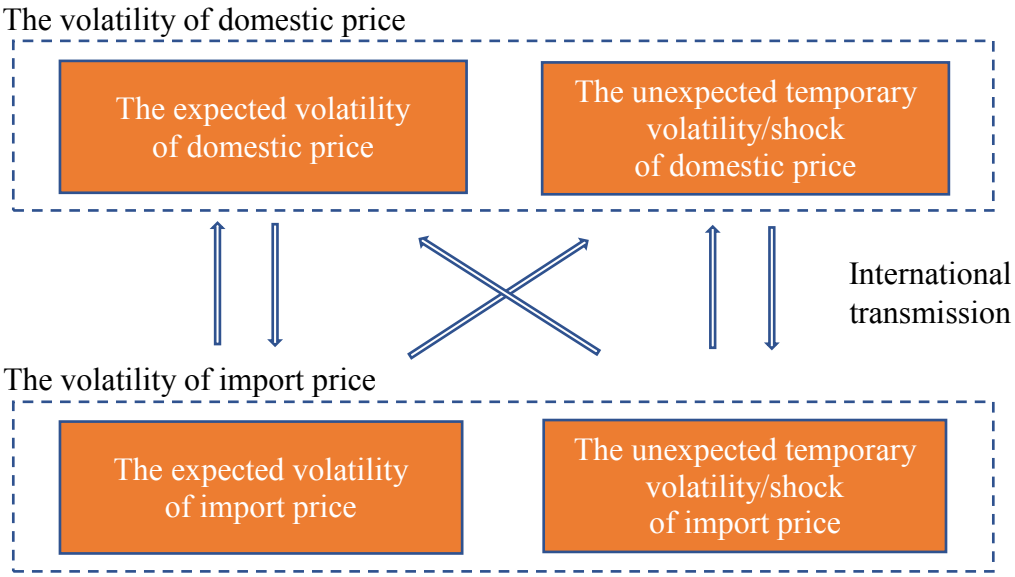


Figure 5-2 The conceptual framework of price volatility of agricultural products and its international transmission in this study

Figure 5-2 shows both the volatility of domestic price and the volatility of import price are divided into the expected volatility and the unexpected temporary volatility/shock. The International transmission of volatility concerns the interactions between the volatility of domestic price and the volatility of import price, including the interactive influences between the expected volatilities of domestic price and import price, the interaction between the temporary volatility/shock of domestic price and import price and cross-interaction between the temporary volatility/shock and the expected volatility.

In addition, we often expect that under the condition of free trade, the interactions of international transmission are supposed to exist in both directions between the price volatility of domestic goods and the price volatility of imported goods, when international trade of the home country and import origin countries occur, and some methods like price support policies, quota, and subsidies that may break free trade mode may limit the international transmission in one or both directions.

5.3 Multivariate time series analysis: a methodology of price volatility

In this study, multivariate time series methods are applied to analyze price volatility. Volatility in a time series refers to the phenomenon where the conditional variance of the time series varies over time. In multivariate cases, it refers to not only variations of each series over time but also dynamical interactions between conditional variances of multivariate time series.

A methodology of price volatility multivariate cases constitutes the main subject of this section. Firstly, in Subsection 5.5.1, an approach for multivariate time series is introduced by an example of a bivariate VAR model. However, the approach should match its properties of a multivariate time series. Thus, secondly, properties of a multivariate time series are introduced in Subsection 5.5.2. Because autoregressive conditional heteroscedasticity models have advantages in variance or volatility forecast, I, thirdly, introduce autoregressive conditional heteroscedasticity in price volatility in Subsection 5.5.3.

5.3.1 An approach for multivariate time series

The approach for multivariate time series that are useful for describing the dynamic behavior of the data of time series is able to understand and use the relationship between several variables. I apply a multivariate vector autoregression (MVAR) model as an example to help understand the approach for multivariate time series in this study. Additionally, because I just have two variables in this study, Equation (5-1) with two variables provides an example of (MVAR) models. The example function can be considered as a bivariate VAR model as well.

$$\begin{pmatrix} y_{1,t} \\ y_{2,t} \end{pmatrix} = \begin{pmatrix} c_1 \\ c_2 \end{pmatrix} + \begin{pmatrix} \boldsymbol{\alpha_{1i}} \\ \boldsymbol{\alpha_{2i}} \end{pmatrix} \begin{pmatrix} y_{1,t-1} \\ \vdots \\ y_{1,t-i} \end{pmatrix} + \begin{pmatrix} \boldsymbol{\beta_{1i}} \\ \boldsymbol{\beta_{2i}} \end{pmatrix} \begin{pmatrix} y_{2,t-1} \\ \vdots \\ y_{2,t-i} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{pmatrix} \qquad (5\text{-}1)$$

Notions are:

$y_{1,t-i}, y_{2,t-i}$	variables at time $t-i,\ i = 0,1,\cdots,n$,
c_1, c_2	constant terms,
$\boldsymbol{\alpha_{1i}}, \boldsymbol{\alpha_{2i}}, \boldsymbol{\beta_{1i}}, \boldsymbol{\beta_{2i}}$	matrices of coefficients, $i = 0,1,\cdots,n$,
$\varepsilon_{1t}, \varepsilon_{2t}$	residuals at time t.

For the time series, the vector of residuals should be a continuous random vector that satisfies the following conditions: the expected value for the error vector is 0 and the expected value of $\varepsilon_{1,t}$ and $\varepsilon_{2,t}$ is the standard deviation of the series.

By this example, we can see that it is obvious that the approach for multivariate time series is useful for describing dynamical interactions of two or several variables. By replacing the variables with price variables, the approach can also be applied to analyze the dynamical pattern in the volatility of prices.

5.3.2 Properties of a multivariate time series

Before estimating or forecasting by a time series model, it is necessary to check whether the time series used in the study is subject to probability laws or check their properties. For properties of a multivariate time series, stationarity and co-integration are the most important properties. Therefore, in this subsection, stationarity and co-integrated are introduced, and the method of difference to transfer a non-stationary series into its stationary structure is introduced as well.

5.3.2.1 Stationarity

When I make statistical inferences about the structure of a stochastic process or random process over time on the basis of an observed record of that process, it is usually necessary to make some assumptions about that structure. The most important one in such assumptions is stationarity, under which the structure is subject to probability laws that govern the behavior of the process unchanging over time (Jonathan and Kung-Sik 2008). In a sense, the process is in statistical equilibrium.

Two definitions are proposed for stationarity: "strictly stationary" and "weakly stationary". For a process $\{Y_t\}$, "strictly stationary" is satisfied when the joint distribution of $Y_{t1}, Y_{t2}, \dots, Y_{tn}$ is the same as the joint distribution of $Y_{t1-i}, Y_{t2-i}, \dots, Y_{tn-i}$ for all choices of time points $t1, t2, \dots, tn$ and all choices of time lag i. "weakly stationary" is satisfied when the mean function of Y_t is constant over time and the covariance function of Y_t is only in relation to the gap of time. When the second moment of Y_t exists, a strictly stationary process is also weakly stationary and the joint distribution is also a multivariate normal distribution, the two stationary processes are equivalent.

The stationarity in this section will always refer to the weaker form of stationarity. It is because that to prove a process subject to the strict form of stationarity is difficult for too many time tn and lag i and possibly unknown joint distributions and distributions. Thus, to meet the statistical equilibrium, I need to check the stationarity of data in the weaker form.

5.3.2.2 Difference stationarity and co-integration

Non-stationarity cannot meet the probability laws for time series. The method of difference is usually applied to transfer a process from a non-stationary structure to a stationary structure for multivariate or single time series. The difference operation is a technique that can remove some time signals like trend and seasonality over time to transfer a time series into a stationary structure. Suppose that a process $\{y_t\}$ is non-stationary and covers a non-stationary process like trend process (βt), the constant term (α), and a stationary residual term (ε_t), the process $\{y_t\}$ can be expressed in Equation (5-2).

$$y_t = \alpha + \beta t + \varepsilon_t \tag{5-2}$$

If the trend is removed, the process $\{y_t\}$ is transferred into a stationary structure since $y_t - \beta t = \alpha + \varepsilon_t$ and ε_t is stationary. Thus, I consider a differencing process (Δ) to remove the trend:

$$\Delta y_t = \Delta\alpha + \Delta\beta t + \Delta\varepsilon_t = 0 + \beta\Delta t + \Delta\varepsilon_t = \beta\big(t - (t-1)\big) + \Delta\varepsilon_t = \beta + \Delta\varepsilon_t \tag{5-3}$$

Consequently, the nonstationary process $\{y_t\}$ is transferred to $\{\Delta y_t\}$ with stationary structure since the trend is removed in Equation (5-3). However, the method can remove some time signals and may eliminate some other initial information in the time series at the meanwhile because the different information between $\{y_t\}$ and $\{\Delta y_t\}$ are not only reflected in the trend.

In addition to differencing method, co-integration is widely applied to transfer processes from non-stationary structures to stationary structures for multivariate time series. A series is said to be integrated, if it is stationary in the mean at differencing order d, denoted I(d). For example, $\{y_t\}$ is an I(1) process since its first difference is stationary, which means that Δy_t is stationary. In the multivariate case, all series may each be an integrated process of order d, and in this case, it is be said as a co-integration process of the series. One idea of co-integration is that any process in the series has no stationary stricture, but their integration of all series has a stationary structure, thus, the co-integrated process can meet the probability laws for time series.

5.3.3 Autoregressive conditional heteroscedasticity in price volatility

Conditional heteroscedasticity that identifies non-constant volatility related to the prior period's volatility is different from unconditional heteroscedasticity that refers to general structural changes in volatility not relating to prior period volatility. Since conditional heteroscedasticity covers consideration of volatility in variances and consequently shows advantages in variance forecast, one of its common application is to price volatility, where the volatility at time t is strongly related to previous volatilities, and it is widely applied to explain periods of persistent with high volatility and low volatility.

Autoregressive conditional heteroscedasticity (ARCH) models and generalized autoregressive conditional heteroscedasticity (GARCH) models are the most widely used in studies about price volatility. Suppose that I have an OLS (Ordinary least squares) model expressed, for example, by Equation (5-4),

$$y_t = \alpha + \beta x_t + \varepsilon_t \tag{5-4}$$

where y_t and x_t stand for variables at time t and h_t^2 is the variance of residual term ε_t, ARCH (p) model can be expressed as:

$$h_t^2 = a_0 + a_1\varepsilon_{t-1}^2 + \cdots + a_p\varepsilon_{t-p}^2 \tag{5-5}$$

and GARCH (p,q) model can be expressed as:

$$h_t^2 = a_0 + a_1\varepsilon_{t-1}^2 + \cdots + a_p\varepsilon_{t-p}^2 + b_1h_{t-1}^2 + \cdots + b_qh_{t-q}^2 \tag{5-6}$$

Suppose that $\{w_t\}$ is a white noise process, if I consider

$\varepsilon_t = w_t\sqrt{a_0 + a_1\varepsilon_{t-1}^2 + \cdots + a_p\varepsilon_{t-p}^2}$ for ARCH (p) models

and $\varepsilon_t = w_t\sqrt{a_0 + a_1\varepsilon_{t-1}^2 + \cdots + a_p\varepsilon_{t-p}^2 + b_1h_{t-1}^2 + \cdots + b_qh_{t-q}^2}$ for GARCH (p,q) models, which imply that the disturbances (volatilities) at time t are expressed by previous disturbances (volatilities), $\{\varepsilon_t\}$ in Equation (5-4) keeps its stationarity and the volatility of $\{\varepsilon_t\}$ is expressed by ARCH models or GARCH models. Additionally, GARCH (1,1) models are widely used, and they can be considered as simplified ARCH (p) models.

5.4 The corn price movement and volatility of China

Before empirical analysis, I make an analysis in statistical description first to show some characteristics of corn price movement and volatility of China. In Subsection 5.4.1, I described the data statistically to show what data I use in this study. I show the movement of corn prices in Subsection 5.4.2 and the volatility of corn prices in Subsection 5.4.3 to explore their characteristics.

5.4.1 The data description

Both the series of domestic corn prices and imported corn prices in this study originate from the Wind Database. Specifically, the series of domestic corn prices is named "Corn: average price,[15]" and the series of imported corn prices is "Corn imports: import price (CIF)[16]" in the database. The prices are daily prices and are separated into two periods: the first period (T1), which applied the corn stockpiling policy, and the second period (T2), which applies the

[15] The "Corn: average price" is expressed as "玉米:平均价" in Chinese in the database.

[16] The "Corn imports: import price (CIF)" is named as "进口玉米:到岸完税价格 (CIF)" in the database.

subsidy policy aiming at corn producers (More details in Table 5-1). The T1 period spans from Jan.4th, 2009 to Jan. 29th, 2016 with 1746 price observations in each series of domestic and imported corn's prices, and the T2 period stated on May 21st, 2016 (and ended on Feb. 22nd, 2021 for this study) with 1186 price observations in each series.

Table 5-1 The change of China's corn policy from the stockpiling to a subsidy

	Date	Description
Start point of the stockpiling policy	Oct.17th, 2008	The State Council of China reported the decision to launch the stockpiling policy.
The period of the stockpiling policy (T1)	Jan. 4th, 2009 - Jan. 29th, 2016	The government launch a reform on corn policy to abolish the corn stockpiling policy on Jan. 29th, 2016.
The transfer period of policies	Jan. 30th, 2016 - May 20th, 2016	No policy decisions about corn were implemented.
The period of the subsidy policy (T2)	May 21st, 2016 -	The ministry of Finance of China started a subsidy policy aiming at corn producers in China on May 21st, 2016.

Information resources: news on webs of China's government branches
Notes: The start time of T1 (Jan.4th, 2009) is selected because the lack of available data during the period of Oct.17th, 2008 to Jan.3rd, 2009. The end date of T2 is selected as Feb. 22nd, 2021 which is the time when I gathered data for this study. It should be noted that the subsidy policy is not stopped in China to this day (Feb. 22nd, 2021).

5.4.2 Movements of corn prices

Figure 5-3 shows the movements of domestic price and import price of corn spanning a period from Jan. 4th, 2009 to Feb. 22nd, 2021. Particularly, the period from Jan. 4th, 2009 to Jan. 29th, 2016 (T1) is considered as the period when the stockpiling policy was affecting in China, and the period from May 21st, 2016 to Feb. 22nd, 2021 (T2) is trodden as the period when the subsidy policy is working in China. We can see from the figure that bigger gaps between domestic price and import price appear in the period of the stockpiling policy rather than the period of the subsidy policy. The possible reason for this is that import restrictions on corn and corn's substitutes[17], which limited the linkages and information exchanges between domestic and import markets, and the stockpiling policy had a supportive effect on domestic price. While in the period of the subsidy policy, the stockpiling policy was abolished, thereby eliminating the supports on domestic price; thus, they move in a similar way in this period.

[17] For example, during period of the investigation of the anti-dumping incident about the U.S.-produced DDGS from 2010 to 2012, the DDGS import decreased by 47% in the year of 2011. Distiller's dried grains with solubles (DDGS) are a kind of substitutes of corn, which are the nutrient rich co-product of dry-milled ethanol production.

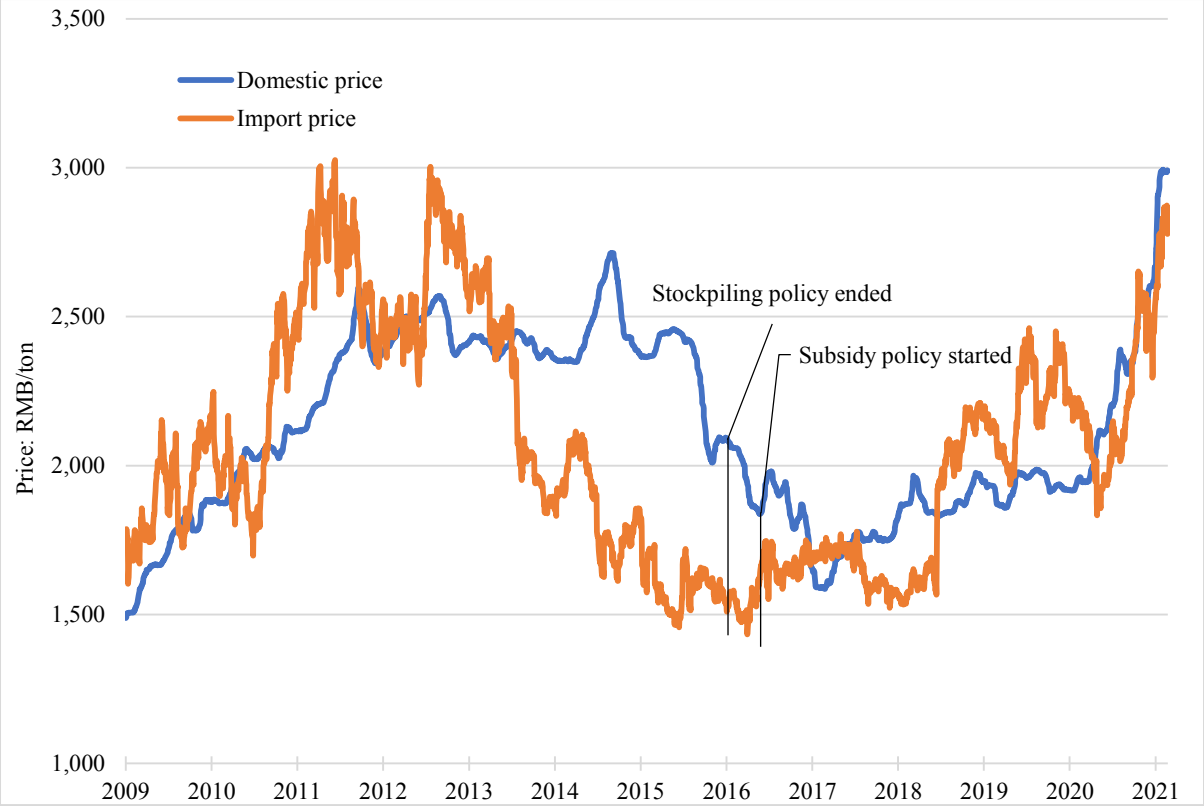


Figure 5-3 Movements of domestic price and import price of corn in China

The stockpiling policy had a supporting effect on rising domestic corn prices[18], which led to several problems and weakened the comparative advantage of Chinese corn. First, high corn prices benefit farmers, but farmers' gains do not offset the losses of, for example, the Chinese government, which suffers a heavy financial burden for managing ever-increasing stocks and subsidies to compensate for some losses in production and consumers which cost more for purchasing corn. The 260 Mt state-stock of corn would cause a 65 billion RMB cost to pay for storing in 2016 (China economic net, 2016). Second, it is a barrier to corn-related industries' development because downstream industries suffer losses due to higher corn costs. Third, it may decrease the production of other agricultural products, which causes resource mismatch. To obtain a solution to these problems and find a balance between farmers' income, losses of corn-related industries, government expenditure, and the economy through policy reforms alone is difficult, and hence, policymakers have been trying to frame a series of suitable policies for corn. For example, the government stopped the corn stockpiling policy in 2016 and started the subsidy policies for corn producers in China.

5.4.3 Volatilities of corn prices

Volatility, which may refer to daily, weekly, or monthly prices, captures the idea that prices fluctuate around a rather stable long-term price or price trend (Hull 2012); however, for initial price series may be not feasible for empirical studies, processed price series like differenced

[18] Although the existence of a price difference between domestic and imported corn is common as they cannot perfectly substitute each other because of the differences in products themselves, such as their quality and brands, we cannot directly infer that domestic corn prices are supported by protection or domestic support. However, other countries with less protection and support that do not have such a significant price difference can help offer evidence that these support and protection policies partly contribute to a higher domestic price.

price series are usually used in the studies. The price volatility in this study is divided into the expected volatility, which also can be considered as a volatility trend, and the temporary volatility, which also can be considered as volatility spikes that are a large, quick, and temporary rise or fall in volatility following a short-term (daily) shock. The volatility is usually measured and expressed by a proxy using the logarithm of period-over-period prices ($\ln p_t$), which can be expressed as a formula:

$$\Delta \ln p_t = \ln p_t - \ln p_{t-1} = \ln \frac{p_t}{p_{t-1}} \tag{5-10}$$

Notions are:

$\Delta \ln p_t$ the logarithm of corn price after first difference at time t,
$\ln p_t$ the logarithm of corn price at time t,
$\ln p_{t-1}$ the logarithm of corn price at time $t-1$.

Table 5-2 represents the statistical description of price volatility of domestic corn and imported corn. Figure *5-4* shows the price volatility of domestic corn and Figure *5-5* sheds light on the price volatility of imported corn.

Table 5-2 A statistical description of price volatility

	T1	T2
Mean of $\Delta \ln p^d$	0.0002	0.0004
Mean of $\Delta \ln p^m$	0.0000	0.0005
Standard deviation of $\Delta \ln p^d$	0.0020	0.0029
Standard deviation of $\Delta \ln p^m$	0.0145	0.0131

Notions: $\Delta \ln p^d$, the logarithm of domestic price after first difference; and $\Delta \ln p^m$, the logarithm of import price after first difference.

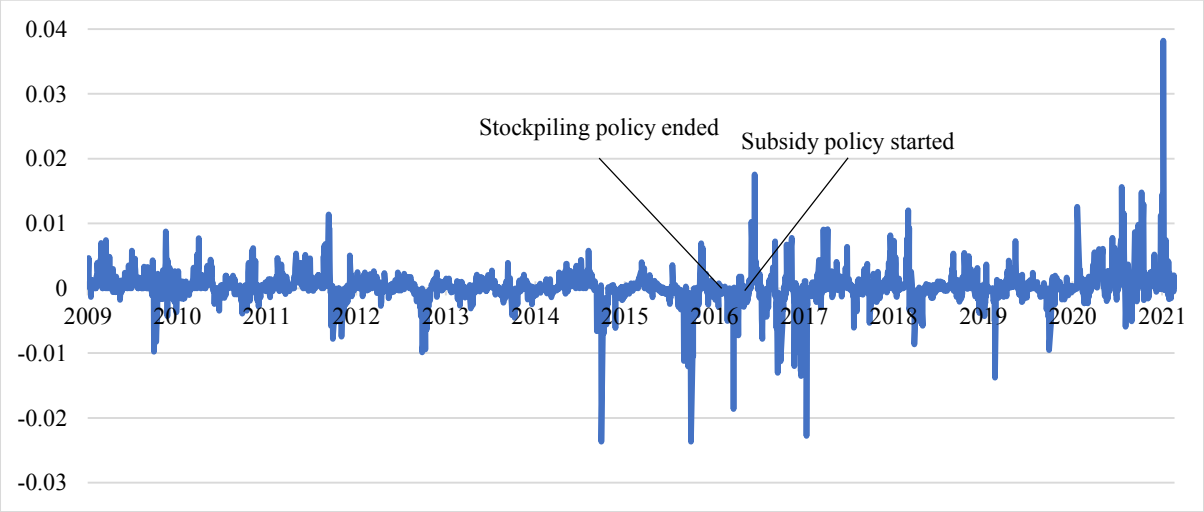


Figure 5-4 The price volatility of domestic corn in China

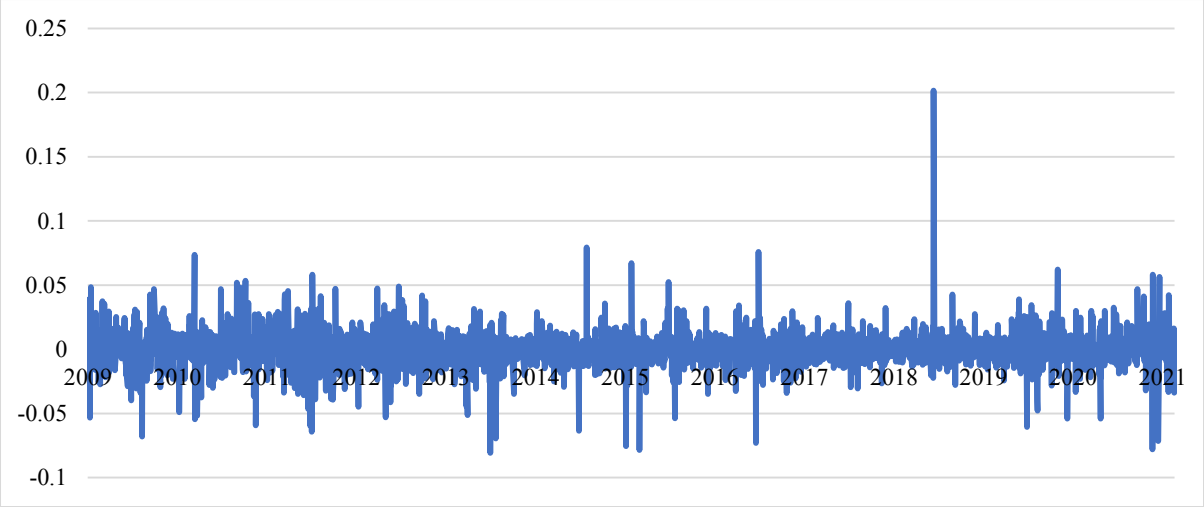


Figure 5-5 The price volatility of imported corn in China

From Table 5-2, we can see the mean of volatility in domestic price and import price are 0.0002 in T1, 0.0004 in T2 and 0.0000 in T1, 0.0005 in T2, respectively. The mean of volatility in domestic price in T1 is less than the mean of volatility in domestic price in T2, which suggests that average price volatility of domestic corn became greater after the policy change from the corn stockpiling policy to the corn subsidy policy. Table 5-2 also shows the standard deviations: 0.0020 of domestic price volatility in T1, 0.0029 of domestic price volatility in T2, 0.0145 of import price volatility in T1 and 0.0131 of import price volatility in T2. The standard deviation of the volatility of domestic price in T2 is less than the standard deviation of the volatility of domestic price in T2, which implies that the volatility amplitude of domestic price became greater after the policy change from the corn stockpiling policy to the corn subsidy policy. The standard deviation of the volatility of domestic price is less than the standard deviation of the volatility of import price, which tells us that the volatility amplitude of domestic price is less than the volatility amplitude of import price. These results are visually displayed in Figure 5-4 and Figure 5-5. Based on the results, we can predict that more corn imports imply that domestic price volatility increases because the larger volatility in import price and its transmission to domestic price.

5.5 Empirical analysis of corn price volatility and its international transmission

In this section, I construct an empirical analysis of corn price volatility and its international transmission. As I state in Subsection 5.1.2, before the empirical analysis, I need to check the properties of our price series. Therefore, properties of our price series are checked in Subsection 5.5.1. Based on the results of properties, a VAR-BEKK-GARCH model is constructed to quantify the volatility and its international transmission of domestic and import price of corn in Subsection 5.5.2. In Subsection 5.5.3, I analyze the results from the model with policy analysis.

5.5.1 Properties of the price series

We have found data for this study as shown in Subsection 5.4.1, and then, data property for empirical models should be tested. Co-integration models like the vector error correction model constructed by Engle and Granger (1987) can express the long-term equilibrium between the domestic price and the price of corn imports and the error correction of price volatility to reach the long-term equilibrium. However, the condition of data property for co-integration models

is co-integrated data series. Co-integration describes that, firstly, the series I expect to be co-integrated must be integrated of order d; secondly, if a linear combination of this collection of the series is integrated of the order less than d, then the collection is said to be co-integrated. This implies that before testing co-integration, the integration of each series has to be tested first. Integration of each series means that the series are non-stationary of order d, while they are stationary of order $d + 1$. I apply a method of unit root test to test the integration of each series and a method of co-integration test to examine whether co-integrations exist between the price series in this study. Table 5-3 and Table 5-4 shows the results of the unit root test and the results of the co-integration test, respectively.

Table 5-3 Results of the unit root test

	T1		T2	
	Probability	Unit root	Probability	Unit root
$\ln p_t^d$	0.891	Y	0.991	Y
$\ln p_t^m$	0.599	Y	0.475	Y
$\Delta \ln p_t^d$	0.000	N	0.000	N
$\Delta \ln p_t^m$	0.000	N	0.000	N

Notes: The null hypothesis of the unit root test is that the tested series has a unit root; trend and intercept are included in test equations: Augmented Dickey-Fuller test equations; lags are selected under Akaike information criterion.
Notions: Y-Yes (with a unit root, non-stationary), N-No (with no unit root, stationary), within 95% confidence interval

Table *5-3* shows the results of unit root test, suggesting that, in both period T1 and period T2 the logarithm series of domestic corn price at time t ($\ln p_t^d$) and the logarithm series of imported corn's price at time t ($\ln p_t^m$) have unit roots, while, in both period T1 and period T2 the logarithm series of domestic corn price after first difference at time t ($\Delta \ln p_t^d$) and the logarithm series of imported corn's price after first difference at time t ($\Delta \ln p_t^m$) have no unit roots. Series with unit roots are non-stationary series, while no unit roots imply stationary series. We can conclude that both the series $\ln p_t^d$ and $\ln p_t^m$ are integrated of first order. Therefore, co-integrations can be tested based on the precondition of the integrations of first order.

Table 5-4 Results of the co-integration test

	T1		T2	
	Probability	Co-integrated	Probability	Co-integrated
$\ln p_t^d$	0.614	N	0.964	N
$\ln p_t^m$	0.797	N	0.495	N

Notes: the null hypothesis of the co-integration test is that the tested series of $\ln p_t^d$ and $\ln p_t^m$ are not co-integrated; the test method is Engel-Granger method; lags are selected under Akaike information criterion; the values of probability are calculated by z-statistics.
Notions: N - Not co-integrated within 95% confidence interval

Table 5-4 shows the results of unit root test, suggesting that, in both period T1 and period T2 the logarithm series of domestic corn price and the logarithm series of imported corn's price are not co-integrated. Thus, co-integration models are not feasible for the data property. Therefore, I apply vector autoregressive (VAR) frameworks with series of $\Delta \ln p_t^d$ and $\Delta \ln p_t^m$ for the stationary series meet the data property of VAR models.

5.5.2 A VAR-BEKK-GARCH model

Based on a bivariate VAR framework, I construct a VAR-BEKK-GARCH model by incorporating with an applied BEKK-GARCH (the framework of generalized autoregressive conditional heteroskedasticity constructed based on the works of Yoshi Baba, Rob Engle, Dennis Kraft, and Ken Krone) framework proposed in Engle and Kroner (1995). The VAR-BEKK-GARCH model can be written as follows:

$$\Delta \ln p_t^d = \sum_{i=1}^{n} \alpha_{1i} \Delta \ln p_{t-i}^d + \sum_{i=1}^{n} \beta_{1i} \Delta \ln p_{t-i}^m + \varepsilon_{1t} \quad (5\text{-}11)$$

$$\Delta \ln p_t^m = \sum_{i=1}^{n} \alpha_{2i} \Delta \ln p_{t-i}^d + \sum_{i=1}^{n} \beta_{2i} \Delta \ln p_{t-i}^m + \varepsilon_{2t} \quad (5\text{-}12)$$

$$H_t = CC^T + A(\epsilon_{t-1}\epsilon_{t-1}^T)A^T + BH_{t-1}B^T \quad (5\text{-}13)$$

Notions are:

$\Delta \ln p_{t-i}^d$	the logarithm of the price of domestic corn after first difference at time $t-i,\ i = 0,1,\cdots,n$,
$\Delta \ln p_{t-i}^m$	the logarithm of the price of imported corn after first difference at time $t-i,\ i = 0,1,\cdots,n$,
$\alpha_{1i}, \beta_{1i}, \alpha_{2i}, \beta_{2i}$	coefficients at time $t-i, i = 0,1,\cdots,n$,
H_{t-j}	matrix of variances and the covariance of ε_{1t} and ε_{2t} at time $t-j, j = 0,1$,
$\varepsilon_{1t-j}, \varepsilon_{2t-j}$	residuals at time $t-j, j = 0,1$,
ϵ_{t-1}	matrix of residuals at time $t-1$,
C	a triangular matrix of constants,
A, B	matrices of coefficients.

Equation (5-11) and Equation (5-12) are equations of mean that express the expected volatility of the price of domestic corn and the price of imported corn at time t, respectively. In the meanwhile, they show that the expected volatility of a price at time t are supposed to be affected by its previous volatility at time $t-i$ $(i = 1,2,\dots,n)$ and the previous volatility of another price at time $t-i$ $(i = 1,2,\dots,n)$. In other word, the previous volatility of domestic corn price and imported corn's price are assumed to affect the expected volatility of both domestic corn price and imported corn's price at time t. Based on Equation (5-11) and Equation (5-12), $\beta_{1i} = 0$ means there is no volatility transmission in mean from import price to domestic price and $\alpha_{2i} = 0$ represents there is no volatility transmission in mean from domestic price to import price.

Equation (5-13) is BEKK-GARCH model that can be transferred to be its determinant as the Equation (5-14).

$$\begin{aligned} \begin{pmatrix} h_{11,t} & h_{12,t} \\ h_{21,t} & h_{22,t} \end{pmatrix} &= \begin{pmatrix} c_{11} & 0 \\ c_{21} & c_{22} \end{pmatrix}^T \begin{pmatrix} c_{11} & 0 \\ c_{21} & c_{22} \end{pmatrix} \\ &+ \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix}^T \begin{pmatrix} \varepsilon_{1,t-1}^2 & \varepsilon_{1,t-1}\varepsilon_{2,t-1} \\ \varepsilon_{1,t-1}\varepsilon_{2,t-1} & \varepsilon_{2,t-1}^2 \end{pmatrix} \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} \\ &+ \begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{pmatrix}^T \begin{pmatrix} h_{11,t-1} & h_{12,t-1} \\ h_{21,t-1} & h_{22,t-1} \end{pmatrix} \begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{pmatrix} \end{aligned} \quad (5\text{-}14)$$

Notions are:

$h_{11,t-j}$	variance of ε_{1t} at time $t-j, j = 0,1$,
$h_{22,t-j}$	variance of ε_{2t} at time $t-j, j = 0,1$,
$h_{12,t-j}, h_{21,t-j}$	covariance between ε_{1t} and ε_{2t} at time $t-j, j = 0,1$,

c_{11}, c_{21}, c_{22} elements in matrix C,
$a_{11}, a_{12}, a_{21}, a_{22}$ elements in matrix A,
$b_{11}, b_{12}, b_{21}, b_{22}$ elements in matrix B.

In Equation (5-14), the residuals (ε_{1t} and ε_{2t}) can be considered as volatility responses (or temporary volatility) to temporary market shocks at time t, which make the volatility deviate from its mean temporarily in a market. The variances ($h_{11,t}$ and $h_{22,t}$) measure the degree of the volatility response at time t or the power of market shocks at time t in a market. The covariance ($h_{12,t}$ or $h_{21,t}$) captures the degree of the combined volatility response of two prices at time t or the power of market shocks that affect both of markets at time t. The degree of the volatility response at time t is supposed to be affected by previous volatility responses at time $t-1$ and temporary market shocks at time $t-1$ in both the domestic corn market and the corn import market.

According to the above statements, three null hypotheses based on the VAR-BEKK-GARCH model are proposed: H1: If $a_{12} = b_{12} = a_{21} = b_{21} = 0$, the volatility of domestic and import price has no response to the volatility of each other; H2: If $a_{12} = b_{12} = 0$, the volatility of import price has no response to the volatility of domestic price; H3: If $a_{21} = b_{21} = 0$, the volatility of domestic price has no response to the volatility of import price[19]. The volatility response of domestic and import prices to each other also means volatility transmission.

5.5.3 Result analysis

In the VAR-BEKK-GARCH model, the mean model (VAR model) describes the expected volatilities in domestic price and import price of corn, and their expected volatilities are expressed by both domestic price and import price. Table *5-5* represents the estimated results of mean models.

Table 5-5 Estimated results of international transmission between expected volatilities in China's domestic and import prices of corn

		T1	T2
Mean model of $\Delta \ln p_t^d$	Constant	0.000 (0.002)	0.000 (0.001)
	α_{11}	0.357 (0.000)	0.342 (0.000)
	α_{12}	0.293 (0.000)	0.280 (0.000)
	α_{13}	0.121 (0.000)	0.106 (0.000)
	β_{11}	-0.002 (0.264)	-0.003 (0.458)
	β_{12}	0.002 (0.132)	0.002 (0.682)
	β_{13}	0.001 (0.735)	0.005 (0.078)
Mean model of $\Delta \ln p_t^m$	Constant	0.000 (0.911)	-0.000 (0.439)
	α_{21}	-0.088 (0.641)	-0.211 (0.056)
	α_{22}	0.180 (0.360)	-0.087 (0.493)
	α_{23}	-0.459 (0.018)	0.236 (0.042)
	β_{21}	-0.010 (0.655)	-0.156 (0.000)
	β_{22}	0.006 (0.769)	0.016 (0.542)
	β_{23}	-0.012 (0.604)	-0.052 (0.038)

[19] In other word, the volatility of domestic and import price has no spillover effects on each other (H1); the volatility of domestic price has no spillover effects on import price (H2); the volatility of import price has no spillover effects on domestic price (H3).

Notes: The selected lag in the mean model for the period T1 is 3 under Akaike information criterion; the selected lag in the mean model for the period T2 is 2 under Akaike information criterion; I select 3 lags for both periods.

From Table 5-5, within 95% confidence interval, we can draw the following conclusions. As for the volatility of the domestic price of corn, the expected volatility of domestic price in both T1 and T2 is significantly and positively affected by its previous volatilities, while the previous volatilities of corn import price have no significant effects on the expected volatility of the domestic price. The conclusions imply the expected volatility of the domestic price is mainly caused by the information in the domestic market, and the information in the market of corn imports of China cannot significantly affect the expected volatility of the domestic price. As for the volatility of the price of imported corn, during T1 and T2, the expected volatility of import price is significantly and negatively affected by the previous volatility of domestic price, which implies the expected volatility of import price of the corn supplying to China's markets is mainly caused by the information in China's domestic market. In addition, based that the volatility of import price is larger than the volatility of domestic price, the negative effects imply that the information in the domestic market can stabilize the import price. During T2, the expected volatility of import price is significantly affected by the previous volatility of both domestic price and import price, which implies the expected volatility of import price of the corn supplying to China's markets is caused by the information in both China's domestic market and its import market in T2. This cause change from T1 to T2 suggests that the influence power of import price got stronger from T1 to T2, partly because the corn imports of China continually increased. In addition, previous volatilities of import price have negative effects on its current volatility, which implies previous information in import price can stabilize the volatility of import price or over-volatility responses to market information appear. It can be concluded that there is no transmission of expected volatilities between domestic and import prices in T1, and the expected volatility can transmit from domestic price to import price rather than from import price to domestic price in T2.

In the VAR-BEKK-GARCH model, the BEKK-GARCH models describe volatility responses (temporary volatility) of domestic price and import price to market shocks which make the volatility deviate from its mean temporarily and to previous volatility responses. Table *5-6* represents the estimated results of BEKK-GARCH models.

Table 5-6 Estimated results of international transmission between temporary volatilities in China's domestic and import prices of corn

	T1	T2
c_{11}	0.000 (0.000)	0.001 (0.000)
c_{21}	0.009 (0.000)	-0.001 (0.421)
c_{22}	-0.000 (0.999)	0.009 (0.000)
a_{11}	0.527 (0.000)	0.474 (0.000)
a_{12}	-0.176 (0.469)	-1.172 (0.000)
a_{21}	-0.001 (0.833)	0.005 (0.292)
a_{22}	0.211 (0.000)	0.796 (0.000)
b_{11}	0.853 (0.000)	0.875 (0.000)
b_{12}	0.052 (0.720)	0.269 (0.035)
b_{21}	-0.016 (0.000)	-0.001 (0.937)
b_{22}	0.726 (0.000)	0.295 (0.000)
H1	Rejected (0.000)	Rejected (0.000)
H2	Accepted (0.765)	Rejected (0.000)

H3	Rejected (0.000)	Accepted (0.412)

Note: The hypotheses, H1, H2 and H3, are tested by Wald test and corresponding results are rejected or accepted within 95% confidence interval.

According to Table 5-6, we can draw the conclusions concerning volatility responses of domestic price and import price. In T1, H1 and H3 are rejected, while H2 is accepted, which means that the volatility of domestic price has responses to the volatility of import price, but the volatility of import price has no response to the volatility of the domestic price. In other words, temporary shocks from the market of imported corn contribute to the volatility of domestic price, while temporary shocks from the domestic market have no significant effects on the volatility of import price. In T2, H1 and H2 are rejected, while H3 is accepted, which means that the volatility of import price has responses to the volatility of domestic price, but the volatility of domestic price has no response to the volatility of import price. This also stands that temporary shocks from the domestic market contribute to the volatility of import price, while temporary shocks from the market of imported corn have no significant effects on the volatility of the domestic price. It can be concluded that volatilities caused by temporary shocks transmit in a single direction, and the direction is from import price to domestic price in T1 and from domestic price to import price in T2. According to the above results in Table 5-5 and Table 5-6, we can visually represent the conclusions in figures shown in Figure 5-6 and Figure *5-7*.

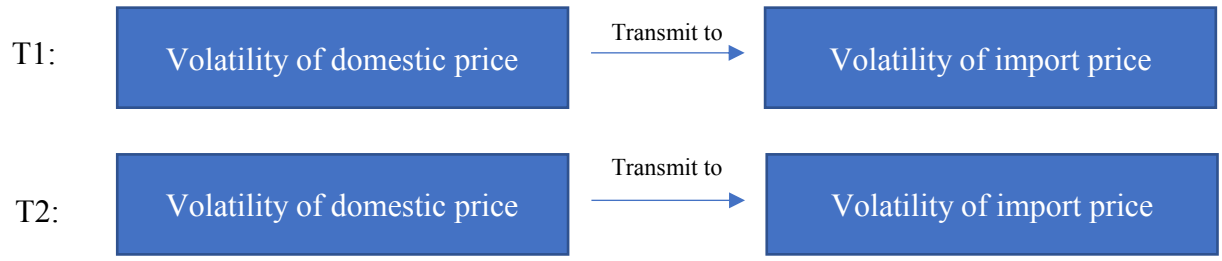


Figure 5-6 The transmission between expected volatilities in China's domestic and import prices of corn

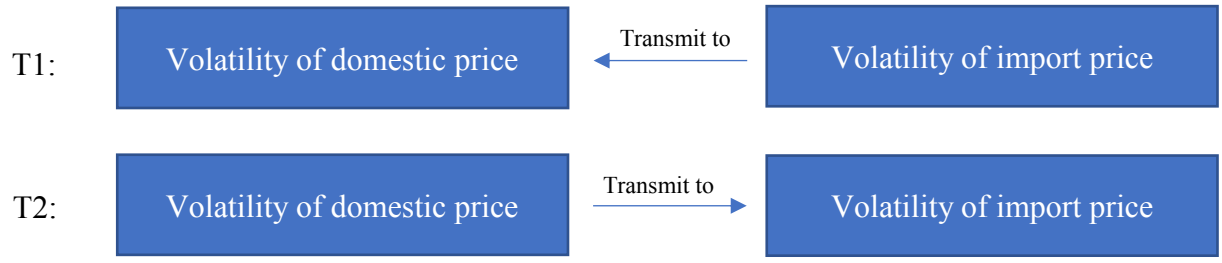


Figure 5-7 The transmission of between temporary volatilities in China's domestic and import prices of corn

From Figure 5-6 and Figure 5-7, in the period of the corn stockpiling policy (T1), the volatility of domestic price transmits to import price, and the volatility transmission of temporary volatility exists with the direction from the volatility of import price to the volatility of the domestic price. In the period of the corn subsidy policy (T2), the volatility transmission with the direction from the volatility of domestic price to the volatility of import price exists in both mean and temporary volatility. The possible reason for these conclusions is that the change of policy from stockpiling policy to the subsidy policy decreased the price support from corn policies, thereby shrinking the gap between domestic and import price of corn, which

consequently leads to less tress of price decreases to some extent. In addition, domestic corn of China dominants the corn supply in China (The self-sufficiency rate of corn in 2017 was 98.5%.), therefore, although the imported corn substitutes for domestic corn in China, thereby possibly affecting the volatility of domestic price to some extents and the volatility of domestic price have responses to temporary market shocks of import market in T1, it does not have significant power to influence the volatility of domestic price for both periods.

5.6 Summary

Prices of agricultural products have a wide effect on an economy; thus, managing price volatility risks in agricultural markets is always a vital priority of the development vision in China. Price volatility and the volatility relationships of agricultural prices between China's and international markets have long been a topic of interest for agricultural economists, but empirical findings vary. However, none of these past price volatility and transmission studies concerned the relationships between domestic and import markets of China. This chapter seeks to investigate the agricultural price volatility and its transmission between domestic and import markets of China by the example of corn. By statistical and empirical methods, I find:

By the statistical analysis, I conclude that bigger gaps between the domestic price and import price appear in the period of the stockpiling policy rather than the period of the subsidy policy, and average price volatility of domestic corn became greater after the policy change from the corn stockpiling policy to the corn subsidy policy. In addition, the volatility amplitude of domestic price became greater after the policy change from the corn stockpiling policy to the corn subsidy policy, and the volatility amplitude of domestic price is less than the volatility amplitude of import price. Based on the results, we can predict that more corn imports may imply that domestic price volatility increases because of the larger volatility in import price and its transmission to domestic price.

By the empirical analysis, we can draw the conclusions that before the policy change from stockpiling policy to the subsidy policy, the volatility in import price has an effect on domestic prices; however, after the change, it shows significant effects of the volatility in domestic price on import price. In detail, firstly, the volatility of the domestic price is mainly caused by the information in the domestic market, and the information in the market of corn imports of China cannot significantly affect the expected volatility of domestic price; secondly, the information in the domestic market can stabilize the import price, and the influence power of domestic price got stronger from the period of stockpiling to the period of the subsidy; thirdly, the expected volatility can transmit from domestic price to import price rather than from import price to domestic price; fourthly, temporary shocks from the market of imported corn contributes to the volatility of domestic price in the period of the stockpiling, while temporary shocks from the domestic market have a significant effect on the volatility of import price in the period of the subsidy. We expect that under the condition of free trade, the interactions of international transmission are supposed to exist in both directions between domestic price and import price. Thus, based on the above conclusions, more imports may imply more volatility transmission from import price on domestic price.

Chapter 6 Simulation on future scenarios of agricultural policies in China: a CGE analysis

A number of empirical methods have been applied to analyze the economic effects of agricultural policies, such as econometric models, input-output models, and CGE models. Some researchers have applied econometric models to analyze various agricultural policies in China. For example, Wang and Shen (2014) applied an econometric model with rural household panel data to analyze the effect of China's agricultural tax abolition on rural families' incomes and production, and they showed the abolition of agricultural tax did not significantly affect agricultural production and increase of families' incomes. Qian et al. (2015) used a time series model to analyze agricultural input subsidies, and they support that agricultural subsidy policies contribute to increases in market prices for grain in China. However, econometric models have significant disadvantages in the application for especially developing countries because developing countries are usually not well suited for economy-wide policy analysis relying on econometric techniques for several reasons. First and foremost, reliable time-series data for sufficiently long time periods are usually not readily available; second, when available, the data are often not appropriate for standard econometric analysis without considerable further preparation to remove inconsistencies; and last but not least, significant changes in policy regimes often take place calling for different structural models, thereby reducing the time span available for hypothesis testing with a selected model (De Melo 1988). As for China, the target country in this study, because it develops so fast and has been through several big economic events, like the economic reform in 1978, the event to be a WTO member in 2001, and trade frictions with the U.S. started from 2016, under which policy regimes often take place, I may face troubles to obtain feasible data for an econometric model if taking data consistencies into consideration. In addition, econometric models have significant limitations in economy-wide analysis because their relatively simple structures cannot analyze relatively large numbers of variables of an economy-wide framework. Some researchers have applied input-output models to analyze agricultural policies in China. For example, Mu and Wang (2008) constructed a 21-sector input-output model to analyze subsidy on grain in China, suggesting that direct subsidy on grain weakly affects non-agricultural sectors and significantly affects downstream industries of corn. However, input-output models have been largely replaced by CGE models in economy-wide policy analysis.

The use of CGE models for agricultural policy analysis has become widespread, and CGE methods have become the dominant economy-wide approaches, largely replacing other methods such as input-output models and econometric models because a CGE model enables us to disentangle the general equilibrium effects on an economy of various policy scenarios on sectoral outputs, incomes, taxes, etc. CGE models play an essential role in estimating how an economy might react to changes in policy, technology, or other external factors. They also provide a comprehensive picture of the effects of the changes on various sectors of an economy as well as the interactions among economic agents, such as consumers, investment agents, governments, and international trade. These advantages of CGE models have fostered their wide application in the analysis of policy changes in developed and developing countries, including China. For example, Yu and Jensen (2010) applied a GTAP model to analyze a series of agricultural policies, including abolishing agricultural taxes, introducing direct subsidies to grains, providing direct subsidies for purchased inputs, etc., and their results support that recent policy changes from taxing to subsidizing grain production have achieved the declared policy goals of increasing grain production and boosting farm income. Zhong et al. (2017) suggested that reducing irrigation subsidy has great potential for

resolving the water scarcity problem in China by a CGE model that incorporates multi-provincial irrigation water inputs, irrigation subsidies, and the water parallel pricing system.

Given that the domestic supply of some agricultural products in China may not be enough to their demands in the future, thereby importing more of these products, this study examines the economic effects of possible future policies for China's agriculture in case of corn trade policies of China by a CGE model. Some researchers have analyzed the effects of the corn stockpiling policy on its price (e.g., Liu and Wang, 2020), production (e.g., Xu et al., 2020), and the effects of the subsidy on production (e.g., Xu et al., 2020) and on macro-economy of China (e.g., Wang et al. 2020). About the corn trade, there are three basic points of view: one, 100% self-sufficiency, two, free reliance on import, and three, reliance on import with feasible import restraints. The first one supports that all consumed corn of China is produced in China to keep 100% self-sufficiency and so-called security. However, with corn demand increase, since the year 2010 when China become a net corn importer, 100% self-sufficiency implies an absolute ban on corn import by the government. The second one implies that the government set the lowest restraints on corn import, which kind of corn are consumed in China depending on the free competition between domestic and imported corn. The third one is popular among researchers because it is relatively compromised, and the other two points of view are more extreme according to current situations. Based on the situation of self-sufficiency, moderate grain imports should be acceptable by launching feasible tariff and quota policies and supporting agriculture under WTO restraints (e.g., Zhai (2011), Huang et al. (2012), Ni (2014a, 2014b), Shang (2014), Jiang (2015), Ding (2015, 2016)). However, which corn trade policy may be feasible ones and what are the economic effects from more corn import of China are in lack of research. In addition, this kind of research concerns future policy scenarios, which is essential for future policy plans and the development of corresponding economic sectors. Therefore, given that corn import of China may significantly increase, this study examines the economy-wide effects of some future policy scenarios about corn trade of China by a CGE model.

In this chapter, Section 6.1 shows CGE methods from theory to empiric. Firstly, theoretical foundations are introduced, including the theory of Walrasian equilibrium, the theories between Walrasian equilibrium allocation and Pareto optimal allocation, and the theory about the existence of Walrasian equilibrium. These theoretical foundations are the basement of the application of CGE methods in practice. Secondly, I outline the framework of CGE approaches, their advantages and shortcomings, and their applications and prospects in practice. By the introduction, we can understand the theoretical foundations of CGE methods, some of their characteristics, their wide applications in practice. In the following sections, I apply a CGE model to analyze the economic effects of corn trade policies of China. Section 6.2 presents the dataset for CGE models: the social accounting matrix (SAM). Firstly, I introduce a typical structure of SAM. Secondly, I demonstrate how to construct a SAM for CGE models by an example for China. Thirdly, I list some methods to adjust and balance SAMs because data from diverse datasets may cause unbalanced SAM that cannot be used as the data source for CGE models. After obtaining the data for a CGE model, in Section 6.3, I construct a CGE model to analyze corn trade in this study. The first subsection is an overview of the CGE model I construct. In the second subsection, I introduce the formula derivation of the CGE model in detail. All formulas in the model system are listed in the third subsection. However, CGE models contain several unknown parameters. Section 6.4 tells us the methods to find values of the unknown parameters. The first subsection introduces the calibration method to estimate some of the parameters, and the second subsection introduces the econometric methods for parameter estimation. By these methods, we can obtain the values of the parameters. After the work for obtaining data, constructing a CGE model, and "solving" unknown parameters in the CGE models, it is ready to simulate some scenarios and find some simulation results. Section

6.5 shows the future scenarios of the corn trade policy I design for China, and I analyze the simulation results from the CGE approach under general equilibrium in the section. However, some of the parameters in the CGE model may affect the robustness of simulation results. I have a sensitivity analysis in Section 6.6 to check the robustness of the results from the CGE model. In addition, Section 6.7 summarizes the analysis results in the above six sections.

6.1 CGE methods from theory to empirics

The theory that CGE methods are based on dates to the 1870s, particularly the work of French economist Walras in his pioneering 1874 work: *Elements of Pure Economics* which provides a succession of models that proves that a vector of prices of a bundle of goods exists to meet the equilibrium condition that every agent maximizes their utilities and the total demand for each good equals the aggregate endowment for each agent. However, for many decades after Walras put his model of general equilibrium, it was an under solved question as to whether such an equilibrium actually existed. Until 1951 in which John Nash proved Nash equilibrium by a fixed-point theorem, general equilibrium theorists realized the idea to prove its existence by the fixed-point theorem. In 1954, Arrow and Debreu (1954) proved the existence of Walrasian equilibrium. Additionally, (Arrow (1951) and Debreu (1951)) proved Walrasian equilibrium allocation is a Pareto optimal allocation, vice versa, under several assumptions, which provides a theoretical condition to apply Walrasian equilibrium in economic allocation. The above results shed light on Arrow and Debreu is recognized as three welfare theorems.

Based on the three welfare theorems, since 1960, CGE modeling has gradually become the dominant economy-wide framework, largely replacing other approaches such as input-output modeling and econometric modeling. A pioneer, Johansen, developed a model including 20 firm agents and a household agent (Johansen, 1960). Scarf (1967a, 1967b) contributed to developing a CGE framework that direct links between theoretical work and CGE modeling by designing an algorithm for solving general equilibrium problems. His students (Shoven and Whalley) also played a leading role in CGE modeling (e.g., Shoven and Whalley, 1984). Many researchers in the 1990s published CGE papers in leading journals and made it an established period for CGE modeling, for example, Devarajan and Robinson (1993), Hertel et al. (1997), Harrison and Pearson (1996). Especially, Hertel with his colleagues, established the GTAP, and Pearson, with his co-workers, developed the GEMPACK software, and they are widely applied by researchers to analyze international trade.

In this section, firstly, the general equilibrium theory is introduced. The general equilibrium theory provides the theoretical framework for CGE modeling. Based on the theory, I, secondly, introduce CGE methods with respect to practice.

6.1.1 General equilibrium theory

In this subsection, I make a production of the general equilibrium theory that offers a basement of application of Walrasian equilibrium in practice. The contents of this subsection consist of the definition of Walrasian general equilibrium, the Walrasian equilibrium in the welfare theorems, and the existence of Walrasian equilibrium. In detail, the definition of Walrasian general equilibrium is introduced by Walras's model, which helps us to understand the simple specification of general equilibrium. After defining Walrasian general equilibrium, the Walrasian equilibrium in the welfare theorems is introduced to explain why an allocation in Walrasian equilibrium is a Pareto optimal allocation, *vice versa*. Optimal allocation is one of the foundations to apply Walrasian equilibrium in practice. Last but not least, the application of Walrasian equilibrium has to base on the evidence of its existence; therefore, the existence of Walrasian equilibrium is introduced.

6.1.1.1 Definition of Walrasian general equilibrium

In economics, general equilibrium theory or Walrasian general equilibrium attempts to explain the functioning of the macroeconomy as a whole and prove that under which macroeconomy the behavior of supply, demand, and prices with several or many interacting markets will result in an overall general equilibrium. Walrasian general equilibrium is a competitive equilibrium that is concerned only with perfect competition (a consumption). In a market with perfect competition, the preference of agents shows the characteristic of convexity, which provides an ideal characteristic for general equilibrium because non-convexity shall not allow a general equilibrium price. The characteristics in a competitive equilibrium are that 1) Producers achieve the goal of maximum profit and they get zero profit in a perfectly competitive market; 2) consumers achieve the goal of maximum utility by expanding all their incomes; 3) prices of goods reach their equilibrium prices after adjusting.

Before explaining Walrasian general equilibrium in detail, markets in a pure exchange economy are constructed to describe the other consumptions inside the general equilibrium framework, in which markets, 1) all agents are in relation to pure exchange; 2) each market has a finite number of goods (x, with $x = (x_1, x_2, \cdots, x_i, \cdots, x_N)$) in a finite number of agents ($h = 1, 2, 3, \cdots, H$); 3) each good has non-negative price (p, with $p = (p_1, p_2, \cdots, p_i, \cdots, p_N)$; 4) each agent has an initial endowment[20] (e_h) for exchange; 5) each agent has a continuous and strictly concave utility function described as $x_{i,h}(p, e_h)$ that is demand function of agent h as well.

In the whole economy, the demand for goods of any agent always equals its endowment, which can be calculated as:

$$\sum_{i=1}^{N} p_i x_{i,h}(p, e_h) = \sum_{i=1}^{N} p_i e_{i,h}, \quad \forall\, h = 1, 2, \cdots, H \tag{6-1}$$

For the whole economy, total values of goods always equal total endowments, which is describes in Equation (6-2):

$$\sum_{h=1}^{H}\sum_{i=1}^{N} p_i x_{i,h}(p, e_h) = \sum_{h=1}^{H}\sum_{i=1}^{N} p_i e_{i,h} \tag{6-2}$$

Equation (6-2) can be transferred as:

$$\sum_{h=1}^{H}\sum_{i=1}^{N} p_i x_{i,h}(p, e_h) - \sum_{h=1}^{H}\sum_{i=1}^{N} p_i e_{i,h} = 0 \tag{6-3}$$

Then, Equation (6-3) can be transferred as:

$$\sum_{i=1}^{N} p_i \left[\sum_{h=1}^{H} x_{i,h}(p, e_h) - \sum_{h=1}^{H} e_{i,h}\right] = 0 \tag{6-4}$$

Then, we can get Equation (6-5) from Equation (6-4):

$$\sum_{i=1}^{N} p_i \left[x_i(p) - e_i\right] = 0 \tag{6-5}$$

where $x_i(p)$ is total demand function of good i with $x_i(p) = \sum_{h=1}^{H} x_{i,h}(p, e_h)$ and e_i is total supply of good i. Equation (6-5) implies that under budget constraints the values of excess demand (or, conversely, excess market supplies) must sum to zero regardless of whether the prices are general equilibrium prices, which is what Walras's law asserts.

[20] In economics, an endowment is commonly understood to be the amount of property like land, labor, capital, and entrepreneurship. In this consumption, it is ownership of goods for exchange.

Thus, Equation (6-5) is a necessary condition for a general equilibrium. A sufficient condition can be described as:

$$x_i(p^*) - e_i = 0 \text{ with } p^* > 0, \qquad \forall\, i = 1, 2, \cdots, N \tag{6-6}$$

where p^* is a vector of equilibrium prices of the goods.

However, under the constraint of Equation (6-5), in N equations of Equations (6-6), just N-1 equations are independent because $\sum_{i=1}^{N} p_i^* [x_i(p^*) - e_i] = 0$ can be aggregated by Equations (6-6). Therefore, one equation in Equations (6-6) is redundant. We cannot calculate N equilibrium prices by N-1 equations. Walras introduced a method with a term p_i/p_i. By this term, Equations (6-6) can be descried as:

$$x_i(1, p_2/{p_1}^*, \cdots, p_i/{p_1}^*, \cdots, p_N/{p_1}^*) - e_i = 0 \tag{6-7}$$

By Equations (6-7), we can find N-1 equilibrium relative prices. These equations also imply that when N-1 markets reach their equilibriums, the left one out of the whole economy must also get its equilibrium. With Equation (6-5), we can infer that when excess demand/ excess demand supply happens of good i, excess supply/ excess demand will occur of another good, or when N-1 markets are clearing[21], the left one out of the whole economy must also get clearing.

In a general economy rather than a pure exchange economy, Walras's law can be understood as the total values of demand for all goods is equal the total values of endowments at any prices of goods and factors of production[22]. It can be presented in math as:

$$\sum_{i}^{m} p_i(S_i - D_i) + \sum_{j}^{n} w_j\big(D_j - S_j\big) = 0 \tag{6-8}$$

In Equation (6-8), p_i and w_j are prices of good i and factor j. S and D means supply quantity and demand quantities. m and n stand the number of agents in product markets and factor markets, respectively. According to Walras's law, when $m + n - 1$ markets are clearing in this economy, the left market gets clearing as well. This implies one economy-wide constraint is rigorously enforced in Walras's law, by which expansion in one sector can usually only occur at the expense of another, given limited resources.

We now define Walrasian general equilibrium in the economy as an economic equilibrium under which every agent maximizes their utilities and the total demand for each good equals the aggregate endowment with a vector of prices, and a consumption bundle for each agent.

6.1.1.2 Walrasian equilibrium allocation and Pareto optimal allocation

Considering welfare theorems about Walrasian equilibrium, I need to understand an important idea that is the notion of Pareto optimality. In this notion, the set of feasible allocations and identifies those allocations at which no consumer could be made better off without another being made worse off. In detail, an allocation x_h is feasible under the constraint of h's budgets ($\sum_{i=1}^{N} p_i e_{i,h}\ \forall\, h = 1, 2, \cdots, H$). As for an economy, a feasible allocation x is Pareto optimal (or Pareto efficient) if there is no other feasible allocation $\hat{x}$ that can cause higher utility than the utility allocation x can cause. Furthermore, Pareto optimality does not mean fairness or justice. It may reach Pareto optimality when one takes all while the other one gets nothing. Therefore, for an economy, Pareto optimality does not necessarily present all "wins" to any agent in this economy.

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[21] In economics, market clearing is the process by which, in a market, the supply of good i is equated to its demand so that there is no leftover supply or demand.

[22] Factors of production are the inputs needed for the produce a good or service.

About Walrasian equilibrium, Arrow (1951) and Debreu (1951) put forward two theorems: the first welfare theorem and the second theorem.

- **Theorem 1 (First welfare theorem):** Every Walrasian equilibrium allocation is a Pareto optimal allocation. Assumptions: 1) utility is increasing from allocation x to x', whenever $x' > x$; 2) local non-satiation of consumer preferences[23] would suffice.
  Proof. Suppose that there is a feasible allocation $\hat{x}$ that can cause higher utility than the utility Walrasian equilibrium allocation x^* can cause. This means:
  $$\sum_{i=1}^{N} p_i^* \hat{x}_{i,h} \geq \sum_{i=1}^{N} p_i^* x_{i,h} \text{ with } \sum_{i=1}^{N} p_i^* \hat{x}_{i,h'} > \sum_{i=1}^{N} p_i^* x_{i,h'} \quad \forall\, h, h' = 1, 2, \cdots, H \text{ with } h \neq h' \tag{6-9}$$
  By calculating a sum of Formula (6-9), we can get:
  $$\sum_{h=1}^{H} \sum_{i=1}^{N} p_i^* \hat{x}_{i,h} > \sum_{h=1}^{H} \sum_{i=1}^{N} p_i^* x_{i,h} \tag{6-10}$$
  Then, by Formula (6-10) and Equation (6-2), we can get:
  $$\sum_{h=1}^{H} \sum_{i=1}^{N} p_i^* \hat{x}_{i,h} > \sum_{h=1}^{H} \sum_{i=1}^{N} p_i^* e_{i,h} \tag{6-11}$$
  The Formula (6-11) shows that the allocation $\hat{x}$ is not feasible because the total value of goods in this allocation exceeds the budget, which goes against with the initial hypothesis. Therefore, there is no other feasible allocations that can cause higher utility than the utility Walrasian equilibrium allocation x^* can cause. So, we can say every Walrasian equilibrium allocation is a Pareto optimal allocation.
- **Theorem 2 (Second welfare theorem):** In an economy, if allocation x is Pareto optimal, a price vector p exist such that x with p is a Walrasian equilibrium allocation. The economy satisfies the assumptions: 1) utility functions of all agents are continuous concave; 2) utility is increasing from allocation x to x', whenever $x' > x$; 3) the endowment of all agents is greater than zero.
  Proof. The proof can be found in *Microeconomic Analysis (Third version)* by Hal R. Varain (1992).

From the two welfare theorems, based on some assumptions, Walrasian equilibrium allocation is a Pareto optimal allocation (First welfare theorem), and not all Pareto optimal allocation is Walrasian equilibrium allocation, but a Pareto optimal allocation that is not a Walrasian equilibrium allocation can be changed to another Pareto optimal allocation that is a Walrasian equilibrium allocation as well, for example, by the method of wealth redistribution from governments (Second welfare theorem). In conclusion, with some assumptions, an economy can reach its Pareto optimality so that getting a maximum total utility when the economy gets Walrasian equilibrium. This laid the foundation for welfare analysis in an analysis of general equilibrium.

6.1.1.3 Existence of Walrasian equilibrium

For many decades after Walras put his model of general equilibrium, it was an under-solved question as to whether such an equilibrium actually existed. Until 1951 in which John Nash proved Nash equilibrium by a fixed-point theorem, general equilibrium theorists realized the

[23] Local non-satiation of consumer preferences states that for any bundle of goods there is always another bundle of goods arbitrarily close that is preferred to it.

idea to prove its existence by the fixed-point theorem. In 1954, Arrow and Debreu (1954) proved the existence of Walrasian equilibrium.

- **Theorem 3 (Existence of Walrasian equilibrium):** In an economy, there exists a Walrasian equilibrium. The economy satisfies the assumptions: 1) utility functions of all agents are continuous concave; 2) utility is increasing from allocation x to x', whenever $x' > x$; 3) the endowment of all agents is greater than zero.
  Proof. The proof can be found in Arrow and Debreu (1954).

6.1.2 CGE methods

The application of CGE methods is on the basis of the aforementioned theories about general equilibrium. CGE methods are computable, multi-sectoral, and in many cases, multi-regional, in which the behavior of economic agents is modeled explicitly through utility and profit-maximizing assumptions. This subsection contains the introduction of the framework of CGE approaches, their advantages and shortcomings, and their applications and prospects. About the framework, I introduce a simple CGE structure and the structure of the CGE model in this study. Then, some of the advantages and shortcomings in the practice of CGE approaches are listed. Finally, the prospects of their application in future scenarios are expected.

6.1.2.1 Framework

CGE models produce numerical results of economic equilibrium under which every agent maximizes their utilities, and the total demand for each good equals the aggregate endowment with a vector of prices and a consumption bundle for each agent. Figure 6-1 represents a simple economy with one household and one firm. The economy satisfies an assumption of perfect competition. In other words, both the household and firm are assumed to be price takers. In this economy, the household and firm supply factors of production and goods, respectively. The household demands for goods subject to its budget, and the firm produces goods subject to its production. The household and the firm make an exchange in a market that equilibrating demand and supply by price adjustment. In this economy, when the market reaches its equilibrium, the household and firm maximize its utility and profit, respectively, and the demand for goods/factors equals the supply of goods/factors with equilibrium prices.

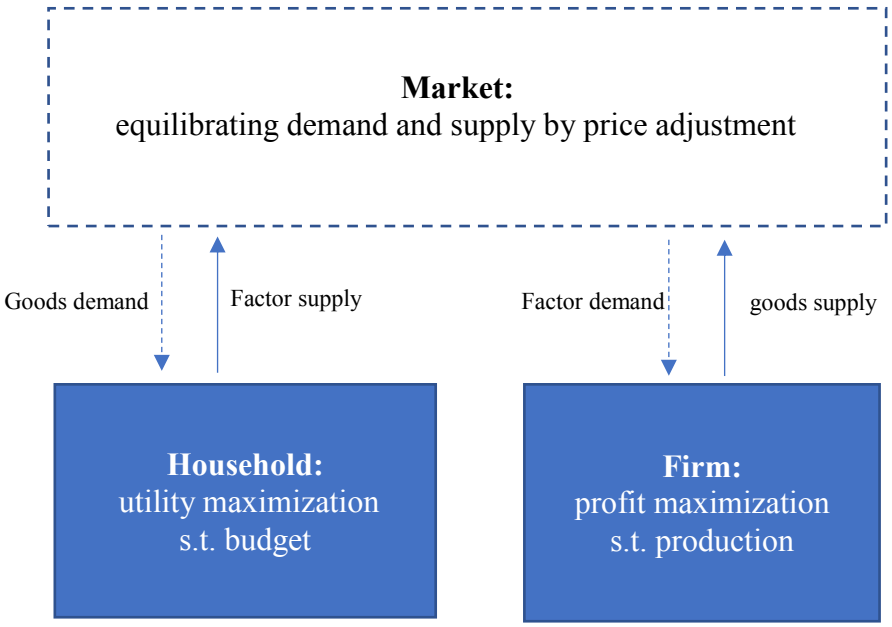


Figure 6-1 A simple structure of CGE models

However, the simple structure cannot meet micro-foundations. By this structure, CGE models assume one household, which supplies factors and demands for goods, and one firm, which produces goods and demands for factors. To further meet micro-foundations, we need to take the behaviors of investment, saving, the government, and the external agent into account. Our CEG model assumes one household, one government, several firms, and one external agent. Figure 6-2 represents a structure to meet micro-foundations and the structure also supports the CGE model designed for this study.

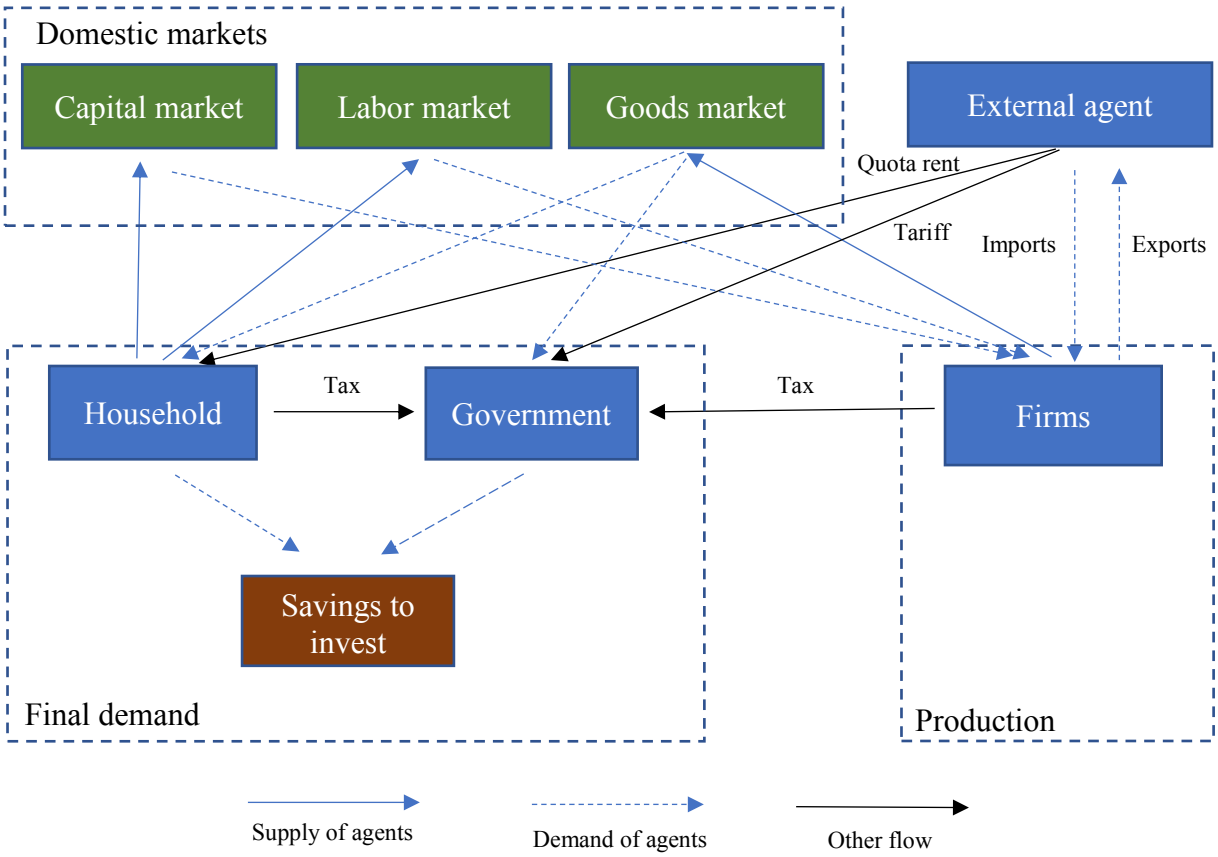


Figure 6-2 The structure of the CGE model in this study

In this structure, as shown in Figure 6-2, firms are agents for producing goods to supply them in goods markets, demand for factors of production (capitals and labors), and pay taxes like value-added taxes to governments. The household is the agent to consume goods, supply factors (capitals and labor), and pay taxes like consumers' taxes to the government. In addition, in this study, I assume the household captures all quota rents formatted by the external agent. The government is an agent to redistribute resources from taxing firms and households for increasing efficiency, providing infrastructure, promoting equity, and fostering macroeconomic stability and growth. The external agent supplies goods to firms for production demands for some goods from firms pays tariffs to the government, and transfer quota rents to households. In addition, households and governments invest their savings to purchase goods. The goods supply/demand and factor supply/demand are equilibrated by price adjustments in the domestic market, including the capital market, the labor market, and the goods market. When all markets get their equilibrium, firms meet their goal of maximum profit subject to

their productions, households get the highest utility subject to their budgets, and governments and the external agents balance their budgets.

6.1.2.2 Advantages

CGE models have a number of advantages that make them powerful tools of economic analysis in contrast with other economic models like macro-econometric models, partial equilibrium models, input-output models, and linear programming models. First, compared with macro-econometric models, CGE models are relatively small data requirements considering the model size. The advantage that most CGE models are developed with macroeconomic data makes them preferable to standard econometric models, which require observations for several years to estimate parameters with sufficient degrees of freedom. Macro-econometric models are often not in line with the economic foundations of developing countries, especially China, which is undergoing economic structural transformation because non-consistency between the data before and after a transformation affects the robustness of model results. In addition, such models neglect micro-foundations in common. Differently, CGE models incorporate macro and microeconomic foundations, and they are often developed with data of one year. Second, compared with partial equilibrium models, general equilibrium models are preferable when the policy experiment to be modeled affects simultaneously many countries and many sectors in several markets. Partial equilibrium models neglect offsetting effects following liberalization and working through inter-sectoral shifts, factor price adjustment, and exchange rate changes (Raihan 2004). Third, compared with input-output models and linear programming models, CGE models incorporate input-out tables and linear or nonlinear programming methods; therefore, CGE models capture some features both of input-output models and linear programming models. In addition, CGE models are based on price adjustment that input-output models and linear programming models neglect, and they can be applied to analyze accounts like taxes, redistribution of governments that input-output models cannot. CGE models link factor markets and goods markets by prices and capture inter-sectoral and inter-agent linkage effects, which make them discipline thinking about how economics actually works.

6.1.2.3 Shortcomings

CGE models have shortcomings. First, the results of CGE models rely too much on parameters used. Results of CGE models are sensitive to elasticities used, which are fixed for a particular situation. Most of the parameters in CGE models are calibrated on the basis of data from a single base year, which means these parameters are sensitive to the choice of the referenced base year. The referenced base year may not be able to represent other years, so the results of CGE models may not show representative information about the analyzed economy. In addition, the parameters, elasticities of substitution/transformation cannot be obtained by calibration, rather by estimation or reference to estimation results by other researchers. To estimate the parameters, we always face the problem that data of some analyzed sectors are not available or not sufficient for an estimation, especially in developing countries like China. To reference, we may face the problem that the estimated parameters for other countries do not fit your study for your selected countries well because differences between countries can lead to differences in parameters. Second, most CGE models assume perfect competition, which is an absence of market failures and non-convexities in production. However, perfect competition is not characteristic for the majority of products in markets, in particular the products produced in state-owned sectors or industries, which are imperfectly competitive. Third, most CGE models cannot deal with financial or monetary phenomena such as exchange rate changes and inflation. Because based on the original Walrasian general equilibrium, most CGE models can analyze

relative prices rather than absolute prices. A few financial CGE models have been developed; however, they tend to be too large to be solved easily, and the results are difficult to interpret (Hosoe et al. 2010).

6.1.2.4 Applications and prospects

CGE models have widely applied in many research fields such as international trade like the issues concerning WTO negotiations, free trade, and trade barriers, environmental issues like eco-taxes and CO_2 emission restraints, transport issues like investments on highways or railways, and macroeconomic issues like public expenditure cuts and tax reforms on production. However, the shortcomings mentioned above in CGE models limit their applications. The assumption of perfect competition is not well subject to the situations of the real economy, and with the development of finance, it more and more affects an economy; however, most CGE models cannot deal with monetary phenomena. Researchers are trying to develop CGE models to overcome these shortcomings.

CGE models are based on imperfect competition. As the assumption of perfect competition is not well subject to the situations of economy, a number of CGE models now incorporated market imperfection features, especially in the field of trade policy studies, where the New Trade Theory put forward that imperfect competition is often associated with the presence of economies of scale. Researchers have introduced several ways to accommodate market imperfections in CGE frameworks; however, the choices of ways have important consequences on simulation results and their interpretations (Roson, 2006).

CGE models analyzing financial/monetary phenomena. A number of so-called financial CGE models have been developed; however, these models tend to be too large to be solved easily, and the results are difficult to interpret (Hosoe et al. 2010). In this field, there are still some difficulties needed to overcome. For example, following the original Walrasian general equilibrium, the CGE models do not interpret the effects of money or currency in an economy; however, exactly expressing the role of currency is inherently difficult in a CEG model. In addition, the economy's response to financial changes is often faster than the response of industrial changes, so that it is difficult to capture the effects of one financial policy or financial shocks because financial policies may change many times in a year, and financial shocks frequently occur, in other words, equilibriums are ever-changing in a year.

CGE models analyzing complex economic systems. An economic system has many elements about production, consumption, investment, trade, saving, distribution, population, energy, environment, finance, technology, etc. These elements interact with each other. Neglecting more elements in a CGE model leads to more unreliable results. Therefore, it is necessary to construct CGE models for complex economic systems because they can provide results that are more in line with the actual economy. Constructing the CGE models will become possible through continuous improvement of, for example, calculating methods, modeling methods, and data statistics methods.

6.2 Data description: social accounting matrix

Social accounting matrix (SAM) is an economic accounting method in matrix form that is the dataset that forms the backbone of CGE models. It presents the various agents of an economy in a matrix and describes the revenues and expenses flows them in a period of an economy, and It extends the classical Input-Output framework and captures the flows of all economic transactions of several economic actors which take place in the economy in a single year. Stone and Brown (1962) developed the first SAM. By the early 1980s, with the wide application of

the CGE model in economy-wide analysis by the World Bank, SAMs had also been widely adopted as a presentational device by the CGE modelers (Mitra-Kahn Benjamin, 2008).

In this section, Subsection 6.2.1 represents an introduction of the typical SAM for an open economy, which records expenses and revenues of activities of production, factors of production, indirect taxes, final demands, and an external sector. In Subsection 6.2.2, I construct a SAM for China and introduce how to construct it. However, various data sources may cause an unbalanced SAM; therefore, in Subsection 6.2.3, how to adjust a SAM to be balanced is introduced.

6.2.1 The structure of a SAM

A SAM is a square matrix table that extends the classical Input-Output (IO) framework, including the complete circular flow of expenses and revenues in the economy. Rows in a SAM keep a record of revenues in each economic account of economic sectors; its volumes record their expenses, and row sums (revenue sums) equals volume sums (expense sums) in a balanced SAM. The accounts in a SAM for an open economy include the accounts of activities of production that can be divided into several specific activities like the activities about bread and milk, factors of production including labors (LAB), capitals (CAP) and other factors, indirect taxies which can be divided into tariffs (TRF) and other indirect taxes (IDT), final demand including households' demands (HOH), governments' demands (GOV) and investment demands (INV), and external sector (EXT) concerning international trade. In addition, in a SAM, accounts can be subdivided, expanded, merged, or deleted according to necessities for studies. For example, the household can be divided into the part in rural areas and the other part in urban areas or high-income, middle-income, and low-income households. Factors can be divided into labor, capital, lands, water, etc., and labor can consist of non-skilled laborers and skilled laborers. The accounts of indirect taxes can be deleted and merged into the account of governments.

Table 6-1 presents a typical SAM for an open economy that can records expenses and revenues of these economic accounts of activities of production, CAP, LAB, IDT, TRF, HOH, GOV, INV, and EXT. The introduction of the SAM is as below:

- **Activities of production.** Accounts of activities of production record the expenses and revenues in production activities of producers. Producers obtain revenues by supplying intermediate goods to producers, final goods/services to meet the private consumption of households, government consumption, and investment demand, and some goods/services exporting to external agents. They pay for purchasing intermediate goods and imported goods/services, paying capital interests, and paying wages to laborers and indirect taxes to governments.
- **Factors of production.** Accounts of factors of production record the expenses (or distributions) and revenues caused by factors. In production activities, the households who provide capital can earn capital returns (initial distribution) and money transfers from firms, governments, and external agents (redistribution), and the households who take advantage of them need to pay interests. Similarly, the ones who provide labor or take advantage of labor can obtain or pay wages.
- **Indirect taxes.** The accounts take a record of indirect tax expenses in production or import activities and indirect tax revenues of governments. The indirect tax is divided into tariff and other indirect tax because international trade occurs in an open economy, and separating tariff from other indirect taxes provides convenience for the general equilibrium studies of international trade.
- **Final demands.** Find demand is divided into the demands of households and governments, and investment demand and accounts in the SAM show their expenses

and revenues. About households, they demand goods/services, pay direct taxes like an income tax, and expense on their investments, which covers their expenses. They obtain revenues of wages and capital returns. About governments, they earn taxes, including indirect taxes and direct taxes, and expense on government demand for goods/services and government investments. Regarding investment, private investments of households and government investment consist of investment revenues and investment demand for fixed capital formation, and inventory changes can be treated as investment expenses.

- **The external sector.** The external sector is in relation to international trade. An account of this agent in the SAM records its expenses on imports and revenues from exports.

Table 6-1 The structure of a typical SAM for an open economy

Expenses / Revenues		Activities of production	Factors of production		Indirect Taxes		Final demands			The external sector	Total
			CAP	LAB	IDT	TRF	HOH	GOV	INV	EXT	
Activities of production		Intermediate goods					Private consumption	Government consumption	Investment demand	Exports	
Factors of production	CAP	Capital interests									
	LAB	Wages									
Indirect Taxes	IDT	Indirect taxes on activities									
	TRF	Tariffs on imports									
Final demands	HOH		Capital earnings	Wages							
	GOV				Indirect taxes	Tariffs	Direct taxes				
	INV						Private investments	Government investments			
The external sector	EXT	Imports									
Total											

6.2.2 Construction: a SAM for China

In Subsection 6.2.1, Table 6-1 has shown us all elements in the typical SAM. However, for empirical CGE studies, I should modify the SAM to fit the studies well. For analysis of corn trade of China, the modifications in the SAM for China include constructing a corn sector and downstream sectors of corn that input corn as intermediate inputs for production, adding a tariff-rate quota account. The widely recognized downstream sectors of corn in China include the sectors of Feed (FEE), Sugar (SUG), Condiment (CON), Other food (OFO), and Alcohol (ALC). I add the sectors of Other agriculture (OAG), Forestry (FOR), Husbandry (HUS), and Fishery (FIS), which are also considered as downstream sectors of corn because these sectors may input corn-relating products that are made by corn. However, these above-mentioned sectors cannot cover all sectors in an economy-wide IO table; thus, the sectors, Agricultural service (ASE), Other manufacture (OMA), and Other services (OSE), are included in the SAM. With the above-mentioned sectors, all sectors in an economy-wide IO table can be covered.

After dividing sectors for the economy of China, I need to find data for all accounts in the SAM. Subsection 6.2.2.1 presents the process to find data in an IO table, and Subsection 6.2.2.2 shows data from other sources. I present an initial SAM for China for empirical CGE analysis in this study at the end of Subsection 6.2.2.

6.2.2.1 Data from the IO table

Table 6-2 shows the data correspondences between the SAM and IO table of 2017. IO tables can provide most of the data included in the SAM. Firstly, if necessary, I need to merge or divide some accounts in the IO table into the accounts in the SAM because subdivided accounts may not need or more subdivided accounts may be needed in a study. In this study, the agriculture sector (01001) is subdivided into the corn sector and the sector of other agriculture. The sectors of 06006 - 13012, 13014, 13016 - 14020, and 15024 - 49013 in the IO table are merged as other manufacture sector. The sectors of 50104 - 91149 are merged as the sector of Other services. The capital account in the SAM is the sum of VA003 and VA004 accounts in the IO table. The indirect tax account (VA002) in the IO table is subdivided into tariff and other indirect tax accounts in the SAM. Household and investment accounts are from the accounts merged by FU101 and FU102, and FU201 and FU202, respectively.

Transferring data in the IO table into correct cells of the SAM is rather straightforward. The numbers in the cells of FOR, HUS, FIS, ASE, FEE, SUG, CON, OFO, ALC, LAB, GOV, and EXT accounts are directly corresponding with the numbers of cells of 02002, 03003, 04004, 05005, 13013, 13015, 14021, 14022, 15023, VA001, FU103 accounts, respectively, in the IO table. The numbers in the cells of OMA, OSE, CAP, HOH, INV are numbers of their corresponding merged accounts, respectively. Notifications are that revenue data in the SAM must correspond to revenue data in the IO table, and expenditure data in the SAM must correspond to expenditure data in the IO table. In addition, a balanced SAM should be subjected to the rule of row-sum and volume-sum equality.

Table 6-2 Data correspondences between the SAM and 2017 IO table

	Account in the SAM	Abbreviation	Account code in 2017 IO table
Activity	Corn	COR	Calculated
	Other agriculture	OAG	01001 (Modified)
	Forestry	FOR	02002
	Husbandry	HUS	03003

	Fishery	FIS	04004
	Agricultural service	ASE	05005
	Feed	FEE	13013
	Sugar	SUG	13015
	Condiment	CON	14021
	Other food	OFO	14022
	Alcohol	ALC	15023
	Other manufacture	OMA	06006-13012, 13014, 13016-14020, 15024-49013
	Other services	OSE	50104-91149
Factor	Labor	LAB	VA001
	Capital	CAP	VA003, VA004
Indirect tax	Other indirect tax	IDT	VA002 (Modified)
	Tariff	TRF	Calculated
Tariff quota rent	Tariff quota rent	TQR	Calculated
Final demand	Household	HOH	FU101, FU102
	Government	GOV	FU103
	Investment	INV	FU201, FU202
External sector	External sector	EXT	IM

Notes: The "calculated" represents that the data are calculated by author and the "modified" means that values of the sector in the SAM are modified based on the corresponding data in IO table and the corresponding calculated data. The process to obtain the data in relation to data modification or calculation is introduced in the next section. The IO table can be downloaded at the website: http://www.stats.gov.cn/.

6.2.2.2 Data from other sources

By copying the data from the 2017 IO table, most of the cells in the SAM can be filled. In addition, some cells can be filled according to row-sum and volume-sum quality, which include the cells of "HOH-CAP," "HOH-LAB," "HOH-EXT," "GOV-EXT," "INV-EXT," and "GOV-IDT." However, there are still some cells unfilled, so that I need to incorporate data from other sources.

Data of corn and other agriculture accounts. As the IO table does not include a corn sector, I get the values in the corn account by calculation. Regarding the volume of corn in SAM, I collect the 2017 data on production, export, import, consumption, and stock quantities from the USDA, 259.071 Mt for production, 19 for exports, 3.456 Mt for imports with 1% in-quota tariff rate, and 263 Mt for consumption. Founder Securities (2017) reported the data of corn consumption as 13% for sugar, 7% for alcohol, 3% for other food, 3% for condiment, 63% for feed, 10% for household consumption, and 1% for seed. The price data of corn in 2017 was 1711.86 RMB/ton, calculated based on the daily average corn price in 2017 from the Wind database (2020). I calculated the corn data in the SAM according to the above data. Thus, the agriculture sector (01001) in the IO table is modified to be other agriculture in the SAM, based on the corn data. Regarding row values of corn in the SAM, I calculated them as the proportion of output value of corn in agriculture where, for the calculation of the output value of corn, the corn price was sourced from the Wind database (2020), and the production quantity of corn from NBSC (2020).

Data of tariff and indirect tax accounts. For tariffs in the SAM, the weighted average tariff rates were 18.79% for other agriculture, 4.2% for forestry, 11.04% for husbandry, 6.8% for feed, 30.01% for sugar, 19.5% for condiment, 10% for other food, and 16.8% for alcohol, according to the data reported in the Trade Analysis Information System (World Bank 2015), and 1% in 2017 for in-quota tariff rate of corn, sourced from the Customs Import and Export

Tariff of the People's Republic of China (2017 version). The total tariff of China in 2017 was 284 778 million RMB. Based on the above data, we can calculate the tariffs of corn, other agriculture, forestry, husbandry, feed, sugar, condiment, other food, and alcohol. For other manufacturers and Other services, their tariffs were calculated using the weighted averages of import quantity. As a result, all numbers of indirect taxes in the IO table minus the corresponding tariff values are indirect tax numbers in the SAM. About indirect tax, the row of other indirect tax is calculated by the indirect tax values in the IO table minus tariffs that I have calculated.

Data of tariff-rate quota account. The quota rents equal the values of within-quota imports at a price in China's markets minus their values at border (CIF) price. The values can be calculated by the import quantities multiplied by their respective prices. However, no officials report the price of imports in China's markets. I then use the export prices of China to approximate the price of imports in China's markets. All quantity and price data used to calculate quota rents are sourced from the UN Comtrade website. Besides, an initial value needs to be applied as a quota level in the benchmark year 2017. The quota level reported by China's officials is 7.2 Mt for corn; however, corn imports were 3.46 Mt, which I treat as the actual quota level for execution in the year. Therefore, I set 3.46 Mt as the initial value of the quota level in the benchmark year. However, adding a rent account breaks the initial balance (row-sum and column-sum equality) of the SAM.

Other data. The data in the above sources are not sufficient for a complete SAM. Therefore, I find supplementary data of household income and income tax data for 2017 from NBSC (2020). The remaining cells in the SAM can then be completed by applying the row-sum and column-sum equality rule.

Table 6-3 The SAM for China (Unbalanced)

	OAG	COR	FOR	HUS	FIS	SER	FEE	SUG	CON	OFO	ALC	OMA	OSE	LAB	IDT	TRF	CAP	HOH	TQR	GOV	INV	EXT	Total
OAG	5920.27	0.00	0.00	2561.38	88.12	457.17	972.22	214.57	606.00	1701.88	1457.84	29929.10	2866.95	0.00	0.00	0.00	0.00	10691.26		0.00	78.80	967.05	58512.61
COR	0.00	45.02	0.00	0.00	0.00	0.00	2836.38	585.28	135.07	135.07	315.15	0.00	0.00	0.00	0.00	0.00	0.00	441.80		0.00	0.00	0.33	4494.10
FOR	0.01	0.00	286.53	0.00	0.00	24.66	0.43	0.05	0.08	7.47	1.34	5456.34	142.76	0.00	0.00	0.00	0.00	131.52		0.00	59.49	15.43	6126.11
HUS	0.01	0.00	0.00	2286.94	0.00	127.80	0.20	0.00	0.87	714.05	1.88	13648.57	647.47	0.00	0.00	0.00	0.00	9936.08		0.00	2229.00	82.49	29675.36
FIS	0.00	0.00	0.00	0.00	361.65	58.66	469.44	0.00	1.82	168.73	0.27	3551.74	2164.40	0.00	0.00	0.00	0.00	5040.03		0.00	33.53	128.28	11978.55
SER	909.65	82.79	548.90	96.34	406.67	421.21	8.33	0.00	0.00	0.00	0.00	1641.34	0.00	0.00	0.00	0.00	0.00	0.00		1237.90	0.00	0.02	5353.15
FEE	69.51	0.00	0.00	6087.29	1764.11	312.31	637.09	0.00	0.12	6.55	0.00	103.06	11.95	0.00	0.00	0.00	0.00	29.26		0.00	88.81	55.29	9165.35
SUG	0.00	0.00	0.00	0.00	0.00	0.00	4.47	155.06	69.35	358.63	15.05	664.44	73.33	0.00	0.00	0.00	0.00	337.82		0.00	60.23	22.83	1761.21
CON	0.00	0.00	0.00	0.00	0.00	0.00	42.18	0.00	302.62	234.58	52.16	418.92	465.64	0.00	0.00	0.00	0.00	1753.81		0.00	85.79	122.13	3477.83
OFO	0.00	0.00	0.00	0.00	0.00	0.00	113.88	0.00	219.04	591.66	155.06	1048.82	1278.38	0.00	0.00	0.00	0.00	11729.51		0.00	200.99	655.75	15993.09
ALC	1.21	0.00	0.73	0.47	0.63	16.10	20.45	0.05	10.96	47.78	1001.10	1972.64	2754.37	0.00	0.00	0.00	0.00	3917.13		0.00	149.74	94.45	9987.81
OMA	9154.25	833.12	480.50	1579.51	759.95	678.50	1554.81	107.22	883.70	5682.53	1914.70	72837 4.17	1295 61.22	0.00	0.00	0.00	0.00	106067.54		0.00	2995 13.89	1320 39.41	1419 185.02
OSE	3315.67	301.76	409.89	2344.47	1181.68	696.24	928.81	169.93	469.32	2453.96	1398.11	19411 9.27	2388 45.34	0.00	0.00	0.00	0.00	170350.93		1225 12.41	6196 0.01	2966 3.40	8311 21.20

LAB	36437.65	3316.16	3323.07	13241.08	6606.75	2346.22	686.59	120.46	225.00	1809.60	680.54	132767.66	221707.26	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	423268.04
IDT	-3114.89	-283.48	-76.47	23.36	40.92	-0.06	117.21	46.58	104.04	400.46	971.30	61513.68	35235.95	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	94978.60
TRF	684.53	0.59	43.23	31.07	24.50	0.00	12.13	24.77	4.21	63.48	72.91	1565.07	291.11	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	2817.60
CAP	1533.55	139.57	123.69	1173.18	407.72	214.33	594.49	279.49	428.23	1045.30	1589.30	124328.77	173111.46	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	304969.08
HOH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	423268.04	0.00		304969.08	0.00	14.20	0.00	0.00	0.00	728251.32
TQR		14.20																					14.20
GOV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	94978.60	2817.60	0.00	11966.38		0.00	0.00	0.00	109762.58
INV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	395844.05		-13987.73	0.00	-17396.04	364460.28
EXT	3601.19	58.57	986.04	250.27	335.85	0.01	166.24	57.75	17.40	571.36	361.10	118081.43	21963.61	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	146450.82
Total	58512.61	4508.30	61266.11	29675.36	11978.55	5353.15	9165.35	1761.21	3477.83	15993.09	9987.81	1419185.02	831121.20	423268.04	94978.60	2817.60	304969.08	728237.12	14.20	109762.58	364460.28	146450.82	

Note: The shadowed cells break the rule of row-sum and volume-sum equality.
Unit: 1/10 billion

6.2.3 Matrix adjustment for a SAM

The data in SAMs generally come from diverse datasets and correspond to different periods of time. As a result, they often show non-balance (row-sum and column-sum inequality). As for the above SAM constructed for China, the data show discrepancies among data derived from different sources. For example, the data about quota rents that generally cannot be found in IO tables are calculated by the author. This breaks the balance of the SAM. However, a balance SAM is required for a CGE model to describe the equilibrium status of an economy in which all markets are cleared and accounts are balanced (row-sum and column-sum equality) for all accounts. In addition, for some other studies, they need to update the data in a SAM based on non-updated IO tables because IO tables cannot be prepared frequently for the reasons of time and cost. This may break the balance of the SAM as well. Regardless of the cause of unbalanced SAMs, they cannot be applied to CGE models. I need to balance them to meet row-sum and column-sum equality by adjustment of cell data. Some methods for SAM balancing are introduced in the following sections.

6.2.3.1 The RAS method

The RAS method (also called as Bi-proportional method) is a well-known method for data reconciliation. The method is used when new information on the matrix rows or columns becomes available, and I want to update the matrix. In this method, a new matrix is generated from an existing matrix of the same dimension while respecting new given row and column totals by applying row and column multipliers which are determined by independent row and column restrictions, using an iterative adjustment procedure. The details of this method can be found in Stone (1942). This method provides a simple solution to apply for balancing matrices like SAMs. However, it lacks economic foundations and shows an inability to accommodate other sources of data than those on row- and column- sums; for example, I cannot fix the new cell values that can be determined accurately. Due to these shortcomings, some researchers tend to use the cross-entropy method.

6.2.3.2 The cross-entropy method

The cross-entropy method is similar to the maximum likelihood approach in econometrics which is to minimize the under updating information of data brought into new SAM comparatively to the prior SAM. In this method, a new SAM close to the prior SAM is found by minimizing the across-entropy distance between them. The details of this method can be found in Robinson et al. (1998). This method allows fixing the new cell values that can be determined accurately. However, the method does not allow negative values.

6.2.3.3 The ordinary least squares method and other methods

Some other methods also can be applied to balance SAMs like ordinary least square, Stone-Byron, and other methods. The ordinary least squares method is analogous to ordinary least squares estimation in econometrics, which is the method applied in this study. The method can be described by the following equations.

$$\underset{x_{i,j}}{\text{minimize}}\, obj = \sum_i \sum_j \left(\frac{x_{i,j} - x_{i,j}^0}{x_{i,j}^0} \right)^2 \qquad (6\text{-}12)$$

$$\sum_i x_{i,j} = \sum_i x_{j,i} \quad \forall\, j \tag{6-13}$$

In Equation (6-12), i and j are labels of rows and columns in the SAM. obj stands for objective values. $x_{i,j}$ denotes variables in row i and column j in adjusted SAM, which represents intermediate goods, labor, capital, household activities, indirect tax, tariff, government activities, and investment. $x_{i,j}^0$ denotes the variables in row i and column j in the SAM under adjustment. For quota rent, I assume during calculations that the numbers are fixed. $x_{i,j}^0$ are the initial numbers of $x_{i,j}$. When $x_{i,j}^0 \neq 0$, I set $x_{i,j}$ as variables; when $x_{i,j}^0 = 0$, I set $x_{i,j}$ as zeros. In addition, the method must be subjected to the constraint that the row sum of each variable equals its column sum, which is described in Equation (6-13). In the minimization problem, the "distance" obj between the under-adjusted SAM and adjusted SAM is minimized. The method is highly probable that some cell numbers should fix as zero because zero terms are ignored from the settings of Equation (6-12).

Table 6-4 The SAM for China (Balanced)

	OAG	COR	FOR	HUS	FIS	SER	FEE	SUG	CON	OFO	ALC	OMA	OSE	LAB	IDT	TRF	CAP	HOH	TQR	GOV	INV	EXT	Total
OAG	5920.27	0.00	0.00	2561.33	88.12	457.17	972.11	214.56	606.00	1701.88	1457.84	29929.17	2866.95					10691.27		0.00	78.80	967.05	58512.52
COR	0.00	45.02	0.00	0.00	0.00	0.00	2841.38	585.46	135.08	135.08	315.22	0.00	0.00					441.94		0.00	0.00	0.33	4499.52
FOR	0.01	0.00	286.53	0.00	0.00	24.66	0.43	0.05	0.08	7.47	1.34	5456.34	142.76					131.52		0.00	59.49	15.43	6126.11
HUS	0.01	0.00	0.00	2286.94	0.00	127.80	0.20	0.00	0.87	714.05	1.88	13650.12	647.47					9936.90		0.00	2229.04	82.49	29677.78
FIS	0.00	0.00	0.00	0.00	361.65	58.66	469.42	0.00	1.82	168.73	0.27	3551.79	2164.42					5040.14		0.00	33.53	128.28	11978.71
SER	909.65	82.78	548.90	96.34	406.67	421.21	8.33	0.00	0.00	0.00	0.00	1641.34	0.00					0.00		1237.90	0.00	0.02	5353.15
FEE	69.51	0.00	0.00	6091.30	1764.46	312.32	637.09	0.00	0.12	6.55	0.00	103.06	11.95					29.26		0.00	88.81	55.29	9169.73
SUG	0.00	0.00	0.00	0.00	0.00	0.00	4.47	155.06	69.35	358.66	15.05	664.53	73.33					337.84		0.00	60.23	22.83	1761.35
CON	0.00	0.00	0.00	0.00	0.00	0.00	42.18	0.00	302.62	234.58	52.16	418.92	465.64					1753.82		0.00	85.79	122.13	3477.84
OFO	0.00	0.00	0.00	0.00	0.00	0.00	113.88	0.00	219.04	591.66	155.06	1048.82	1278.38					11729.55		0.00	200.99	655.75	15993.12
ALC	1.21	0.00	0.73	0.47	0.63	16.10	20.45	0.05	10.96	47.78	1001.10	1972.65	2754.38					3917.16		0.00	149.74	94.45	9987.86
OMA	9154.24	832.61	480.50	1579.49	759.95	678.50	1554.53	107.22	883.70	5682.52	1914.69	72837.17	129561.29					106067.92		0.00	299515.80	132039.41	141918 6.54
OSE	3315.67	301.69	409.89	2344.42	1181.67	696.24	928.71	169.92	469.32	2453.96	1398.11	194119.10	238845.34					170351.80		122512.37	61960.08	29663.40	83112 1.69
LAB	36437.56	3308.05	3323.07	13239.62	6606.57	2346.21	686.53	120.46	225.00	1809.60	680.54	132767.91	221708.19					0.00		0.00	0.00	0.00	42325 9.31

IDT	-3799.42	-284.13	-119.70	-7.71	16.42	-0.06	105.08	21.81	99.83	336.98	898.39	59948.62	34944.85					0.00		0.00	0.00	0.00	92160.96
TRF	684.53	0.59	43.23	31.07	24.50	0.00	12.13	24.77	4.21	63.48	72.91	1565.07	291.11					0.00		0.00	0.00	0.00	2817.60
CAP	1533.55	139.56	123.69	1173.17	407.72	214.33	594.45	279.47	428.23	1045.30	1589.30	124328.41	173110.90					0.00		0.00	0.00	0.00	304968.07
HOH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	423259.31			304968.07	0.00	14.20	0.00	0.00	0.00	728241.58
TQR	0.00	14.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					0.00		0.00	0.00	0.00	14.20
GOV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		92160.96	2817.60		11966.38		0.00	0.00	0.00	106944.94
INV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					39586.07		-16805.33	0.00	-14578.45	364462.29
EXT	4285.72	59.16	1029.27	281.34	360.35	0.01	178.37	82.52	21.61	634.84	434.01	119646.50	22254.72					0.00		0.00	0.00	0.00	149268.41
Total	58512.52	44994.52	61266.11	29677.78	11978.71	53535.15	91769.73	17611.35	34773.84	15993.12	99879.86	141918654.54	83112169.69	42325959.31	92160.96	28176.60	30496807	72824158	14.20	106944.94	36446229	14926841	

Note: balanced by the method of ordinary least squares

6.3 The CGE model for the study

In this section, the CGE model for the study is introduced. Firstly, in Subsection 6.3.1, I outline the setup of the CGE model by an overview. In order to analyze the quota of corn in the international trade of China, the CGE model includes a quota module. Secondly, I introduce the formulas of the CGE model in detail in Subsection 6.3.2. Finally, I list all formulas in the model system in Subsection 6.3.3.

6.3.1 Overview of the CGE model

Figure 6-3 Overview of the CGE model summarizes the factor and commodity flows in the model economy. For the first stage, capital $F_{CAP,j}$ and labor $F_{LAB,j}$ for producing good j are aggregated into the composite factor Y_j by the composite factor production function in Cobb-Douglas style. For the second stage, firms produce goods by inputting composite factor Y_j and intermediate inputs $X_{i,j}$. The composite factor and intermediate inputs are aggregated into gross domestic output by the production function of gross domestic output in Leontief style Z_j. For the third stage, the gross domestic output is transferred into domestic good D_j consumed in domestic markets and exports E_j traded in international market by the transformation function in CET (constant elasticity of transformation) style. For the fourth stage, the domestic good D_j is combined with the imports M_j to produce the composite good Q_j by the production function of composite good in CES (constant elasticity of substitution) style. For the fifth stage, the composite good Q_j is distributed into the household consumption X_j^p, government consumption X_j^g, investment X_j^v, and intermediate uses $X_{I,j}$. For the sixth stage, the household consumption X_j^p causes the household utility UU that is described by utility function in Cobb-Douglas style.

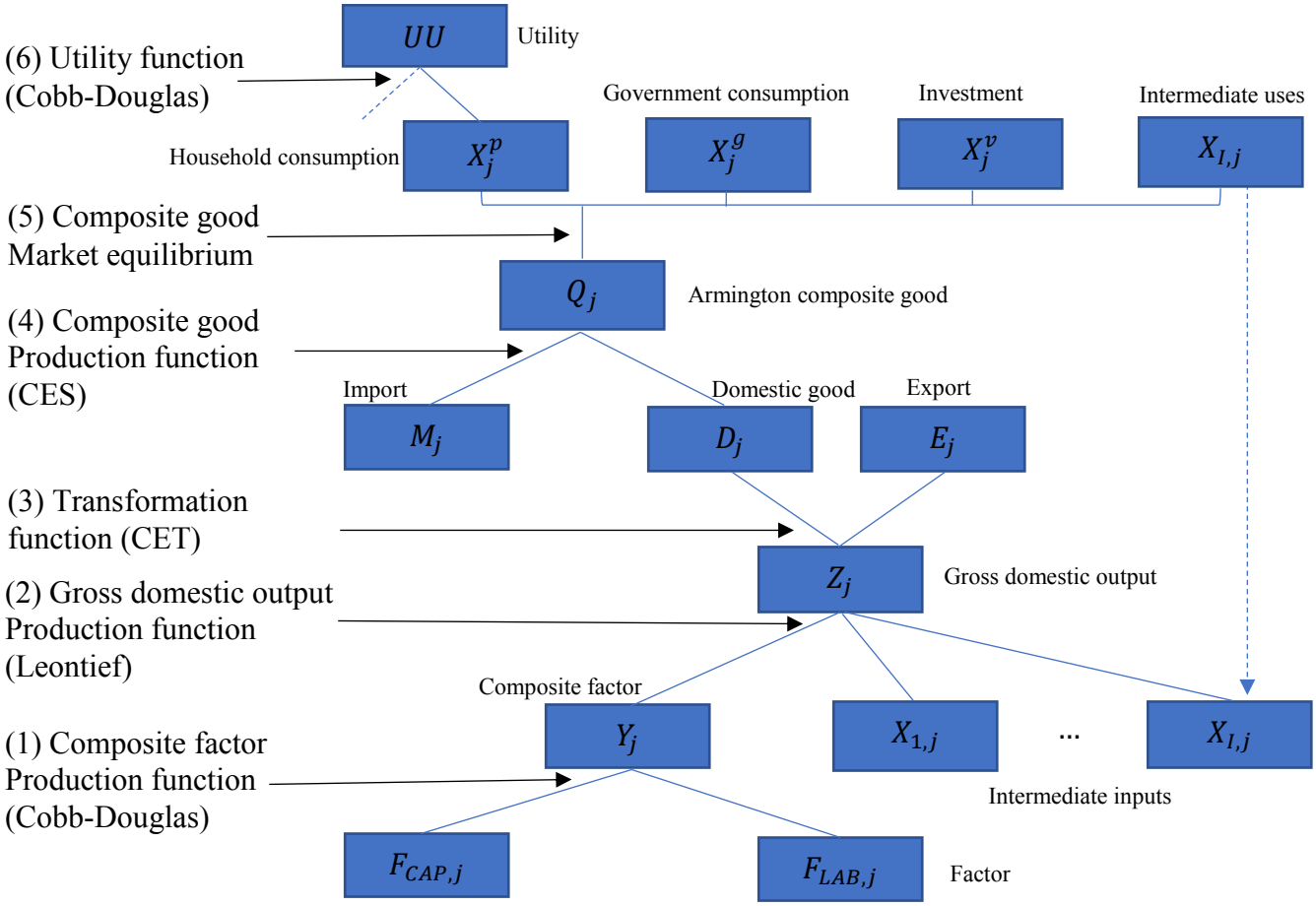


Figure 6-3 Overview of the CGE model

Source: Hosoe et al. (2010)

Note: It should be noted that the notions in this chapter are referenced to Hosoe et al. (2010) (similarly hereinafter).

6.3.2 Formula derivation

The model system in this study is based on the standard CGE model constructed by Hosoe et al. (2010) and incorporates some modifications and a quota module I design. I divide the model system into seven modules, including the domestic production module, the government module, the household module, the module of investment and savings, the international trade module, the quota module, and the module about market-clearing conditions. The international trade module is further divided into three submodules, including the submodules about substitution between imports and domestic goods (Armington composite), the transformation between exports and domestic goods, and export and import prices and the balance of payments constraint. The following subsections show the detailed process of formula derivation in each module.

6.3.2.1 Domestic production

Production is a firm behavior in which, in the stage, factors are generated as the composite factor for production, and in the second stage, the composite factor is combined with intermediate inputs to produce goods. The first stage implies that a virtual firm maximizes its profit by choosing the output level of composite factors and inputs between factors (labor and

capital in this study) depending on their relative prices, subject to its production. The second stage implies that a firm combines the composite factor and intermediate inputs to get a maximized profit, subject to input levels of intermediate inputs. The two profit-maximization problems can be written as follows:

- For the first stage:

$$\underset{Y_j, F_{h,j}}{\text{maximize}}\, \pi_j^y = p_j^y Y_j - \sum_h p_h^f F_{h,j} \quad \forall j \tag{6-14}$$

$$\text{s.t. } Y_j = b_j \prod_h F_{h,j}^{\beta_{h,j}} \quad \forall j \tag{6-15}$$

- For the second stage:

$$\underset{Z_j, Y_j, X_{i,j}}{\text{maximize}}\, \pi_j^z = p_j^z Z_j - (p_j^y Y_j + \sum_i p_i^q X_{i,j}) \quad \forall j \tag{6-16}$$

$$\text{s.t. } Z_j = \text{Min}\left(\frac{X_{1,j}}{ax_{1,j}}, \cdots, \frac{X_{i,j}}{ax_{i,j}}, \cdots, \frac{X_{I,j}}{ax_{I,j}}, \frac{Y_j}{ay_j}\right) \quad i \in I, \forall j \tag{6-17}$$

Notations are:

π_j^y	profit of the period-over-period prices j-th firm producing composite factor Y_j in the first stage,
π_j^z	profit of the j-th firm producing gross domestic output Z_j in the first stage,
Y_j	composite factor produced in the first stage and used in the second stage by the j-th firm,
$F_{h,j}$	the h-th factor used by the j-th firm in the first stage,
$X_{i,j}$	intermediate input of the i-th good used by the j-th firm,
Z_j	gross domestic output of the j-th firm,
p_j^y	price of the j-th composite factor,
p_h^f	price of the h-th factor,
p_j^z	price of the j-th gross domestic output,
p_i^q	price of the i-th composite good,
$\beta_{h,j}$	share coefficient for the h-th factor used by the j-th firm in the composite factor production function,
b_j	scaling coefficient in the j-th composite factor production function,
$ax_{i,j}$	input requirement coefficient of the i-th intermediate input for a unit output of the j-th good,
ay_j	input requirement coefficient of the j-th composite good for a unit output of the j-th good,
I	the set of i.

In the above two stages, I assume Cobb-Doulas production functions for composite factor production and Leontief production functions for gross domestic output production, by which returns are constant to scale of production. Cobb-Doulas production functions can describe the substitution between factors, capital, and labor in this study, while Leontief production functions cannot. Leontief production functions in the second stage significantly reduce the complexity of the model and computational load because distinguishing the goods/sectors would significantly increase the number of endogenous variables.

In the first stage, Equation (6-14) describes a virtual firm by producing composite factor maximizes its profit that equals its gross income from sales of composite factor minus its cost caused by factor inputs. This maximization problem is constricted by its production of composite factor, formulated in Cobb-Douglas function (Equation (6-15)). In the second stage, Equation (6-16) describes a firm combines the composite factor and intermediate inputs to get a maximized profit that equals its gross income from sales of composite goods minus its cost caused by composite factor and intermediate goods inputs. This maximization problem is constricted by its production of composite goods, formulated in Leontief function (Equation (6-17)).

By solving the above two maximization problems, the following equations can be obtained:

$$Y_j = b_j \prod_h F_{h,j}^{\beta_{h,j}} \quad \forall j \tag{6-18}$$

$$F_{h,j} = \frac{\beta_{h,j} p_j^y}{p_h^f} Y_j \quad \forall h,j \tag{6-19}$$

$$X_{i,j} = ax_{i,j} Z_j \quad \forall i,j \tag{6-20}$$

$$Y_j = ay_j Z_j \quad \forall j \tag{6-21}$$

$$Z_j = \text{Min}\left(\frac{X_{1,j}}{ax_{1,j}}, \cdots, \frac{X_{i,j}}{ax_{i,j}}, \cdots, \frac{X_{I,j}}{ax_{I,j}}, \frac{Y_j}{ay_j}\right) \quad i \in I, \forall j \tag{6-22}$$

However, the Equation (6-22) generates isoquants and thereby cause difficulty in computations. Therefore, the equation is replaced by Equation (6-23) that transferred from $\pi_j^z = 0$ (zero-profit condition) and Equation (6-16).

$$p_j^z = ay_j p_j^y + \sum_i ax_{i,j}\, p_i^q \quad \forall j \tag{6-23}$$

6.3.2.2 Government

In the CGE model, the government behaviors are the collection of indirect and direct taxes, consumption of goods, and saving to invest. By this specification, the CGE model can be applied to analyze some government policies like tax rate changes. In this specification, a government collects an income tax (direct tax, T^d) on household at the tax rate τ^d, a production tax (indirect tax, T^d) on firms at the *ad valorem* tax rate τ_j^z, and an import tariff (indirect tax, T_i^m) on imports at the *ad valorem* tax rates $\tau_i^{m\_in}$ and $\tau_i^{m\_out}$. At the same time, it expends the part of its revenues excluding its savings for investment (S^g) to consumption on goods with fixed consumption propensities ($\frac{\mu_i}{p_i^q}$) on each good. In detail, in Equation (6-24) to describe income tax payments of the government, the household incomes include endowment incomes including payments on labors and capital returns, and a rent income where I assume the household captures all quota rents. In Equation (6-26) to describe the tariff income of the government, I divide imports into the within quota import (M_i^{in}) at the in-quota tariff rate ($\tau_i^{m\_in}$) and the out-of-quota import (M_i^{out}) at the out-of-quota tariff rate ($\tau_i^{m\_out}$). In Equation (6-26) to describe the consumption of the government, the part of its revenues excluding its savings and expending on goods equals the income tax plus the production tax and tariff, minus the government savings for investment. The specification can be formulated as follows:

$$T^d = \tau^d \left(\sum_h p_h^f FF_h + \sum_j RT_j \right) \tag{6-24}$$

$$T_j^z = \tau_j^z p_j^z Z_j \quad \forall j \tag{6-25}$$

$$T_i^m = \tau_i^{m\_in} p_i^m M_i^{in} + \tau_i^{m\_out} p_i^m M_i^{out} \quad \forall i \tag{6-26}$$

$$X_i^g = \frac{\mu_i}{p_i^q} \left(T^d + \sum_j T_j^z + \sum_j T_j^m - S^g \right) \quad \forall i \tag{6-27}$$

Notations are:

T^d	direct tax,
T_j^z	production tax on the j-th good,
T_i^m	import tariff on the i-th good,
τ^d	direct tax rate,
τ_j^z	production tax rate on the j-th good,
$\tau_i^{m\_in}$	import tariff rate in quota on the i-th good,
$\tau_i^{m\_out}$	import tariff rate out of quota on the i-th good,
FF_h	endowments of the h-th factor for the household,
RT_j	quota rent rate in the j-th sector,
Z_j	gross domestic output of the j-th firm,
M_i^{in}	imports within quota of the i-th good,
M_i^{out}	imports out of quota of the i-th good,
p_h^f	price of the h-th factor,
p_j^z	price of the j-th gross domestic output,
p_i^q	price of the i-th composite good,
p_i^m	price of the i-th imported good,
X_i^g	government consumption of the i-th good,
μ_i	share of the i-th good in government expenditure ($0 \leq \mu_i \leq 1, \sum_i \mu_i = 1$),
S^g	government savings.

It should be noted that if the government sells its assets, the government consumption of goods can be negative values in SAMs or IO tables. Thus, consumption propensities can be negative as well when I use these negative values in SAMs to calibrate them; however, negative consumption propensity cannot meet the "positive" assumption on the propensity. We can apply other assumptions to the government behavior. For example, I assume the government always keep an initial equilibrium of its consumption, which can be formulated as follows:

$$X_i^g = X_i^{g0} \tag{6-28}$$

where:

X_i^{g0} stands government consumption of the i-th good in benchmark year.

By this way, a CGE model can also be simplified. The CGE model in this study incorporate with this simple assumption.

6.3.2.3 Household

The household gets maximum utility from the behavior of consumption on goods, subject to its budget. Net income of the household equals its revenues including payments for endowments ($\sum_h p_h^f FF_h$) and the quota rent revenue ($\sum_j RT_j$) minus its expenditure including the household saving (S^p) for investment and the direct tax (T^d) to the government. I assume all its net income expends on goods for maximizing its utility, which implies its expenditure on goods ($\sum_i p_i^q X_i^p$) equals its net income.

$$\underset{X_i^p}{\text{maximize}}\, UU = \prod_i (X_i^p)^{\alpha_i} \quad \forall i \tag{6-29}$$

$$\text{s.t.} \sum_i p_i^q X_i^p = \sum_h p_h^f FF_h + \sum_j RT_j - S^p - T^d \tag{6-30}$$

Notions are:

UU	utility,
X_i^p	household consumption of the i-th good,
α_i	share parameter in the utility function ($0 \le \alpha_i \le 1, \sum_i \alpha_i = 1$),
p_i^q	price of the i-th composite good,
FF_h	endowments of the h-th factor for the household,
p_h^f	price of the h-th factor,
RT_j	quota rent rate in the j-th sector,
S^p	household savings,
T^d	direct tax.

Solving the above maximization problem, we can get the function of household demand as follows:

$$X_i^p = \frac{\alpha_i}{p_i^q}\left(\sum_h p_h^f FF_h + \sum_j RT_j - S^p - T^d\right) \quad \forall i \tag{6-31}$$

6.3.2.4 Investment and savings

Since investment often has a significantly large share in final demand, we cannot ignore the investment, especially, for China that has a huge investment amount. The investment agent is supposed to collect funds from the household (S^p), the government (S^g), and the external sector (εS^f) and expend them to invest goods. I assume that the investment spends all funds to invest and it invests in fixed proportions ($\frac{\lambda_i}{p_i^q}$) in total investment. The investment can be written as follows:

$$X_i^v = \frac{\lambda_i}{p_i^q}(S^p + S^g + \varepsilon S^f) \quad \forall i \tag{6-32}$$

Notions are:

X_i^v	demand for the i-th investment good,
p_i^q	price of the i-th composite good,
S^p	household savings,
S^g	government savings,
S^f	equivalently foreign savings,
ε	foreign exchange rate (domestic currency/foreign currency),
λ_i	expenditure share of the i-th good in total investment ($0 \le \lambda_i \le 1, \sum_i \lambda_i = 1$).

The total funds can be considered as total savings of the household (S^p), the government (S^g), and the external sector (εS^f). The sum of expenditure share (λ_i) as 1 implies that total savings in an economy always equals its total investment.

Savings in the CGE model originate from the household (S^p), the government (S^g), and external sector (εS^f). The saving equations can be written as follows:

$$S^p = ss^p \left(\sum_h p_h^f \, FF_h + \sum_j RT_j \right) \tag{6-33}$$

$$S^g = T^d + \sum_j T_j^z + \sum_j T_j^m - \sum_i (p_i^q \, X_i^{g0}) \tag{6-34}$$

Notions are:

ss^p	average propensity for savings by the household,
FF_h	endowments of the h-th factor for the household,
p_h^f	price of the h-th factor,
RT_j	quota rent rate in the j-th sector,
T^d	direct tax,
T_j^z	production tax on the j-th good,
T_i^m	import tariff on the i-th good,
X_i^{g0}	government consumption of the i-th good in benchmark year.

Equation (6-33) represents the household saving that equals total household income multiplied by its average saving propensity (ss^p). Equation (6-34) represents the government saving that equals total government tax revenues minus its expenditure on goods. It should be noted that the government can also have an average saving propensity; however, I may calibrate a negative propensity because the government deficit and thereby government deficit appears in all equilibriums. In the CGE model, I do not assume a saving propensity of government because government deficit rarely appears in China's central government. However, the saving propensity of the government can be an alternative consumption.

6.3.2.5 International trade

Substitution between domestic and imported goods. Regarding the imperfect substitution under which domestically produced goods for home markets imperfectly substitute for imported goods and domestically produced goods for foreign markets, I have constructed a model in Section 4.3 to estimate the elasticity of substitution (σ_i). To incorporate the "Armington assumption" into the CGE model, I obtain the equations as follows based on the maximization problem in the first stage in Section 4.3.

$$Q_i = \gamma_i \left(\delta m_i M_i^{\eta_i} + \delta d_i D_i^{\eta_i} \right)^{\frac{1}{\eta_i}} \quad \forall i \tag{6-35}$$

$$M_i = \left[\frac{\gamma_i^{\eta_i} \delta m_i p_i^q}{\left(1 + \tau_i^{m\_in} + \tau_i^{m\_p}\right) p_i^m} \right]^{\frac{1}{1-\eta_i}} Q_i \quad \forall i \tag{6-36}$$

$$D_i = \left[\frac{\gamma_i^{\eta_i} \delta d_i p_i^q}{p_i^d} \right]^{\frac{1}{1-\eta_i}} Q_i \quad \forall i \tag{6-37}$$

Notions are:

Q_i	the i-th Armington composite good,
γ_i	scaling coefficient in the i-th Armington composite good production function,
$\delta m_i, \delta d_i$	input share coefficients in the i-th Armington composite good production function stage ($0 \leq \delta m_i \leq 1$, $0 \leq \delta d_i \leq 1$, $\delta m_i + \delta m_i = 1$),
D_i	the i-th domestic good,
M_i	imports of the i-th good from the external agent,
η_i	parameter defined by the elasticity of substitution ($\eta_i = 1 - 1/\sigma_i$, $\eta_i \leq 1$),
p_i^q	price of the i-th composite good,
p_i^m	price of the i-th imported good in terms of domestic currency,
p_i^d	price of the i-th domestic good,
σ_i	elasticity of substitution in the i-th Armington composite good production function[24].

Equation (6-35) is the production function of composite goods. Equation (6-36) is the demand function of imported goods. Equation (6-37) is the demand function of domestic goods. It should be noted that firms to produce Armington composite goods face the import price including a within quota tariff ($\tau_i^{m\_in}$), and a price premium ($\tau_i^{m\_p}$) caused by quota because I assume the household captures all quota rents, which is described by Equation (6-36). Additionally, when the elasticity is positively infinite, the assumption is changed to perfect substitution, and the number 0 implies non-substitution.

Transformation between domestic and exported goods. I have assumed imperfect substitution between goods in the same category by their origins. Also, I assume that domestically produced goods for domestic markets are to be similar to but slightly different from them for international markets. Because firms often slightly modify their products to meet the preferences of consumers in markets of different countries. This implies firms produce goods, and transfer some of the outputs to exports for international markets and keep some of the outputs supplying to domestic markets. The elasticity of transformation (ψ_i) is a parameter that explains the substitution between domestically produced goods for home markets and those for foreign markets and affects the outputs of two types of goods in a production process. Firms choose how many quantity goods are transferred into exports to maximize their profits, subject to their production. The maximization problem can be written as follows:

$$\underset{Z_i, D_i, E_i}{\text{maximize}}\, \pi_i = \left(p_i^e E_i + p_i^d D_i\right) - (1 + \tau_i^z) p_i^z Z_i \tag{6-38}$$

$$\text{s.t. } Z_i = \theta_i (\xi e_i E_i^{\phi_i} + \xi d_i D_i^{\phi_i})^{\frac{1}{\phi_i}} \tag{6-39}$$

Notions are:

π_i	profit of the firm engaged in the i-th transformation,
p_i^e	price of the i-th export good in term of domestic currency,
p_i^z	price of the i-th gross domestic output,
E_i	exports of the i-th good to the external agent,
Z_i	supply of the i-th domestic good,
τ_i^z	production tax on the i-th gross domestic good,
θ_i	scaling coefficient in the i-th good transformation function,
$\xi e_i, \xi d_i$	share coefficients in the i-th good transformation function ($0 \leq \xi e_i \leq 1$, $0 \leq \xi d_i \leq 1$, $\xi e_i + \xi d_i = 1$),
ϕ_i	parameter defined by the elasticity of transformation ($\phi_i = 1 - 1/\psi_i$, $\phi_i \leq 1$),
ψ_i	elasticity of transformation in the i-th good transformation function.

[24] The elasticity of substitution, σ_i, covers σ_1 rather than σ_2 in Section 4.3.

In Equation (6-38), the right side describes its profit by the sum of revenues from the exported good ($p_i^e E_i$) and the domestic good ($p_i^d D_i$), minus the sum of expenditures on the input of the domestically produced good ($p_i^z Z_i$) and the production tax ($\tau_i^z p_i^z Z_i$). Equation (6-39) represents the production function of domestically produced goods in CES style which is because it can meet the assumption of imperfect substitution. Additionally, when the elasticity is positively infinite, the assumption is changed to perfect substitution, and the number 0 implies non-substitution.

Then, to solve the profit-maximization problem, I obtain the equations as below:

$$E_i = \left[\frac{\theta_i^{\phi_i}\xi e_i(1+\tau_i^z)p_i^z}{p_i^e}\right]^{\frac{1}{1-\phi_i}} Z_i \quad \forall i \tag{6-40}$$

$$D_i = \left[\frac{\theta_i^{\phi_i}\xi d_i(1+\tau_i^z)p_i^z}{p_i^d}\right]^{\frac{1}{1-\phi_i}} Z_i \quad \forall i \tag{6-41}$$

Equation (6-40) is supply function of export goods and Equation (6-41) is supply function of domestic goods.

Balance of payments of a large country. As China has a large economy and significant shares in most markets, it has significant power to affect international markets. Therefore, I assume China is a large country that its exports and/or imports have significant power to affect international markets[25]. To incorporate the large country consumption, I add the following equations to the CGE model.

$$\frac{E_i}{E_i^0} = \left(\frac{p_i^{We}}{p_i^{W_e^0}}\right)^{-\sigma_i} \quad \forall i \tag{6-42}$$

$$\frac{M_i}{M_i^0} = \left(\frac{p_i^{W_m}}{p_i^{W_m^0}}\right)^{\psi_i} \quad \forall i \tag{6-43}$$

Notions are:

E_i^0	exports of the i-th good to the external agent in benchmark year,
M_i^0	imports of the i-th good from the external agent in benchmark year,
p_i^{We}	price of the i-th exported good in terms of foreign currency,
$p_i^{W_e^0}$	price of the i-th exported good in terms of foreign currency in benchmark year,
p_i^{Wm}	price of the i-th imported good in terms of foreign currency,
$p_i^{W_m^0}$	price of the i-th imported good in terms of foreign currency in benchmark year.

Regarding the above two equations, I assume constant price elasticities to describe a country's (China in this study) effect power, and both home and external countries have the same elasticities of substitution and transformation of one good. Equation (6-42) implies that the more quantity of a good exports to the external agent, the world price decreases more. Equation (6-43) implies that the more quantity of a good imports from the external agent, the world price increases more. Additionally, when the price elasticities are positively infinite, the economy will meet a small country assumption under which the economy has no significant power to affect international markets.

Then, three equations are applied to describe balanced payments.

[25] This assumption is empirically supported on corn by the results in Chapter 5.

$$p_i^e = \varepsilon p_i^{We} \quad \forall i \tag{6-44}$$

$$p_i^m = \varepsilon p_i^{Wm} \quad \forall i \tag{6-45}$$

$$\sum_i p_i^{We} E_i + S^f = \sum_i p_i^{Wm} M_i \tag{6-46}$$

Notions are:

p_i^e price of the i-th exported good,

ε foreign exchange rate (domestic currency/foreign currency),

S^f current account deficits in foreign currency terms (or equivalently foreign savings).

Equation (6-44) and Equation (6-45) link domestic export prices and international export prices, and domestic import prices and international import prices. Thus, the analyzed economy balances its payments in international markets by the way described by Equation (6-46).

6.3.2.6 Quota module

Our CGE model includes a quota module to analyze the quota policies in China. I assume that all rents are captured by the household. The model also incorporates the assumptions of Van der Mensbrugghe et al. (2003) about the tariff-rate quota. These assumptions are as follows: 1) if the import level is less than the quota level, the domestic price of imported goods, i, equals the border price (CIF), p_i^m, times 1 plus the in-quota tariff rate, $\tau_i^{m\_in}$; 2) if the import level is equal to the quota level, the domestic price of imported goods is the border price times 1 plus the in-quota tariff rate plus a premium, $\tau_i^{m\_p}$; and 3) if imports exceed the quota level, the domestic price of imported goods will be equal to the border price times 1 plus the out-of-quota tariff rate, $\tau_i^{m\_out}$, which will be applied to all out-of-quota imports. Equation (6-47) to Equation (6-51) incorporate some of these assumptions.

$$\tau_i^{m\_in} + \tau_i^{m\_p} \leq \tau_i^{m\_out} \quad \forall i \tag{6-47}$$

$$M_i^{quota} - M_i^{in} \geq 0 \quad \forall i \tag{6-48}$$

$$(M_i^{quota} - M_i^{in})\, \tau_i^{m\_p} = 0 \quad \forall i \tag{6-49}$$

$$RT_i = \tau_i^{m\_p} p_i^m M_i^{in} \quad \forall i \tag{6-50}$$

$$M_i = M_i^{in} + M_i^{out} \quad \forall i \tag{6-51}$$

Notions are:

$\tau_i^{m\_in}$ import tariff rate in quota on the i-th good,

$\tau_i^{m\_out}$ import tariff rate out of quota on the i-th good,

$\tau_i^{m\_p}$ price premium,

M_i^{quota} quota ceiling on the i-th good imports,

M_i^{in} imports within quota of the i-th good,

M_i^{out} imports out of quota of the i-th good,

RT_j quota rent rate in the j-th sector,

p_i^m price of the i-th imported good,

M_i imports of the i-th good from the external agent.

Formula (6-47) describes a constraint on tariff rates and the premium under which the domestic price of imports cannot exceed the price of out-of-quota imports. Formula (6-48) determines

that the level of in-quota imports, M_i^{in}, cannot be greater than the quota level, M_i^{quota}. The orthogonality constraint, Equation (6-49), holds the condition that if the premium equals zero, in which case, the level of quota imports is less than the quota level, or if the level of in-quota imports is equal to the quota level, the premium is positive. Equation (6-50) shows that the quota rent level equals the premium times border price multiplied by the total import quantity of goods j, M_j. Equation (6-51) expresses that the sum of imports within quota of the i-th good and imports out of quota of the i-th good is imports of the i-th good.

6.3.2.7 Market-clearing conditions

Market-clearing in this study implies the demand of an Armginton composite good or a factor meets its supply. Market-clearing conditions for the CGE model are conditions of Armington composite good markets and factor markets. The conditions are expressed as follows:

$$Q_i = X_i^p + X_i^{g0} + X_i^v + \sum_j X_{i,j} \quad \forall i \tag{6-52}$$

$$\sum_j F_{h,j} = FF_h \quad \forall h \tag{6-53}$$

Notions are:

Q_i	the i-th Armington composite good,
X_i^p	household consumption of the i-th good,
X_i^{g0}	government consumption of the i-th good in benchmark year,
X_i^v	demand for the i-th investment good,
$X_{i,j}$	intermediate input of the i-th good used by the j-th firm,
$F_{h,j}$	the h-th factor used by the j-th firm in the first stage,
FF_h	endowments of the h-th factor for the household.

Equation (6-52) describes that the demand meets its supply in any market of Armington composite goods. In detail, the demand can be divided into the household consumption (X_i^p), the government consumption (X_i^{g0}), the investment demand (X_i^v), and the intermediate uses ($\sum_j X_{i,j}$). Equation (6-53) describes the market-clearing condition of factor under which the supply of the factor ($\sum_j F_{h,j}$) equals endowments of the factor for households.

6.3.3 System of the CGE model

Based on the above discussion, an algebraic summary of the CGE model is provided in this section. The CGE model can be divided into nine modules, including domestic production, government, household, investment and savings, substitution between imports and domestic goods (Armington composite), the transformation between exports and domestic goods, export and import prices, and the balance of payments constraint, quota module and market-clearing conditions, which are presented by equations as follows:

- Domestic production:

$$Y_j = b_j \prod_h F_{h,j}^{\beta_{h,j}} \quad \forall j$$

$$F_{h,j} = \frac{\beta_{h,j} p_j^y}{p_h^f} Y_j \quad \forall h,j$$

$$X_{i,j} = ax_{i,j} Z_j \quad \forall i,j$$

$$Y_j = ay_j Z_j \quad \forall j$$

$$p_j^z = ay_j p_j^y + \sum_i ax_{i,j}\, p_i^q \quad \forall j$$

- Government:

$$T^d = \tau^d \left(\sum_h p_h^f FF_h + \sum_j RT_j\right)$$

$$T_j^z = \tau_j^z p_j^z Z_j \quad \forall j$$

$$T_i^m = \tau_i^{m\_in} p_i^m M_i^{in} + \tau_i^{m\_out} p_i^m M_i^{out} \quad \forall i$$

- Household:

$$X_i^p = \frac{\alpha_i}{p_i^q}\left(\sum_h p_h^f FF_h + \sum_j RT_j - S^p - T^d\right) \quad \forall i$$

- Investment and savings:

$$X_i^v = \frac{\lambda_i}{p_i^q}(S^p + S^g + \varepsilon S^f) \quad \forall i$$

$$S^p = ss^p \left(\sum_h p_h^f FF_h + \sum_j RT_j\right)$$

$$S^g = T^d + \sum_j T_j^z + \sum_j T_j^m - \sum_i (p_i^q X_i^{g0})$$

- Substitution between imports and domestic goods (Armington composite):

$$Q_i = \gamma_i \left(\delta m_i M_i^{\eta_i} + \delta d_i D_i^{\eta_i}\right)^{\frac{1}{\eta_i}} \quad \forall i$$

$$M_i = \left[\frac{\gamma_i^{\eta_i} \delta m_i p_i^q}{\left(1 + \tau_i^{m\_in} + \tau_i^{m\_p}\right) p_i^m}\right]^{\frac{1}{1-\eta_i}} Q_i \quad \forall i$$

$$D_i = \left[\frac{\gamma_i^{\eta_i} \delta d_i p_i^q}{p_i^d}\right]^{\frac{1}{1-\eta_i}} Q_i \quad \forall i$$

- Transformation between exports and domestic goods:

$$Z_i = \theta_i\left(\xi e_i E_i^{\phi_i} + \xi d_i D_i^{\phi_i}\right)^{\frac{1}{\phi_i}} \quad \forall i$$

$$E_i = \left[\frac{\theta_i^{\phi_i}\xi e_i(1+\tau_i^z)p_i^z}{p_i^e}\right]^{\frac{1}{1-\phi_i}} Z_i \quad \forall i$$

$$D_i = \left[\frac{\theta_i^{\phi_i}\xi d_i(1+\tau_i^z)p_i^z}{p_i^d}\right]^{\frac{1}{1-\phi_i}} Z_i \quad \forall i$$

- Export and import prices and the balance of payments constraint:

$$\frac{E_i}{E_i^0} = \left(\frac{p_i^{We}}{p_i^{We^0}}\right)^{-\sigma_i} \quad \forall i$$

$$\frac{M_i}{M_i^0} = \left(\frac{p_i^{Wm}}{p_i^{Wm^0}}\right)^{\psi_i} \quad \forall i$$

$$p_i^e = \varepsilon p_i^{We} \quad \forall i$$

$$p_i^m = \varepsilon p_i^{Wm} \quad \forall i$$

$$\sum_i p_i^{We} E_i + S^f = \sum_i p_i^{Wm} M_i$$

- Quota module:

$$\tau_i^{m\_in} + \tau_i^{m\_p} \leq \tau_i^{m\_out} \quad \forall i$$

$$M_i^{quota} - M_i^{in} \geq 0 \quad \forall i$$

$$(M_i^{quota} - M_i^{in})\,\tau_i^{m\_p} = 0 \quad \forall i$$

$$RT_i = \tau_i^{m\_p} p_i^m M_i^{in} \quad \forall i$$

$$M_i = M_i^{in} + M_i^{out} \quad \forall i$$

- Market-clearing conditions:

$$Q_i = X_i^p + X_i^{g0} + X_i^v + \sum_j X_{i,j} \quad \forall i$$

$$\sum_j F_{h,j} = FF_h \quad \forall h$$

In this CGE system, the endogenous variables are: Y_j, $F_{h,j}$, $X_{i,j}$, Z_j, p_j^y, p_h^f, p_j^z, p_i^q, p_i^m, p_i^d, p_i^e, T^d, T_j^z, T_i^m, M_i^{in}, M_i^{out}, X_i^v, X_i^p, S^p, S^g, ε, E_i, Q_i, M_i, D_i, $\tau_i^{m\_p}$, p_i^{We}, p_i^{Wm} and RT_j. The

exogenous variables are: $\tau_i^{m\_in}$, $\tau_i^{m\_out}$, τ_i^d, τ_i^z, M_i^{quota}, S^f, FF_h, $p_i^{We^0}$, $p_i^{Wm^0}$, X_i^{g0}, E_i^0. The parameters are: α_i, $\beta_{h,j}$, b_j, $ax_{i,j}$, ay_j, λ_i, δm_i, δd_i, γ_i, ξe_i, ξd_i, θ_i, ss^p, ϕ_i, ψ_i, η_i and σ_i.

According to Walras's law represented in Subsection 6.1.1, to obtain the equilibrium in $m + n$ markets, just $m + n - 1$ market-clearing conditions are required. Therefore, in the CGE model, one equation is redundant. To solve this problem, I apply the method by relative prices, which are also used by Walras. I choose a numeraire as a relative price index, by which the price of the numeraire is fixed at a certain level, and all the other prices are expressed relative to the numeraire. For example, I set a numeraire as the price of capital is 1; thus, all the other prices are expressed relative to the capital price.

6.4 Parameters in the CGE model: calibration and econometric estimation

The CGE model contains several parameters including α_i, $\beta_{h,j}$, b_j, $ax_{i,j}$, ay_j, λ_i, δm_i, δd_i, γ_i, ξe_i, ξd_i, θ_i, ss^p, ϕ_i, ψ_i, η_i and σ_i, which are unknown. Calibration and econometric estimation are the largely applied methods to "solve" these unknown parameters. Calibration is to estimate the parameters by generating a benchmark year equilibrium observation that, in common, originates from the SAM of the study, and the econometric estimation method works with econometric models whose observations cannot be sufficiently supported by a SAM. The following subsections are outlining the processes of calibration and econometric estimation for "solving" unknown parameters.

6.4.1 Calibration

Calibration, which is a method to find the values of unknown parameters that feed the equations of a model system by generating a benchmark year equilibrium observation, is commonly used so as to specify a numerical CGE model. Its definition implies that the model is solved from equilibrium data for its parameter values rather than vice versa. We can set the equilibrium depicted by a SAM (the SAM for China in this study) as the benchmark equilibrium.

However, the data in the SAM are expressed in terms of values[26] rather than separating data like price and quantity, which are needed in calibration. I need a method to separate the value data in the SAM. In the calibration in this study, I set all prices as 1 with a change of physical units in benchmark equilibrium. For example, the value of popcorn is 10 RMB, with its price as 2 RMB/packet and its quantity as 5 packets. Then, the price of popcorn is set as 1 with its unit as RMB/half-packet; thus, the quantity can be 10 half-packets[27]. In this way, the value data in the SAM can be treated as quantity numbers[28].

The parameters in our CGE model are: α_i, $\beta_{h,j}$, b_j, $ax_{i,j}$, ay_j, λ_i, δm_i, δd_i, γ_i, ξe_i, ξd_i, θ_i, ss^p, ϕ_i, ψ_i, η_i and σ_i in which α_i, $\beta_{h,j}$, b_j, $ax_{i,j}$, ay_j, λ_i, δm_i, δd_i, γ_i, ξe_i, ξd_i, θ_i and ss^p can be "solving" by calibration. The parameters can be calibrated by the following equations in which the superscript or subscript, 0, implies the initial value in benchmark year or in the SAM of variables and all initial values of price are set as 1:

$$\alpha_i = \frac{p_i^{q0} X_i^{p0}}{\sum_j p_j^{q0} X_j^{p0}} \quad \forall i \tag{6-54}$$

[26] Value = Price × Quantity

[27] which can be expressed by Value = 1 × Quantity.

[28] This is also based on tax-exclusive data in SAMs. If the data in a SAM do not separate indirect taxes from values, we may need to consider the equations as follows rather than the above equations: Tax_inclusive value = (1 + Indirect tax rate) × Tax_exclusive price × Quantity and Tax_inclusive value − Indirect tax = 1 × Quantity.

$$\sum_i p_i^q X_i^p = \sum_h p_h^f FF_h + \sum_j RT_j - S^p - T^d \tag{6-55}$$

$$\pi_j^y = X_i^p - \frac{\alpha_i}{p_i^q}\left(\sum_h p_h^f FF_h + \sum_j RT_j - S^p - T^d\right) \quad \forall i \quad \text{with } \pi_j^y = 0 \tag{6-56}$$

By Equation (6-54), we can get the values of α_i. The equation is calculated by the two equations (Equation (6-55) and Equation (6-56)) in the household module with the zero-profit condition, $\pi_j^y = 0$ that is expressed in Equation (6-56), and corresponding values in benchmark year.

$$\beta_{h,j} = \frac{p_h^{f0} F_{h,j}^0}{\sum_k p_k^{f0} F_{k,j}^0} \quad \forall h,j \tag{6-57}$$

$$F_{h,j} = \frac{\beta_{h,j} p_j^y}{p_h^f} Y_j \quad \forall h,j \tag{6-58}$$

$$p_j^y Y_j = \sum_h p_h^f F_{h,j} \tag{6-59}$$

By Equation (6-57), we can get the values of $\beta_{h,j}$. The equation is calculated by Equation (6-58) and Equation (6-59) in the domestic production module with the zero-profit condition.

$$b_j = \frac{Y_j^0}{\prod_h F_{h,j}^{0\beta_{h,j}}} \tag{6-60}$$

By Equation (6-60) with the values of $\beta_{h,j}$ calculated by Equation (6-57), we can get the values of b_j. Equation (6-60) originates from Equation (6-15) in the domestic production module.

$$ax_{i,j} = \frac{X_{i,j}^0}{Z_j^0} \quad \forall i,j \tag{6-61}$$

By Equation (6-61), we can obtain the values of $ax_{i,j}$. The equation is calculated by Equation (6-20) in the domestic production module.

$$ay_j = \frac{Y_j^0}{Z_j^0} \quad \forall j \tag{6-62}$$

By Equation (6-62), we can obtain the values of ay_j. The equation is calculated by Equation (6-21) in the domestic production module.

$$\lambda_i = \frac{p_i^{q0} X_i^{v0}}{S^{p0} + S^{g0} + \varepsilon S^f} \quad \forall i \tag{6-63}$$

By Equation (6-63), we can obtain the values of λ_i. The equation is calculated by Equation (6-32) in the module of investment and savings.

$$\delta m_i = \frac{\left(1 + \tau_i^{m\_in} + \tau_i^{m\_p}\right) p_i^{m0} M_{i0}^{1-\eta_i}}{p_i^{q0}\left(\left(1 + \tau_i^{m\_in} + \tau_i^{m\_p}\right) p_i^{m0} M_{i0}^{1-\eta_i} + p_i^{d0} D_{i0}^{1-\eta_i}\right)} \quad \forall i \tag{6-64}$$

$$\delta d_i = \frac{p_i^{d0} D_{i0}^{1-\eta_i}}{p_i^{q0}\left(\left(1 + \tau_i^{m\_in} + \tau_i^{m\_p}\right) p_i^{m0} M_{i0}^{1-\eta_i} + p_i^{d0} D_{i0}^{1-\eta_i}\right)} \quad \forall i \tag{6-65}$$

$$\lambda_i = \frac{p_i^{q0} X_i^{v0}}{S^{p0} + S^{g0} + \varepsilon S^f} \quad \forall i \tag{6-66}$$

The Equation (6-64), Equation (6-65) and Equation (6-66) can calibrate parameters δm_i, δd_i and γ_i, respectively. The three equations can be resulted from Equation (6-35), Equation (6-36) and Equation (6-37) in the module of substitution between domestic and imported goods.

$$\xi e_i = \frac{p_i^{e0} E_{i0}^{1-\phi_i}}{p_i^{z0}(p_i^{e0} E_{i0}^{1-\phi_i} + p_i^{d0} D_{i0}^{1-\phi_i})} \quad \forall i \tag{6-67}$$

$$\xi d_i = \frac{p_i^{d0} D_{i0}^{1-\phi_i}}{p_i^{z0}(p_i^{e0} E_{i0}^{1-\phi_i} + p_i^{d0} D_{i0}^{1-\phi_i})} \quad \forall i \tag{6-68}$$

$$\theta_i = \frac{Z_i^0}{\left(\xi e_i E_{i0}^{\phi_i} + \xi d_i D_{i0}^{\phi_i}\right)^{\frac{1}{\phi_i}}} \quad \forall i \tag{6-69}$$

The Equation (6-67), Equation (6-68) and Equation (6-69) can calibrate parameters ξe_i, ξd_i and θ_i, respectively. The three equations can be resulted from Equation (6-40), Equation (6-41) and Equation (4-39) in the module of transformation between exports and domestic goods.

$$ss^p = \frac{S^{p0}}{\sum_h p_h^{f0} FF_h + \sum_j RT_j^0} \tag{6-70}$$

By Equation (6-70), we can obtain the value of ss^p. The equation is calculated by Equation (6-33) in the module of investment and savings.

Merit and demerit of calibration. Calibration involves the evaluation of model parameters based on a single observation in the benchmark year. The basis can be an advantage in cases of limited availability of data. However, the reliance on a single observation to evaluate the parameters and exogenous variables for a model causes doubt on the reliability of the results obtained using the model. A reason can support the doubt as specific shocks in benchmark year may appear and affect the evaluation of the parameters in calibration, thereby decreasing the reliability of the model results because they cannot be considered as being universally accepted.

To evaluate model parameters, econometric methods can be applied to replace calibration to avoid the weakness of single observation in evaluation. Despite this, econometric approaches are not very common as their application very relies on data requirements. In addition, Taylor (1990) pointed a warning that too much reliance on econometrically estimated parameters, especially in cases of developing countries where model closures and directions of macroeconomic causality may change very often, may cause bias in CGE models. The calibration for parameter specification still prevails in CGE modeling.

6.4.2 Econometric estimation

From the above section, we can obtain most of the parameters in the CGE model. However, the elasticity of substitution (σ_i) and elasticity of transformation (or parameters, η_i and ψ_i, defined by elasticity parameters) cannot be obtained by calibration. These parameters can be estimated mainly by regressions by time-series data or panel data; however, the lack of data may make them impossible to be estimated such as the countries to analyze may not report enough data for the estimation, and they may not report the data of the good to analyze. Therefore, referencing approximate elasticity values from existing studies is a common method in CGE analysis. For example, in this study, I apply the elasticity of substitution from Aguiar et al. (2019), employing the GTAP model in a similar good category to the good category in this study.

However, finding elasticities in a similar good category brings an error to the model results because elasticities estimated in the same good category, in theory, are more accurate. The elasticity of substitution and elasticity of transformation are key parameters that directly and

significantly reflect imports and exports, especially for CGE models of international trade. Thus, to increase the credibility of the results of the CGE model, it is necessary to select feasible elasticities. Given that this CGE model is exampled by corn, I apply the elasticity of substitution of corn especially estimated for this study. All elasticities applied in this study are listed in Table 6-5.

Table 6-5 Selected values of elasticity of substitution and elasticity of transformation

	σ_i	Source and description	ψ_i
Corn	2.45	Estimated in Section 4.3	4.9
Other agriculture	3.25	Crops n.e.c. in GTAP	6.5
Forestry	2.5	Forestry in GTAP	5
Husbandry	1.3	Animal products n.e.c in GTAP	2.6
Fishery	1.25	Fishing in GTAP	2.5
Agricultural service	1.9	Recreational and Other services in GTAP	3.8
Feed	2.5	Plant-based fibers in GTAP	5
Sugar	2.7	Sugar in GTAP	5.4
Condiment	2	Food products n.e.c in GTAP	4
Other food	2	Food products n.e.c in GTAP	4
Alcohol	1.15	Beverages and tobacco products in GTAP	2.3
Other manufacture	3.75	Manufactures n.e.c. in GTAP	7.5
Other services	1.9	Recreational and Other services in GTAP	3.8

In Table 6-5, we can observe the elasticity values in detail. As corn is the main product examined in this study, corn elasticities significantly affect the results of the CGE model. To ensure the accuracy of the results, I applied the elasticity of substitution for corn estimated in Section 4.3 because this elasticity is estimated for CGE analyses for China's corn trade. For the elasticities of substitution for other products in this study, the estimated elasticities in the GTAP database are used. Detailed descriptions of the classification of these elasticities are illustrated in Table 6-5. Regarding the selection of elasticity of transformation, I applied some large values. Given that we assume imperfect substitution between domestically produced goods for home markets and those for foreign markets, positively infinite values of elasticity of transformation that are usually applied by GTAP models and some CGE modelers are not feasible for this study. Besides, imperfect substitution is closer to the reality of world trade because producers always modify their products to meet the unique preferences of consumers, different product standards of different countries, and other such requirements. Suppose that the substitution between domestic and exported goods is larger than the substitution between domestic and imported goods because domestic and exported goods are produced in the same country and domestic and imported goods are from different origins, which may cause differentiation between domestic and imported goods are more than them between domestic and exported goods, I assume that the elasticities of transformation are two times of the elasticities of substitution. The values of elasticities are listed in Table 6-5.

6.5 Simulations and results on corn trade policies

We have constructed the SAM for China and the CGE model and estimated the parameters in the CGE model. To make an analysis with CGE approaches, I also need to design some simulations. In this study, I take the analysis of economic effects of corn trade as an example,

thus, I design three simulations about corn import[29] concerning tariff policy and quota policy of corn in China, and they are divided into nine scenarios, which are represented in Subsection 6.5.1. Then, based on these scenarios, I run the CGE model and find some simulation results. The results are analyzed under general equilibrium in Subsection 6.5.2.

6.5.1 Simulation design concerning corn imports of China

We design three types of simulations, as described below, by releasing restrictions on corn trade in China:

- **Simulation 1 (S1): tariff reduction with quota abolition.**
  S1-1 (Scenario 1-1): corn tariff rate is reduced to 20% ($\tau_{corn}^{m\_in} = \tau_{corn}^{m\_out} = 20\%$) and the corn tariff quota is abolished ($M_i^{quota} = 0$).
  S1-2: corn tariff rate is reduced to 10% ($\tau_{corn}^{m\_in} = \tau_{corn}^{m\_out} = 10\%$) and the corn tariff quota is abolished ($M_i^{quota} = 0$).
  S1-3: corn tariff rate is reduced to 2% ($\tau_{corn}^{m\_in} = \tau_{corn}^{m\_out} = 2\%$) and the corn tariff quota is abolished ($M_i^{quota} = 0$).
- **Simulation 2 (S2): quota level expansion**
  S2-1: corn tariff quota level is expanded by 1.1 times ($M_{corn}^{quota} \times 1.1$).
  S2-2: corn tariff quota level is expanded by 1.5 times ($M_{corn}^{quota} \times 1.5$).
  S2-3: corn tariff quota level is expanded by 2 times ($M_{corn}^{quota} \times 2$).
- **Simulation 3 (S3): tariff reduction**
  S3-1: corn tariff rate out-of-quota is reduced to 20% ($\tau_{corn}^{m_{out}} = 20\%$ with $\tau_{corn}^{m\_in} = 1$).
  S3-2: corn tariff rate out-of-quota is reduced to 10% ($\tau_{corn}^{m_{out}} = 10\%$ with $\tau_{corn}^{m\_in} = 1$).
  S3-3: corn tariff rate out-of-quota is reduced to 2% ($\tau_{corn}^{m_{out}} = 2\%$ with $\tau_{corn}^{m\_in} = 1$).

All simulations should be designed to meet the relaxation of restrictions on corn. Therefore, the three types of simulation (9 scenarios) - tariff reduction with quota abolition, quota level expansion, and tariff reduction - are designed. To ensure fair trade and offer opportunities for entry of foreign corn, if the quota is abolished, the tariff rate must decline. Therefore, in simulation 1, I set at least three lower values for tariff rates than the out-of-quota rate. As our calculation with the data from UN Comtrade, the in-quota tariff of corn plus the premium is about 25.2% in 2017; to obtain an effective and comparatively high value of tariff rate, I set 2% as a high tariff rate level in simulation 1. The number, 2%, is the lowest tariff rate for grain in China, reported by the Customs of Import and Export Tariff of the People's Republic of China (2020 version) and 1% is a relatively middle value for the tariff rate. Additionally, the same values are applied in simulation 3 as in simulation 1. In simulation 2, I applied a quota level of 1.1 times in 2017 because it is an effective and comparatively low value. The quota level in 2017 multiplied by two is approximately equal to China's scheduled quota level, 7.2 Mt. Therefore, 1.5 times the quota level is a relatively middle number. In each simulation, the more corn import is supposed to be relaxed from scenario 1 to scenario 2, and to scenario 3.

6.5.2 Result analysis under equilibrium

The results concerning the economic effects of the corn trade of China are divided into three parts, including the results on corn supply, demand, and price, the results on domestic supply and import of corn, the results on downstream sectors of corn, and the results on welfare. These results are analyzed in the following subsections.

[29] It should be noted that corn export was approximately 0 in the recent decade in China.

6.5.2.1 Results analysis of corn supply/demand and price in China

According to Amington assumption, the corn for final demand is Armington composite corn rather than domestic or imported corn. Therefore, I mainly analyze Armington composite corn of China. Table 6-6 presents the results on corn supply, demands, and price in China.

Table 6-6 Simulated percentage changes in corn supply/demand and price in China (%)

	S1-1	S1-2	S1-3	S2-1	S2-2	S2-3	S3-1	S3-2	S3-3
Supply or demand	0.006	0.021	0.035	0.007	0.033	0.038	0.006	0.021	0.036
Intermediate use	0.001	0.006	0.011	0.002	0.01	0.011	0.002	0.006	0.011
Household demand	0.045	0.156	0.279	0.051	0.244	0.279	0.047	0.157	0.264
Price	-0.048	-0.16	-0.269	-0.052	-0.248	-0.284	-0.048	-0.16	-0.269

Notes: the corn is Armington composite corn. In an equilibrium, supply of corn equals demand of corn: $Q_{corn} = X^{p}_{corn} + X^{g0}_{cron} + X^{v}_{cron} + \sum_j X_{corn,j}$ with $X^{g0}_{cron} = 0$ and $X^{v}_{cron} = 0$ in the benchmark and scenarios. Price of corn: p^{q}_{corn}

Corn import relaxation by tariff reductions and quota level increases can cause the corn supply and demand increases and its price decrease, and in each simulation the more corn import relaxes, the much degree of changes appears. Table 6-6 shows both tariff reductions and quota level increases can cause the corn supply increase and the corn demand decrease. In the scenarios that the tariff rate of corn decreases from 65% to 20%, 10%, and 2% with quota abolition, the corn supply or demand increases by 0.006%, 0.021%, and 0.035% in S1-1, S1-2, and S1-3, respectively. In detail, the demand of intermediate corn increases by 0.001%, 0.006%, and 0.011% and the household demand increases by 0.045%, 0.156%, and 0.279%. If the quota level is expanded 1.1, 1.5, and 2 times, the corn supply or demand increases by 0.007%, 0.033%, and 0.038%, respectively. The demand of intermediate corn increases by 0.002%, 0.01%, and 0.011% and they are 0.051%, 0.244%, and 0.279% of the household demand increases. when the tariff rate of corn decreases from 65% to 20%, 10%, and 2%, the corn supply or demand increases by 0.006%, 0.021%, and 0.036%, respectively. The demand of intermediate corn increases by 0.002%, 0.006%, and 0.011% and the household demand increases by 0.047%, 0.157%, and 0.264%. In each simulation, the more corn import relaxes, the much degree of changes appears in the corn supply and demand. In addition, corn price decreases in the scenarios. It decreases by 0.048% in S1-1, 0.16% in S1-2, 0.269% in S1-3, 0.052% in S2-1, 0.248% in S2-2, 0.284% in S2-3, 0.048% in S3-1, 0.16% in S3-2, 0.269% in S3-3. The results represented in Table 6-6 prove that corn import relaxation by tariff reduction or quota level expansion can increase the corn supply and demand and decrease its price, which are showed visually in Figure 6-4.

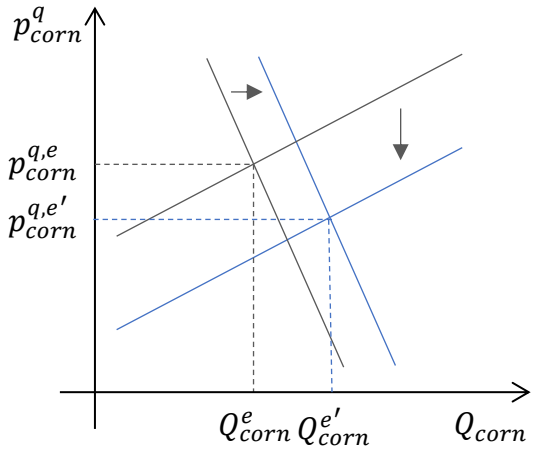


Figure 6-4 Simulated changes of Armington composite corn in the demand and supply curves
Notes: This figure describes directions rather than sizes of the changes. The superscript, e, stands for equilibrium.

From Figure 6-4, we can see the corn import relaxation by tariff reduction or quota level expansion causes the initial supply curve in benchmark equilibrium moves down and the initial demand curve in benchmark equilibrium moves to its right side, thereby leading to the increased corn supply and demand ($Q^{e'}_{corn}$) and the decreased price ($p^{q,e'}_{corn}$) in the equilibrium of the scenarios.

Under equilibrium, the reason why the supply of Armington composite corn increases is mainly because more imported corn enters Chinese markets in these scenarios for the import relaxation on corn, which is supported by the analysis in Subsection 6.5.2.2. In this subsection, the reason why the price decreases, is discussed as well. Its demand increase is mainly reflected in the increases of the intermediate use and household demand caused by the price decreases and the increases of corn expenditures[30] which are expressed by the results in Table 6-6.

6.5.2.2 Results analysis of the supply/demand of domestic corn and corn import in China

In this section, I aim to obtain some results on equilibriums of domestic corn and imported corn. In addition, I discuss the reason why the supply of Armington composite corn increases and its price decreases as well. Domestic supply and import of corn in China are analyzed. In our CGE model structure, domestic corn combines with imported corn to be Armington composite corn. To analyze the reasons why the supply of Armington composite corn increases, the domestic supply[31] and import of corn are necessary to be discussed. In this section, Table 6-7 presents the results on the supply of domestic corn and corn import of China.

[30] The CGE model can provide with the results about the household expenditure, government expenditure, investment, and firm's expenditure on corn, however, I do not discuss the household expenditure, government expenditure and investment in this study, so the results are not represented and discussed. The firm's expenditure on corn (corn inputs) are represented and discussed in Section 6.5.2.3.

[31] In the CGE structure, firms choose between domestic and imported corn as inputs to produce Armington composite corn. Under this structure, the supply of Armington composite corn directly corresponds to the demand of domestic corn of the firms. However, I consider the demand as the supply of domestic corn because they equal in equilibriums, and the corn self-sufficiency can be analyzed with the concept of domestic corn supply.

Table 6-7 Simulated changes in the supply/demand of domestic corn, corn import, and the corn self-sufficiency rate of China (%)

	S1-1	S1-2	S1-3	S2-1	S2-2	S2-3	S3-1	S3-2	S3-3
Domestic supply/demand	-0.145	-0.482	-0.811	-0.158	-0.748	-0.857	-0.14	-0.482	-0.811
Import	9.145	31.481	54.495	10	50	57.778	9.146	31.481	54.495
SSR	98.363	98.028	97.683	98.35	97.75	97.634	98.363	98.028	97.683

Notes: The self-sufficiency rate of corn in 2017 (the benchmark year) was 98.5%.

Domestic supply/demand: D_i, Import: M_i, Self-sufficiency rate: $SSR_i = \frac{D_i+E_i}{D_i+M_i}$, E_i: Export, $i = corn$

The results in Table 6-7 reveal that if the tariff cuts or quota level increases, the supply/demand of domestic corn decreases and import quantity of corn increases, and consequently, self-sufficiency rates go down. If the tariff rate of corn decreases from 65% to 20%, 10%, and 2% with quota abolition, the import quantity increases by 9.145%, 31.481%, and 54.495%, and the domestic supply of corn decreases by 0.145%, 0.482%, and 0.811%, respectively. When the quota level is expanded 1.1, 1.5, and 2 times, the import quantity increases by 10%, 50%, and 57.778%, and the domestic supply of corn decreases by 0.158%, 0.748%, and 0.857%, respectively. If the tariff rate of corn decreases from 65% to 20%, 10%, and 2%, the import quantity increases 9.146%, 31.481%, and 54.495%, and the domestic supply of corn decreases by 0.14%, 0.482%, and 0.811%, respectively. The results of S1, S2, and S3 show positive effects on import quantity and negative effects on domestic supply. As is evident from Table 6-7, the results imply the reason why the supply of Armington composite corn increases and its price decreases is mainly because more imported corn that is cheaper than domestic corn enters Chinese markets in these scenarios for the import relaxation on corn. The cheaper corn inputs decrease the cost to produce Armington composite corn; thus, it pulls the price of Armington composite corn down and contributes to the production of the composite corn.

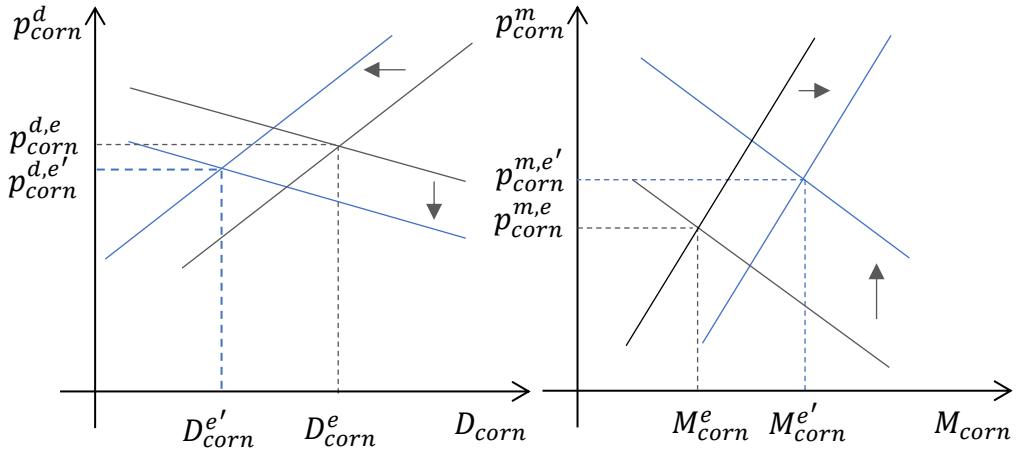
Firms tend to choose more imported corn and less domestic corn than them in benchmark choice, which is supported by the results in Table 6-7. This is because the price (CIF) of imported corn is much cheaper than domestic corn, and imported corn substitutes domestic corn if corn import is assumed to be relaxed by tariff reduction or quota level expansion. As a result, import prices are pushed up, and domestic price is pulled down, which can be supported by the results in Table 2. The price of domestic corn (domestic price) changes by -0.001%, -0.005%, -0.008%, -0.002%, -0.007%, -0.008%, -0.001%, -0.005% and -0.008% in S1-1, S1-2, S1-3, S2-1, S2-2, S2-3, S3-1, S3-2 and S3-3, respectively. The import price increases by 1.356% in S1-1, 4.302% in S1-2, 6.923% in S1-3, 1.477% in S2-1, 6.439% in S2-2, 7.27% in S2-3, 1.356% in S3-1, 4.302% in S3-2 and 6.923% in S3-3. Both the reduction in tariff and the expansion of the quota level can cause a slight drop in domestic corn price and a significant increase in import price, and the more corn import relaxes, the much degree of changes appears in domestic and import prices.

Table 6-8 Simulated percentage changes in corn prices of China (%)

	S1-1	S1-2	S1-3	S2-1	S2-2	S2-3	S3-1	S3-2	S3-3
Domestic price	-0.001	-0.005	-0.008	-0.002	-0.007	-0.008	-0.001	-0.005	-0.008
Import price	1.356	4.302	6.923	1.477	6.439	7.27	1.356	4.302	6.923

Notions: Domestic price: p_i^d, Import price: p_i^m, $i = corn$

The simulation results of percentage changes in Table 6-7 and Table 6-8 can be visually described as shown in Figure 6-5. From Figure 6-5, we can see the corn import relaxation by tariff reduction or quota level expansion causes that the initial demand curve of imported corn in benchmark equilibrium moves to its right side leading to more corn import, and the initial demand curve of imported corn in benchmark equilibrium moves to upper side resulting in more supply of corn trading in the market of corn imports because the price of corn imports increases, which are described in Figure 6-5(b). More corn imports enter China's markets and domestic corn is substituted by the corn imports in these scenarios. The initial demand curve of domestic corn in benchmark equilibrium moves to its lower side and the demand decreases, and at the meanwhile, the supply of domestic corn decreases with its initial curve in benchmark equilibrium moving its left side because domestic price decreases, which are described in Figure 6-5(a).



(a) Market of domestic corn (b) Market of corn imports

Figure 6-5 Simulated changes of domestic and imported corn in the demand and supply curves

Notes: This figure describes directions rather than sizes of the changes. The superscript, e, stands for equilibrium.

6.5.2.3 Results analysis of downstream sectors of corn in China

In this section, I aim to obtain some results on equilibriums about downstream sectors of corn. The downstream sectors of corn include the sectors of feed (FEE), sugar (SUG), condiment (CON), other food (OFO), and alcohol (ALC). In this section, domestic supply, import, and export of downstream sectors of corn (results in Table 6-9), their prices (results in Table 6-10) of corn and corn inputs (results in Table 6-11) in China are analyzed. In addition, both the decrease and increase are marginal because corn is not the only raw material for these industries, and the effect of changes in corn prices is small.

Table 6-9 Simulation results on domestic supply, import and export of downstream sectors of corn (%)

FEE	S1-1	S1-2	S1-3	S2-1	S2-2	S2-3	S3-1	S3-2	S3-3
Domestic supply	0.002	0.009	0.016	0.003	0.015	0.017	0.003	0.009	0.016
Import	-0.027	-0.091	-0.154	-0.03	-0.142	-0.163	-0.027	-0.091	-0.154

Export	0.03	0.101	0.17	0.033	0.157	0.18	0.03	0.101	0.17
SUG	S1-1	S1-2	S1-3	S2-1	S2-2	S2-3	S3-1	S3-2	S3-3
Domestic supply	0.007	0.026	0.044	0.009	0.041	0.047	0.008	0.026	0.044
Import	-0.030	-0.101	-0.17	-0.033	-0.156	-0.179	-0.03	-0.101	-0.17
Export	0.038	0.127	0.214	0.041	0.197	0.226	0.038	0.127	0.214
CON	S1-1	S1-2	S1-3	S2-1	S2-2	S2-3	S3-1	S3-2	S3-3
Domestic supply	0	0.005	0.01	0.002	0.009	0.011	0.002	0.006	0.01
Import	-0.004	-0.012	-0.021	-0.004	-0.019	-0.022	-0.004	-0.01	-0.021
Export	0.005	0.018	0.03	0.006	0.028	0.032	0.005	0.018	0.031
OFO	S1-1	S1-2	S1-3	S2-1	S2-2	S2-3	S3-1	S3-2	S3-3
Domestic supply	0	0.003	0.006	0.001	0.005	0.006	0	0.003	0.006
Import	-0.003	-0.008	-0.013	-0.002	-0.012	-0.014	-0.002	-0.008	-0.013
Export	0.003	0.011	0.019	0.004	0.017	0.02	0.003	0.011	0.019
ALC	S1-1	S1-2	S1-3	S2-1	S2-2	S2-3	S3-1	S3-2	S3-3
Domestic supply	0	0.004	0.007	0.001	0.006	0.007	0.001	0.004	0.007
Import	-0.002	-0.005	-0.008	-0.002	-0.008	-0.009	-0.001	-0.005	-0.008
Export	0.002	0.009	0.015	0.003	0.014	0.016	0.003	0.009	0.015

Notions: Domestic supply: D_i, Import: M_i, Export: E_i

Table 6-9 shows the changes in domestic supply, import and export of corn downstream industries in the scenarios. Both tariff cuts and quota level increases cause cheaper corn (than domestic corn) to enter China's corn market. As a result, the cost on corn inputs of producers in downstream sectors of corn reduces. Therefore, we can predict that the production of these products (the sum of the domestic good, D_i, and exported good, E_i) will increase, imports will drop. The results listed in Table 6-9 describe and are subjected to the prediction. In addition, the more corn import relaxes, the much degree of changes appears in domestic supply, import and export. Therefore, we can say both tariff cuts and quota level increases can contribute to domestic supply, export of corresponding goods in the industries, and domestic goods substitutes the imported goods for composite good production. The reason is that the prices of domestic goods reduce more than their import prices, which is described by the results in Table 6-10.

Table 6-10 Simulation results on good prices of downstream sectors of corn (%)

FEE	S1-1	S1-2	S1-3	S2-1	S2-2	S2-3	S3-1	S3-2	S3-3
Domestic price	-0.017	-0.057	-0.095	-0.019	-0.089	-0.102	-0.017	-0.057	-0.096
Import price	-0.005	-0.017	-0.029	-0.006	-0.026	-0.03	-0.005	-0.017	-0.029
Export price	-0.012	-0.039	-0.066	-0.013	-0.061	-0.069	-0.012	-0.039	-0.066
SUG	S1-1	S1-2	S1-3	S2-1	S2-2	S2-3	S3-1	S3-2	S3-3
Domestic price	-0.019	-0.064	-0.104	-0.021	-0.1	-0.115	-0.019	-0.064	-0.108
Import price	-0.005	-0.018	-0.029	-0.006	-0.027	-0.031	-0.005	-0.017	-0.029
Export price	-0.014	-0.046	-0.077	-0.015	-0.071	-0.081	-0.014	-0.046	-0.077
CON	S1-1	S1-2	S1-3	S2-1	S2-2	S2-3	S3-1	S3-2	S3-3

Domestic price	-0.003	-0.011	-0.018	-0.004	-0.017	-0.019	-0.003	-0.011	-0.018
Import price	0	-0.002	-0.003	0	-0.003	-0.003	0	-0.002	-0.003
Export price	-0.002	-0.008	-0.013	-0.003	-0.012	-0.014	-0.002	-0.008	-0.013
OFO	S1-1	S1-2	S1-3	S2-1	S2-2	S2-3	S3-1	S3-2	S3-3
Domestic price	-0.002	-0.006	-0.01	-0.002	-0.01	-0.011	-0.002	-0.006	-0.011
Import price	0	0	-0.001	0	-0.001	-0.001	0	0	-0.001
Export price	-0.001	-0.004	-0.007	0	-0.01	-0.008	-0.001	-0.004	-0.007
ALC	S1-1	S1-2	S1-3	S2-1	S2-2	S2-3	S3-1	S3-2	S3-3
Domestic price	-0.003	-0.009	-0.014	-0.003	-0.014	-0.016	-0.003	0.009	-0.015
Import price	0	-0.001	-0.002	0	-0.001	-0.002	0	0	-0.001
Export price	-0.002	-0.007	-0.011	-0.002	-0.01	-0.012	-0.002	-0.007	-0.011

Notions: Domestic price: p_i^d, Import price: p_i^m, Export price: p_i^e

From Table 6-10, domestic prices and export prices of the goods decrease, which is because more imported corn that is cheaper than domestic corn enters Chinese markets in these scenarios for the import relaxation on corn, and as imported corn is the input to produce the goods, firms cost less by inputting more imported corn. Table 6-11 presents the results that support the increase in corn inputs of downstream sectors of corn. Import prices of the goods decrease because the cheaper exports pull the import price (world price) down.

Table 6-11 Simulation results on corn inputs of downstream sectors of corn (%)

	S1-1	S1-2	S1-3	S2-1	S2-2	S2-3	S3-1	S3-2	S3-3
FEE	0.003	0.01	0.017	0.003	0.016	0.018	0.003	0.01	0.017
SUG	0.008	0.027	0.046	0.009	0.043	0.049	0.008	0.027	0.046
CON	0	0.006	0.011	0.002	0.01	0.011	0.002	0.006	0.011
OFO	0	0.003	0.006	0.001	0.006	0.007	0.001	0.004	0.006
ALC	0	0.004	0.007	0.001	0.006	0.007	0.001	0.004	0.007

Corn input: $X_{i,corn}$

6.5.2.4 Result analysis of welfare

Table 6-12 shows the welfare change resulting from nine scenarios. The results demonstrate, first, that when the quota is abolished, and the tariff rate is reduced from 65% to 20%, 10%, and 2%, welfare changes −5.109, −2.402, and 0.217, respectively. The welfare change ranges from negative to positive as tariff decreases and the differences in these percentage changes are large, which supports that China is more sensitive to this change in policy. Second, when the quota expands 1.1, 1.5, and 2 times, welfare increases 0.415, 0.727, and 0.578, respectively, which reveals that reasonable expansion in quota to import more corn increases welfare. Third, when the tariff reduces to 20%, 10%, and 2%, the welfare changes −0.075, 0.052, and 0.496, respectively. Extreme tariff cuts in S1-3, S3-2, and S2-3 also usher positive welfare changes; however, the contributions to welfare are smaller on average than those by expanding the quota level. By comparing the values of welfare change, we can conclude that expanding the quota level is a better method for increasing corn imports.

Table 6-12 Simulated welfare changes in each scenario

	S1-1	S1-2	S1-3	S2-1	S2-2	S2-3	S3-1	S3-2	S3-3
Welfare change	-5.109	-2.402	0.217	0.415	0.727	0.578	-0.075	0.052	0.496

Welfare index: Hicksian equivalent variation

As for our simulations, all of them are designed to increase the corn imports to meet the increasing demand for corn in China. I expect corn tariff reduction would increase the welfare because it causes that cheaper corn imports enter China, thereby reducing the prices of corn and other domestic goods for the input cost of corn decreases. It is also expected that quota abolition would decrease the welfare because it causes less cheap corn imports to enter China, and quota expansion would increase the welfare because it causes that cheaper corn imports enter China. The results concerning quota expansion are subject to our expectations. By comparing the results in Simulation 1 and Simulation 2, we can conclude that the effects of quota abolish are also subject to our expectations. However, cheaper corn imports enter China, which also implies a substitution of imported corn to domestic corn, thereby reducing corn production and increasing the import price of corn. This may cause negative effects on welfare, which is supported by the results in S3-1. All in all, whether the welfare increases or not depends on the values of benefits and losses caused by increased cheaper corn imports.

6.6 Sensitivity analysis

For the CGE model, I find most of the parameters by calibration and econometric estimation. However, the calibration method only allows us to estimate parameters by a single observation. In addition, some parameters are not estimated by calibration or econometric estimation. For example, both Cobb-Douglas type and Leontief type functions imply constant values of elasticity of substitution, which are determined not by estimation. The parameters of elasticity of transformation are determined by the calculation based on the equation: $\psi_i = 2\sigma_i$. The robustness of simulation results of a CGE model is often criticized because the model corporates with some parameters whose robustness cannot be objectively tested.

To address the critique, a sensitivity analysis is often constructed to check the robustness of the results from a CGE model. A sensitivity analysis for a CGE model determines how different values of parameters affect the model results by varying their values of parameters that may significantly affect the results. However, given that a CGE model may include many parameters, examining the robustness of the model results with respect to all the assumed parameter values may be unrealistic. Usually, the focuses are the key parameters that are expected to affect the results significantly. In the case of this study, the key parameters are the elasticity of substitution and elasticity of transformation that significantly affect the imports and production that I want to analyze by this CGE model of international trade. In addition, the elasticity of substitution is directly or indirectly determined by econometric estimation, under which I expect they can cause robust simulation results of the CGE model. In this section, the elasticity of transformation is examined because their values have no foundations that economic data can support.

6.6.1 The effects of elasticity of transformation on simulation results

As is aforementioned in Subsection 6.4.2, suppose that the substitution between domestic and exported goods is larger than the substitution between domestic and imported goods, I assume that the elasticities of transformation are two times of the elasticities of substitution. Therefore, $\psi_{i,b} = 2\sigma_i$ is considered as the condition in baseline case. Then, I set $\psi_{i,l} = 0.5\psi_{i,b}$ as the

condition in lower-elasticity case and $\psi_{i,h} = 1.5\psi_{i,b}$ as the condition in higher-elasticity case. The values of elasticity of transformation of sectors are listed in Table 6-13.

Table 6-13 Elasticities of transformation of each sector for the sensitivity analysis (ψ_i)

	Lower-elasticity case ($\psi_{i,l}$)	Baseline case ($\psi_{i,b}$)	Higher-elasticity case ($\psi_{i,h}$)
Corn	2.45	4.9	7.35
Other agriculture	3.25	6.5	9.75
Forestry	2.5	5	7.5
Husbandry	1.3	2.6	3.9
Fishery	1.25	2.5	3.75
Agricultural services	1.9	3.8	5.7
Feed	2.5	5	7.5
Sugar	2.7	5.4	8.1
Condiment	2	4	6
Other food	2	4	6
Alcohol	1.15	2.3	3.45
Other manufacture	3.75	7.5	11.25
Other services	1.9	3.8	5.7

Notes: $\psi_{i,l} = 0.5\psi_{i,b} = \sigma_i$ in lower-elasticity case; $\psi_{i,b} = 2\sigma_i$ in baseline case; $\psi_{i,h} = 1.5\psi_{i,b}$ in higher-elasticity case.

In this subsection, I analyze how the parameter, elasticity of transformation, affect the robustness of simulation results. The Equation (6-43) expresses the relationship between import quantities and world prices of good i.

$$\frac{M_i}{M_i^0} = \left(\frac{p_i^{W_m}}{p_i^{W_m^0}}\right)^{\psi_i} \quad \forall i \tag{6-43}$$

Notions are:

M_i imports of the i-th good from the external agent,
M_i^0 imports of the i-th good from the external agent in benchmark year,
p_i^{Wm} price of the i-th imported good in terms of foreign currency,
$p_i^{W_m^0}$ price of the i-th imported good in terms of foreign currency in benchmark year.
ψ_i elasticity of transformation in the i-th good transformation function.

According to the Equation (6-43), we can draw the import supply curves with different elasticity of transformation which are showed in Figure 6-6.

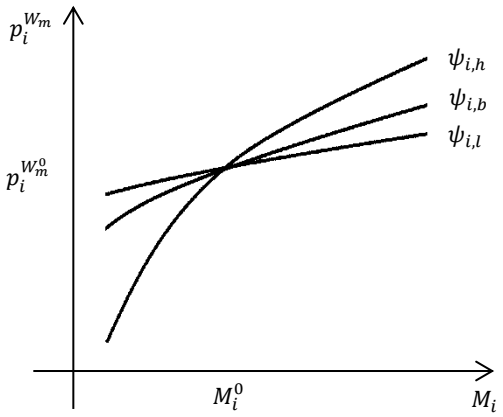


Figure 6-6 Import supply curves with different elasticity of transformation

The import supply curves can be divided into two situations by the conditions of $p_i^{W_m} < p_i^{W_m^0}$ and $p_i^{W_m} > p_i^{W_m^0}$. In our scenarios, downstream sectors of corn are subject to the condition: $p_i^{W_m} < p_i^{W_m^0}$, because import prices of the downstream goods decrease in all scenarios, which is showed in Table 6-10, and the corn sector is subject to the condition: $p_i^{W_m} > p_i^{W_m^0}$, because corn import price increases in all scenarios, which is represented in Table 6-8. According to Figure 6-6, the equilibrium prices and import quantities in our scenarios may vary by values of elasticity of transformation, which is a root cause about the parameter that may be against robustness of simulation results.

We take an example of the effects of the corn transformation elasticity on the simulation results of sectoral outputs (Z_i) to analyze the effects of elasticity of transformation to the robustness of our simulation results. As for domestic corn output (Z_{corn}), value increases of corn elasticity of transformation cause corn import decrease, thereby increasing the demand for domestic corn because of the substitution between domestic and imported corn; therefore, domestic supply also increases. However, value increases of elasticities of transformation about downstream sectors of corn cause imports of their products to increase, which decreases domestic corn demand (intermediate inputs of domestic corn). As for domestic outputs in downstream sectors of corn ($Z_i, i \neq corn$), value increases of corn elasticity of transformation cause corn import price increases and domestic corn price increases because its demand increases, which leads to domestic outputs in downstream sectors of corn decrease because of higher cost on corn inputs. However, value increases of elasticities of transformation about downstream sectors of corn cause import prices of corresponding products lower, which implies lower cost on inputs of these products, thereby increasing the domestic outputs in downstream sectors. As a result, generally, when I change values of elasticity of transformation, we cannot assume absolute increases or decreases appearing in domestic outputs (Z_i). This implies if the elasticity values change, the simulation results of domestic outputs may change significantly in wide ranges from being negative to being positive.

Thus, given that the values of elasticity of transformation applied in this study are not estimated from calibration or econometric estimation, and they may have a significant effect on the simulation results, an analysis of results' sensitivity to the elasticity of transformation is necessary.

6.6.2 Analysis of results' sensitivity to elasticity of transformation

In Subsection 6.5.2, I have found some results estimated by the CGE model, including the results about the corn sector, downstream sectors of corn, and welfare changes of China. In this subsection, the sensitivities of these results to the elasticity of transformation are tested to help judge the robustness of our simulation results. To judge the robustness of our simulation results, I set a criterion: whether the signs of changes in sectors are unchanged in all cases in a scenario. When the results of the sensitivity analysis satisfy the criterion in one scenario, I may well conclude that simulation results of this scenario are robust for policy implications. If it is not satisfied, I say that the simulation results are not robust for policy implications.

6.6.2.1 The results' sensitivity about corn sector

The results of corn concern the results in Subsection 6.5.2.1 and Subsection 6.5.2.2. To analyze the results' sensitivity of corn, I test the results' sensitivity of two variables in the CGE model: the supply/demand of Armington composite corn (Q_{corn}) and the corn output (Z_{corn}). If the results of two variables do not show their sensitivities to elasticity of transformation, I further infer that the results of corn from the CGE model are robust. Table 6-14 shows the supply/demand changes of Armington composite corn in three cases of elasticity of transformation. Table 6-15 shows the corn output changes in three cases of elasticity of transformation.

Table 6-14 Supply/demand changes of Armington composite corn in three cases of elasticity of transformation

	Lower-elasticity case	Baseline case	Higher-elasticity case
S1-1	0.004	0.006	0.007
S1-2	0.015	0.021	0.024
S1-3	0.025	0.035	0.041
S2-1	0.007	0.007	0.007
S2-2	0.026	0.033	0.033
S2-3	0.026	0.038	0.044
S3-1	0.005	0.006	0.007
S3-2	0.015	0.021	0.024
S3-3	0.025	0.036	0.041

Note: To judge the robustness of the simulation results of Armington composite corn (Q_{corn}), we modify the criterion as: whether the signs of the supply/demand changes of Armington composite corn are unchanged in all cases in a scenario.

The simulation results in Table 6-14, indicate that in the three cases, corn sector would increase its supply/demand of Armington composite corn in the three cases, which implies that the results are robust with respect to the criterion. Therefore, we can well conclude that the simulation results about the supply/demand of Armington composite corn are robust in this study.

Table 6-15 Corn output changes in three cases of elasticity of transformation

	Lower-elasticity case	Baseline case	Higher-elasticity case
S1-1	-0.108	-0.145	-0.163
S1-2	-0.355	-0.482	-0.547
S1-3	-0.588	-0.811	-0.928
S2-1	-0.158	-0.158	-0.158

S2-2	-0.62	-0.748	-0.748
S2-3	-0.62	-0.857	-0.981
S3-1	-0.108	-0.144	-0.163
S3-2	-0.355	-0.482	-0.547
S3-3	-0.588	-0.811	-0.928

Note: To judge the robustness of the simulation results of corn output (Z_{corn}), we modify the criterion as: whether the signs of the corn output changes are unchanged in all cases in a scenario.

The simulation results in Table 6-15 indicate that in the three cases, corn sector would decrease its output in the three cases, which implies that the results are robust with respect to the criterion. Therefore, we can well conclude that the simulation results about corn output are robust in this study.

Given that the simulation results about both the supply/demand of Armington composite corn and corn output are robust, I infer the simulation results of corn in this study are robust.

6.6.2.2 The results' sensitivity about downstream sectors of corn

The results about downstream sectors of corn concern the results in Subsection 6.5.2.3. To analyze the results' sensitivity about downstream sectors of corn, I test the results' sensitivity of one variable in the CGE model: the sectoral output ($Z_i, i \neq corn$). I select Feed and Sugar as example sectors because they input more corn as intermediate input than other sectors. If the results of the variable do not show their sensitivities to the elasticity of transformation, I further infer that the results about downstream sectors of corn from the CGE model are robust. Table 6-16 represents the sectoral output changes in three cases of elasticity of transformation.

Table 6-16 Sectoral output changes in three cases of elasticity of transformation (%)

	Sector	Lower-elasticity case	Baseline case	Higher-elasticity case
S1-1	Feed	0.002	0.003	0.003
	Sugar	0.005	0.008	0.009
S1-2	Feed	0.007	0.01	0.012
	Sugar	0.019	0.027	0.032
S1-3	Feed	0.011	0.017	0.02
	Sugar	0.031	0.046	0.055
S2-1	Feed	0.003	0.003	0.003
	Sugar	0.008	0.009	0.009
S2-2	Feed	0.012	0.016	0.016
	Sugar	0.033	0.043	0.044
S2-3	Feed	0.012	0.018	0.021
	Sugar	0.033	0.049	0.058
S3-1	Feed	0.002	0.003	0.003
	Sugar	0.006	0.008	0.01
S3-2	Feed	0.007	0.01	0.012
	Sugar	0.019	0.027	0.032
S3-3	Feed	0.011	0.017	0.02
	Sugar	0.031	0.046	0.055

Note: To judge the robustness of the simulation results of corn output ($Z_i, i \neq corn$), we modify the criterion as: whether the signs of the sectoral output changes are unchanged in all cases in a scenario.

The simulation results in Table 6-16 indicate that in the three cases, the Feed sector and Sugar sector would increase their output in the three cases, which implies that the results are robust with respect to the criterion. Therefore, we can well conclude that the simulation results about the Feed sector and Sugar sector are robust in this study. Thus, I further infer that the results about downstream sectors of corn from the CGE model are robust.

6.6.2.3 The results' sensitivity of welfare change

This subsection is to test the results' sensitivity of welfare change. If the results of the welfare change do not show their sensitivities to elasticity of transformation, we can infer that the results about welfare changes from the CGE model are robust. Table 6-17 represents the welfare changes in three cases of elasticity of transformation.

Table 6-17 Welfare changes in three cases of elasticity of transformation (%)

	Lower-elasticity case	Baseline case	Higher-elasticity case	Robustness
S1-1	-5.277	-5.109	-5.021	Robust
S1-2	-2.979	-2.402	-2.089	Robust
S1-3	-0.789	0.217	0.772	Not robust
S2-1	0.172	0.415	0.499	Robust
S2-2	-0.489	0.727	1.299	Not robust
S2-3	-0.489	0.578	1.169	Not robust
S3-1	-0.206	-0.075	-0.005	Robust
S3-2	-0.471	0.052	0.338	Not robust
S3-3	-0.5	0.496	1.047	Not robust

Welfare index: Hicksian equivalent variation
Note: To judge the robustness of our welfare results, we modify the criterion as: whether the signs of the welfare changes are unchanged in all cases in a scenario.

According to the results in Table 6-17, for most scenarios, the welfare changes are sensitive to value changes of elasticity of transformation under the criterion. I consider that the non-robust results in the scenarios cannot provide evidence for policy implications. Based on the robust simulation results, we get positive welfare changes in S2-1, while S1-1 and S3-1 show negative results of welfare change. These results imply that the way of quota expansion is more likely to bring welfare growth.

In addition, increasing import by tariff cuts may imply extreme tariff rate decreases because the out-of-quota tariff rate is at least 50% on corn imports in China; however, concerning food security, reducing tariffs may not be a feasible option for a country like China that has underdeveloped agriculture, extreme tariff cuts will weaken the food security system, and China might risk losing its food security power when sourcing from overseas. After 2018, a large gap between the prices of domestic corn and imported corn didn't appear; this means that domestic corn may lose tariff protection to much extent if cutting its import tariffs.

6.7 Summary

A number of empirical methods have been applied to analyze the economic effects of agricultural policies, such as econometric models, input-output models, and CGE models. However, econometric models have significant disadvantages in the application, especially in developing countries. The use of CGE models for agricultural policy analysis has become widespread, and CGE approaches have become the dominant economy-wide framework,

largely replacing other approaches such as input-output models and econometric models. In this chapter, I have made the simulations on future scenarios about agricultural quota and tariff in China by a CGE analysis to compare their economic effects on the agricultural sectors, corresponding downstream sectors, and the economy. I construct a SAM for China and a CGE model to simulate these policies. On the basis of the above works, I obtained the simulation results from the model and made a sensitivity analysis to check the robustness of the results. The findings in this chapter provide:

The following findings are about (Armington composite) corn supply/demand and price in China. Corn import relaxation by tariff reductions and quota level increases can cause the corn supply and demand increases and its price decrease, and in each simulation, the more corn import relaxes, the much degree of changes appears. Under equilibrium, the reason why the supply of Armington composite corn increases is mainly because more imported corn enters Chinese markets in these scenarios for the import relaxation on corn. Its demand increase is mainly reflected in the increases of the intermediate use and household demand caused by the price decreases and the increases of expenditures on corn.

The following findings are about the supply/demand of domestic corn and corn import in China. If the tariff cuts or quota level increases, the supply/demand of domestic corn and import quantity increases, and consequently, self-sufficiency rates go down. This implies that firms tend to choose more imported corn and less domestic corn than them in benchmark choice because the price (CIF) of imported corn is much cheaper than domestic corn, and imported corn substitutes domestic corn if corn import is assumed to be relaxed by tariff reduction or quota level expansion. As a result, import prices are significantly pushed up, and domestic price is slightly pulled down. In addition, the more corn import relaxes, the much degree of changes appears in domestic and import prices.

The following findings are about the downstream sectors of corn in China. Firstly, because both tariff cuts and quota level increases cause cheaper corn (than domestic corn) to enter China's corn market, the cost of corn inputs of producers in downstream sectors of corn reduces. Therefore, the production of these products increases and imports drop. Secondly, these measures can contribute to domestic supply, export of corresponding goods in the sectors, and domestic goods substitute the imported goods for composite good production because the prices of domestic goods of these sectors reduce more than their import prices. Thirdly, domestic prices and export prices of the goods in these sectors decrease because more imported corn that is cheaper than domestic corn enters Chinese markets in these scenarios for the import relaxation on corn, and as imported corn is the input to produce the goods, firms cost less by inputting more imported corn. In addition, import prices of the goods decrease because the cheaper exports pull the import price (world price) down.

The following findings are about the downstream sectors of corn in China. For most scenarios, the welfare changes are sensitive to value changes of elasticity of transformation under the criterion. I consider that the non-robust results in the scenarios cannot provide evidence for policy implications. Based on the robust simulation results, I get positive welfare changes in the scenario that corn tariff quota level is expanded by 1.1 times, while the results about the scenario that corn tariff rate is reduced to 20% and corn tariff quota are abolished and about the scenario that corn tariff rate is reduced to 20% shows negative results of welfare change. These results imply that the way of quota expansion is more likely to bring welfare growth. A number of empirical methods have been applied to analyze the economic effects of agricultural policies, such as econometric models, input-output models, and CGE models. However, econometric models have significant disadvantages in the application, especially in developing countries. The use of CGE models for agricultural policy analysis has become widespread, and CGE approaches have become the dominant economy-wide framework, largely replacing other approaches such as input-output models and econometric models. In

this chapter, I have made the simulations on future scenarios about agricultural quota and tariff in China by a CGE analysis to compare their economic effects on the agricultural sectors, corresponding downstream sectors, and the economy. I construct a SAM for China and a CGE model to simulate these policies. On the basis of the above works, I obtained the simulation results from the model and made a sensitivity analysis to check the robustness of the results. The findings in this chapter provide:

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Chapter 7 Conclusions, suggestions, and an outline of the methodologies in this dissertation

Sufficient agricultural supply is at the basis of the development of the national economy in China. Supply shocks like African Swine Fever (ASF) may cause insufficient agricultural supply in China. Agricultural sectors of China are standing at the crossroad of reform. Chinese officials have been launching a supply-side structural reform. Agricultural policies are powerful tools to continuously deepen the reform of the supply-side structural reform in agriculture. In this dissertation, the topic is research on the economic effects of agricultural policies on the agricultural sectors, corresponding down-stream sectors, and the economy of China by taking corn as an example. Under this topic, I have explored feasible agricultural policies for the further reform in the future and the policies have been analyzed, simulated, and evaluated to quantify their effects on the agricultural sectors, corresponding down-stream sectors, and the economy of China by taking corn as an example. By the above analysis, I have drawn the conclusions and put forward to some suggestions list as below. In addition, this chapter provides an outline of methodologies in this dissertation.

7.1 Conclusions

The evaluation of China's agricultural policy reflects its process of reform for agricultural marketization and trade liberalization. However, China is still complained of violating WTO rules by implementing excessive agricultural support by the U.S. In this context, when the domestic supply of some agricultural products is not sufficient to support their demand, relaxation of imports to increase imports may be an optional way. China's agricultural policy history reflects gradual marketization and trade liberalization in the agriculture of China. For some agricultural varieties like corn, price policies with direct price intervention have been eliminated but still work for some varieties like wheat and rice, and the trade of corn, wheat, and rice is governed by quota and tariff policies. As for domestic support, China can apply green box measures, blue box measures, and non-exempt measures without exceeding its commitment that declares the non-exempt support cannot exceed 8.5% for all agricultural products under WTO rules. The disputes on the values of China's FERPs and QEPs between the U.S. and China on agriculture are still in the process of settling. In this context, launching policies to expand imports is a widely accepted solution to shortages and to not sufficient domestic supply of agricultural products by considering economic effects.

Even with the support of agricultural policies, China's domestic supply of some agricultural products like corn has made significant progress; however, their domestic supply may still be insufficient to support their demand. Corn consumption in China has witnessed a sharp upward trend since 1980, mainly for animal feed, and China still has scope for expansion in animal products and the input of corn as feed. In this context, what policies about food security and self-sufficiency goal of corn are feasible for corn in China are still under debate. Also, China has made remarkable progress in the production and domestic supply of corn from 1980 to 2020. However, the domestic supply of corn in China did not continue its upward trend from 2016. Although the quantity of corn exported reduced from positive numbers before 2006 to almost negligible since 2007 and China has corn stocks, the self-sufficiency of corn has been decreasing in recent years. From 2010 to 2016, domestic production can meet the consumption of corn in China in 100%, and from the year 2017, corn production had been being no longer enough to meet corn consumption in China partly because of the elimination of the stockpiling policy with price support. In addition, in most years from 1980 to 2020, the self-sufficiency rate of corn is above 95%, which meets the target of self-

sufficiency rate of China well; however, the self-sufficiency rate dropped dramatically from 121.2% in 2014 to 93.9% in 2020.

By taking the example of corn, I find China's agricultural import has gradually increased to reach its quota, which implies increasing its imports means relaxation in its import policies. In addition, imported corn has a larger substitution for China's corn, which can promote imports. Countries mainly import corn from 6 countries, including Argentina, Brazil, Canada, the USA, Ukraine, and Russia, and China mainly imports from the USA and Ukraine; however, some countries, including the USA, may not be the origin with sufficient corn for China. In recent years from 2008, the imports significantly increased, and they almost reached the top quantity of its import quota from 2019. Thus, if corn demand gradually increases in the future, China may face a shortage of corn supply, and expanding its import quota or lowering its above quota import tariff to liberalize its corn market for China are possible future scenarios of corn trade policy in China. Regarding the substitution, comparing with some other countries, China has a larger elasticity of substitution between domestic and imported corn, which points domestically produced corn in China is more likely to be substituted by corn from other countries when domestic corn price rises or world corn price falls. Regarding the export capacity of import origin countries of China, both world corn production and corn export show upward trends. In addition, the upward trend of corn export quantity in recent 10 years is more significant than before. Countries mainly import corn from 6 countries, including Argentina, Brazil, Canada, the USA, Ukraine, and Russia. China's corn imports are extremely dependent on two countries' exports of, corn including Ukraine and the USA. However, some countries, including Brazil, France, Germany, as well as the USA, may not be the origins with sufficient corn for China.

By taking the example of corn, I find the volatility has a larger amplitude in import price than domestic price of corn, and after the change from stockpiling policy to subsidy policy, it gets larger in domestic corn price. In addition, before the change, the volatility in import price has an effect on domestic prices. However, after the change, it shows significant effects of the volatility in domestic price on import price. By the statistical analysis, I conclude that bigger gaps between domestic price and import price appear in the period of the stockpiling policy rather than the period of the subsidy policy and the average price volatility of domestic corn became greater after the policy change. In addition, the volatility amplitude of domestic price became greater after the policy change, and the volatility amplitude of domestic price is less than the volatility amplitude of import price. By the empirical analysis, I draw the conclusions that: firstly, the volatility of the domestic price is mainly caused by the information in domestic market and the information in the market of corn imports of China cannot significantly affect the expected volatility of domestic price; secondly, the information in the domestic market can stabilize the import price, and the influence power of domestic price got stronger from the period of stockpiling to the period of the subsidy; thirdly, the volatility in the mean can transmit from domestic price to import price rather than from import price to domestic price; fourthly, temporary shocks from the market of imported corn contributes to the volatility of domestic price in the period of the stockpiling, while temporary shocks from the domestic market have a significant effect on the volatility of import price in the period of the subsidy.

For China, increasing corn imports by tariff reductions or quota level increases have a wide economic impact, particularly on corn and corn-related industries. In addition, increasing corn imports does not necessarily lead to welfare growth, and regarding welfare growth, it is a more feasible way to increase corn imports by quota level expansion. About the corn sector, the measures to increase corn imports can cause the corn supply and demand increases and its price decreases, and in each simulation, the more corn import relaxes, the much degree of changes appears. If the tariff cuts or quota level increases, the

supply/demand of domestic corn and import quantity increases, and consequently, self-sufficiency rates go down. As a result, import prices are significantly pushed up, and domestic price is slightly pulled down. In addition, the more corn import relaxes, the much degree of changes appears in domestic and import prices. About downstream sectors of corn, the production of the products of increases, and their imports drop because these measures to increase corn imports and these measures can contribute to domestic supply, export of corresponding goods in the sectors, and domestic goods substitute the imported goods for composite good production. In addition, they cause that domestic prices and export prices of the goods in these sectors decrease. About welfare, based on the robust simulation results, I get positive welfare changes in the scenario that corn tariff quota level is expanded by 1.1 times, while the results about the scenario that corn tariff rate is reduced to 20% and corn tariff quota are abolished and about the scenario that corn tariff rate is reduced to 20% shows negative results of welfare change. These results imply that the way of quota expansion is more likely to bring welfare growth.

7.2 Suggestions

It is recommended to avoid further strong support or stimulus policies to expand domestic agricultural production and focus on the maintenance of current agricultural resources and insuring agricultural supply by promotion of productivity and by imports. WTO has not proposed a bilaterally accepted solution to settle down the U.S.-China disputes on agriculture, and the U.S. still complains that China has used more agricultural support on its agricultural producers that exceed its commitment to agricultural support. Regardless of this, using more agricultural support to improve agricultural production and competitiveness costs much, particularly in such a situation that small-scale production in China does not have the premise of showing higher production capacity than large-scale production. In front of rising agricultural demand in China, China should not continue the past practice of seeking growth regardless of resource wastes, ecological and environmental damages, but focus on the maintenance of current agricultural resources and ensuring agricultural supply by promotion of productivity and by imports. The measures for promotion of productivity include, for example, further improvement of agricultural infrastructures such as water conservancy facilities and further support on agricultural production training for farmers. In addition, import is also an option as well for ensuring agricultural supply. Although it can be predicted that increasing imports will lower the self-sufficiency and the domestic prices of some agricultural products and subsequently lower farmers' incomes, increasing imports can also increase the influence of global agricultural pricing.

It is necessary to diversify sources of agricultural imports for sufficient agricultural supply, optionally by the considerable measures: construction of a global agricultural supply information system, cooperation with potential partner countries, development of overseas agriculture, and promotion of WTO agreements on agricultural export restrictions. A centralized agricultural import pattern is not conducive to a sufficient agricultural supply. For example, corn from the U.S. and Ukraine accounted for most of the share of China's corn import market, which may cause insufficient supply, particularly when some frictions and even wars exist in such partner countries. In this context, diversifying sources of agricultural imports are necessary. Some considerable measures are listed below. Firstly, an agricultural supply information system is essential to gather the information of agricultural export capacities of China's partner countries and potential partners. Due to the serious destruction of global agricultural, natural resources, rapid population growth, conflicts around the world, and the adverse effects of climate change, the uncertainty in the global food supply is also increasing. However, the first point for import is to ensure that sufficient

agricultural products are available on the international agricultural market. Thus, the construction of a global agricultural supply information system shows great significance for the sufficient agricultural supply of China. Secondly, it is necessary to establish a cooperative relationship with potential partners for diversifying sources of agricultural imports. China can, under the structure of the "Belt and Road Initiative," develop and strengthen cooperation with agricultural export countries so as to actively seek agricultural trade cooperation with these countries as new origins of agricultural imports of China. Thirdly, developing overseas agriculture is also optional. As the measures of Japan and Korea, enhancing investment in overseas agricultural resources and encouraging the transfer of some agricultural industries to foreign countries are also viable ways to ensure sufficient agricultural import resources. Fourthly, as a net agricultural importer like Japan and Korea, China should promote WTO negotiations on agricultural export restrictions to result in an agreement on agricultural export restrictions to avoid insufficient global agricultural supply in some certain situations.

When suffering potential shortages in domestic supply of some agricultural varieties, increasing import by expanding import quotas is a more feasible way. Among these robust results about welfare, expanding agricultural quota like corn quota can bring about an increase in welfare. In addition, increasing import by tariff cuts may imply extreme tariff rate decreases; however, concerning food security, reducing tariffs may not be a feasible option for a country like China that has underdeveloped agriculture, extreme tariff cuts will weaken the food security system, and China might risk losing its food security power when sourcing from overseas. Regardless of these, because it is expected that under the condition of free trade, the interactions of international transmission are supposed to exist in both directions between the price volatility of domestic goods and the price volatility of imported goods when international trade of the home country and import origin countries occur, and some methods like price support policies, quota, and subsidies that may break free trade mode may limit the international transmission in one or both directions, extreme tariff cuts may lead to more price volatility according to our estimated results and subsequently to more price risks and more uncertainty of farmers' incomes. These go against the original intention of stabilizing domestic food prices and bring difficulties to anti-poverty as well.

7.3 An outline of the methodologies in this dissertation

The linkages of the methodologies. The methodologies concluded in this dissertation consist of the panel data analysis, time series analysis, and CGE analysis. In detail, the panel data analysis is applied to empirically study the substitution between commodities from different countries. This analysis is a foundation to the CGE analysis that incorporates a fundamental assumption under which commodities from different countries imperfectly substitute for each other. The panel data analysis in Chapter 4 and the CGE analysis in Chapter 6 can briefly provide a complete analysis of general equilibrium. In addition, the CGE model also incorporates a fundamental assumption that China is "large" country where domestic prices have effects on world (import) prices, which is proved by the results in Chapter 5. However, many researchers did not prove this in their studies and they applied the "large" country consumption or a "small" country consumption directly, which may lead to bias. Additionally, with the methodology of time series, we can also find some results about the interactions between domestic prices and import prices, which are essential indexes that governments, consumers, producers and traders need to consider when discussing international trade; thus, this dissertation includes a chapter to study the important indexes.

Applications and future developments of the CGE model. The CGE model is constructed for application at the "large" country level that implies the export and import prices quoted in terms of the foreign currency are given endogenously. However, only minimal changes are

needed before it can be applied to a “large” or “small” region/country within the world involved international trade activities. As a CGE model at country level, it can be applied to economic analyses of behaviors of producers, consumers, governments and international trade agents of a country. The analyses involve changes in tax and tariff, welfare, balance of Government finances, wage adjustments, GDP estimation, international trade of a country with the world, etc. In particular, the CGE model incorporates a tariff-quota module; therefore, the CGE model can also be specially applied in a tariff-quota analysis, particularly, for developing countries. The model well describes the relationships of quota, tariff, imports and prices. However, we assume that consumers capture all quota rents in this dissertation, which should be further discussed and considered. Concerning the target country: China, the CGE model can also be applied to these analyses about, for example, wheat and rice on which tariff-quota policies have also been launched in China. Additionally, it should be noted that given that China has been developing fast, relating economic conditions may change quickly, applying a dynamic model to simulate the changing conditions is better in the analysis with a large time span. However, the CGE model in this dissertation is a static model; therefore, developing this model to be dynamic to meet dynamic conditions is one of next works in the future.

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Doctoral Dissertation, Kobe University
Economic Analysis of China's Agricultural Policies: A Case Study on Policy Reforms of Corn (中国の農業政策に関する経済分析:トウモロコシの政策の事例を中心に), 150 pages
Submitted on July, 13th, 2021
The date of publication is printed in cover of repository version published in Kobe University Repository Kernel.