Simulation of Chinese Sorghum Imports from a New Perspective: U.S. and Global Impacts

Wei Zhang

Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of Master of Science in Agricultural and Applied Economics

Mary A. Marchant, Chair
Jason Grant
James Hansen

May 9th, 2017
Blacksburg, Virginia

Keywords: China, U.S.-China Trade, Sorghum, USDA-ERS China Model, Simulation, Global Impacts, Agricultural Policy
Simulation of Chinese Sorghum Imports from a New Perspective:
U.S. and Global Impacts

Wei Zhang

ABSTRACT

This thesis aims to analyze the impacts on U.S. and global sorghum trade, and whether China will continue importing sorghum from the global sorghum market for feed use, if the Chinese government cancels its corn price support policy and corn temporary reserve program nationwide. This study uses the USDA-ERS China Model and the Country-Commodity Linked System (CCLS) to simulate the impacts on U.S. sorghum exports and the reduction of sorghum’s global price, global production, and global trade volumes. The simulations are based on three scenarios: if China’s sorghum import volume decreased by 50% from USDA-ERS’s baseline projection, if China’s sorghum import volume decreased by 35% each year from the previous year, and if China’s sorghum import volume decreased by 70% from USDA-ERS’s baseline projection in year one and by 90% from USDA-ERS’s baseline projection in subsequent years.

The modeling system is a large scale multi-country and multi-commodity partial equilibrium dynamic simulation model which solves for global prices and trade using individual country models. Policy instruments are applied to the China model and solved globally. The USDA-ERS China Model and the CCLS, used to project Chinese and global sorghum trends, includes the following policy instruments: tariffs, quotas, tariff rate quotas, export tax, direct payments, input subsidies, and procurement policies. This model simulates projections using price and income elasticities and assumed values for exogenous variables such as income and population growth. This model also incorporates behavior of state trading enterprises and WTO commitments into imported and exported equations for sorghum.
Simulation of Chinese Sorghum Imports from a New Perspective: U.S. and Global Impacts

Wei Zhang

General Audience Abstract

This research uses the USDA-ERS China model to analyze the impacts on U.S. and global sorghum trade, and whether China will continue importing sorghum for feed use, if the Chinese government cancels its corn price support policy nationwide. Results show that the decrease of China’s sorghum imports resulted in less sorghum demand and lower sorghum price in the global market. Sorghum exports for U.S. and other major sorghum exporters decreased significantly. The results show the necessity to seek new sorghum export opportunities worldwide for U.S. sorghum exporters. Meanwhile, U.S. sorghum exporters may change their cropping patterns to continue making profits by switching out of sorghum.
I would like to thank all my committee members, Dr. Mary Marchant, Dr. Jason Grant, and Dr. James Hansen for providing support and comments on this thesis. I would like to especially thank my major professor, Dr. Mary Marchant, for her guidance, advice and encouragement throughout the whole process. I would like to deliver thanks to Mina Hejazi and Jue Zhu, who provide a lot of help and comments on understanding and explaining the USDA-ERS China Model and the Country-Commodity Linked System.
# Table of Contents

ABSTRACT  
ACKNOWLEDGEMENT  
LIST OF FIGURES  
LIST OF TABLES  
ACRONYMS  

CHAPTER 1: INTRODUCTION  
1.1 Problem Statement  
1.2 Objectives  
1.3 Organization of Thesis  

CHAPTER 2: BACKGROUND INTRODUCTION AND LITERATURE REVIEW  
2.1 Current Situation of China’s Sorghum Market  
2.2 Current Situation of the U.S. and Global Sorghum Market  
2.3 China’s Demand for Sorghum  
2.3.1 Tannins  
2.3.2 Sorghum in Swine Production  
2.3.3 Sorghum in Beef and Dairy Production  
2.3.4 Sorghum in Baijiu Production  
2.4 China’s Feed Industry Development  
2.4.1 Start-up Phase  
2.4.2 Rapid Development Phase  
2.4.3 Integration Phase  

CHAPTER 3: MODELING  
3.1 Methods and Procedure  
3.2 Demand  
3.3 Supply  
3.4 Imports  
3.5 Stock Change  
3.6 Anticipated Results

CHAPTER 4: EMPIRICAL RESULTS

4.1 Baseline Description 46

4.2 Scenarios 51

4.2.1 Scenario One: If China’s sorghum import volume decreased by 50% from USDA’s baseline projection 54

4.2.2 Scenario Two: If China’s sorghum import volume decreased by 35% each year from the previous year 58

4.2.3 Scenario Three: If China’s sorghum import volume decreased by 70% for year one from USDA-ERS’s baseline projection and by 90% from the USDA-ERS’s baseline projection in subsequent years 63

4.3 Summary of the Scenarios 67

4.4 Discussion 69

CHAPTER 5: SUMMARY AND CONCLUSION 71

REFERENCE 76

APPENDIX 87
List of Figures

Figure 1: Sorghum as Feed in China from MY 2000/01 to MY 2016/17 .....................................................8
Figure 2: China’s Corn Stocks From 2008 to 2016 (Dollar Per Metric Ton) ..................................................9
Figure 3: China’s Corn Stocks From 2008 to 2016 (Million Metric Tons) ......................................................9
Figure 4: China Sorghum Imports from MY 2000/01 to MY 2015/16 ..............................................................10
Figure 5: Top Three Sorghum Importers in the World in MY 2015/16 .............................................................11
Figure 6: The Proportion of China’s Sorghum Imports in Global Market in MY 2014/15 ..............................11
Figure 7: China’s Sorghum/Corn Production Price Ratio .................................................................................12
Figure 8: Figure 8. Sorghum Imports for Selected Countries (China, Mexico, Japan) .................................13
Figure 9: Top U.S. States in Sorghum Production for Grain in 2016 (in 1,000 bushels) ...............................15
Figure 10: Major Sorghum Exporters in the World in MY 2015/16 ...............................................................16
Figure 11: The Proportion of U.S. Sorghum Exports in Global Market in MY 2014/15 ..........................17
Figure 12: U.S. Sorghum Exports and Chinese Imports, MY 2000/01-2016/17 ..........................................18
Figure 13: U.S. Sorghum Exports from MY 2000/01 to MY 2016/17 ............................................................18
Figure 14: Global Sorghum Price from MY 2000/01 to MY 2016/17 .............................................................19
Figure 15: Total Pork Consumption in China from 1981 to 2016 (Million Metric Tons) ...........................21
Figure 16: Estimated Uses of Grains in China, 2004-2024 ..............................................................................30
Figure 17: U.S.–China Trade Model for Sorghum .........................................................................................36
Figure 18: China’s Sorghum Market—When Imports Fall .............................................................................46
Figure 19: Global Sorghum Market—Decrease in China’s Imports ............................................................47
Figure 20: Global and U.S. Sorghum Market—Decrease in China’s imports .............................................48
Figure 21: China’s Domestic Corn Market .................................................................................................49
Figure 22: China’s Domestic Sorghum Demand and Imports (Million Metric Tons) ...............................52
Figure 23: China’s Sorghum Imports for Scenario One (1,000 Metric Tons) .............................................55
Figure 24: Projected Sorghum Imports for Selected Countries for Scenario One .................................56
Figure 25: Projected Sorghum Exports for Selected Countries for Scenario One ..................................57
Figure 26: China’s Sorghum Imports for Scenario Two (1,000 Metric Tons) .........................................60
Figure 27: Projected Sorghum Imports for Selected Countries for Scenario Two .................................60
Figure 28: Projected Sorghum Exports for Selected Countries for Scenario Two ................................61
Figure 29: China’s Sorghum Imports for Scenario Three (1,000 Metric Tons) ........................................61
Figure 30: Projected Sorghum Imports for Selected Countries for Scenario Three .................................65
Figure 31: Projected Sorghum Exports for Selected Countries for Scenario Three .................................66
Figure 32: The Baseline Projection and Three Scenarios for China’s Sorghum Imports .............................68
List of Tables
Table 1: Own and Cross Price Elasticities for Sorghum Feed Demand ..............................................42
Table 2: Result of Scenario One: China’s Sorghum Imports Decreased by 50% From USDA’s Baseline Projection..................................................................................................................................................55
Table 3: The Impact Toward Corn for Scenario One...................................................................................57
Table 4: Result of Scenario Two: China’s Sorghum Imports Decreased by 35% Each Year from the Previous Year..................................................................................................................................................59
Table 5: The Impacts Toward Corn for Scenario Two ..................................................................................62
Table 6: Result of Scenario Three: China’s Sorghum Imports Decreased by 70% in Year One from USDA-ERS’s Baseline Projection and by 90% from the USDA-ERS’s Baseline Projection in Subsequent Years. ........................................................................................................................................63
Table 7: The Impacts Toward Corn for Scenario Three.................................................................................66
## Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>UN-FAO</td>
<td>Food and Agriculture Organization of the United Nations</td>
</tr>
<tr>
<td>TRQs</td>
<td>Tariff Rate Quotas</td>
</tr>
<tr>
<td>NDRC</td>
<td>The National Development and Reform Commission</td>
</tr>
<tr>
<td>GMOs</td>
<td>Genetically Modified Organisms</td>
</tr>
<tr>
<td>WTO</td>
<td>World Trade Organization</td>
</tr>
<tr>
<td>USDA-ERS</td>
<td>The United States Department of Agriculture-Economic Research Service</td>
</tr>
<tr>
<td>PRC</td>
<td>The People's Republic of China</td>
</tr>
<tr>
<td>CCLS</td>
<td>The Country-Commodity Linked System</td>
</tr>
</tbody>
</table>
Chapter 1: Introduction

1.1 Problem Statement

China is currently the world’s dominant sorghum importer, and its sorghum demand is a big reason why global sorghum trade is expected to gradually increase over the next decade (Tran et al., 2015). Despite the increasing volume of imports, there is a possibility that sorghum imports will decline significantly because of the change of China’s corn policy. Chinese importers started to decrease their rate of sorghum imports from the U.S. beginning in 2016, and there is a possibility that Chinese sorghum imports will continue to decline because of the change of China’s corn temporary reserve policies. According to the prediction from the Food and Agriculture Organization of the United Nations (FAO), a 50% reduction of China’s sorghum imports will result from Chinese corn policy change (FAO, 2014).

The U.S. sorghum market, as well as the world sorghum market, will be significantly affected if China shrinks sorghum imports. According to Hansen’s research, if China banned sorghum imports completely, the global sorghum price would fall 35% and China’s global import share would fall from 61% to 2%. Sorghum is thinly traded worldwide, which means that the magnitude of sorghum trade is relatively small compared to other commodities, and China’s sorghum imports accounts for most of global sorghum exports (Hansen et al., 2015). Simultaneously, global sorghum production and trade would decrease by 6% and 46% respectively, and most U.S. sorghum production
would be consumed domestically with only 12% to 13% of production being traded (Hansen, et al., 2015). As a result of China’s potential sorghum ban, major sorghum exporters (the U.S., Argentina, and Australia) would decrease production and export less sorghum.

At the same time, sorghum trade between the U.S. and China is a success story. The U.S. seized the opportunity to get access to the Chinese sorghum market, which could provide an experience in exploring future potential market worldwide. This study may enable U.S. government agencies to negotiate with the Chinese government from a stronger bargaining position by gaining critical information regarding Chinese sorghum policies.

In the past few decades, the rapid growth of China’s economy led to a significant change in consumption patterns. The demand for dairy and meat products increased dramatically, which promoted China’s livestock industry. Simultaneously, because of high urbanization rates, the Chinese economy structure is transferring from a producer-driven economy to a consumer-driven economy (Sagami, 2011). Accordingly, the food consumption structure is shifting from grain food to meat food; thus, the high meat demand is promoting a fast-developing feed industry. Sorghum demand is a derived demand from the demand for food and feed, and the primary demand is for feed. The increasing demand of livestock, in turn, resulted in a growing demand for feed grains, such as corn and sorghum.
China’s agricultural and trade policies in the corn sector are driving much of the growth in sorghum demand and imports. Corn used to be the primary feed grain in China. China initiated a corn temporary reserve program in 2007 and a price support policy in 2011 to support Chinese farmers’ income and to move China toward self-sufficiency. Under this program, once the corn market price is less than the support price, the Chinese authorities purchase corn from farmers at the support price, and accumulated corn in national storage facilities (Wu & Zhang, 2016). Under the price support policy, China’s support price for corn continuously increased, which increased China’s domestic corn production. Thus, China’s higher domestic corn production generated huge corn stocks. Since China imposes tariff rate quotas (TRQs) on corn imports, China’s corn price remained high domestically and imports of cheaper feed substitutes increased. In this regard, sorghum is considered as a low-cost feed substitute for corn, and China was projected to maintain high sorghum import volumes (Hansen & Gale, 2014). As shown in Appendix 11, China’s feed-to-use ratio increased significantly from less than 10% in 2010 to more than 80% in 2014, while corn feed-to-use ratio maintained steady during this period of time at approximately 70% (Wang & Malaga, 2016). However, the magnitude of China’s sorghum market is still very small compared with China’s corn market, and China’s corn demand is much larger than China’s sorghum demand.

From 2016 onward, the situation began to change. China ended its price support policy and temporary reserve program for corn in two areas, Northeastern provinces and
Inner Mongolia, as a pilot program to decrease the excessive corn stockpiles. On March 28, 2016, Liu Xiaonan, Deputy Director of the Economy and Trade Department of the National Development and Reform Commission (NDRC), announced that the temporary reserve policy in the Northeastern provinces and Inner Mongolia would be terminated. Instead, a new mechanism of “marketized purchases” and a direct payment subsidy policy toward corn would be implemented in these areas (China Politics, 2016). China abandoned the price support policy and temporary reserve program for corn based on three reasons: a huge amount of stockpiles, cheaper imports from the world market, and quality deterioration of corn stocks. The new policy decreased China’s corn production and corn price; thus, imports of sorghum decreased with it as well.

In summary, US-China sorghum trade is a temporary success story in the field of agriculture, and it provides an example of U.S. market of expansion in foreign countries. This thesis analyses the impact of a decrease in sorghum imports in year 2016 forward; thus after the corn policy change. This study is important because it presents an understanding of China’s sorghum trade policies and knowledge for U.S. sorghum exporters to evaluate potential opportunities and risks in U.S.-China sorghum trade. The U.S. government, farmers, and agribusinesses can utilize this research to take advantage of the Chinese agricultural market to increase U.S.-China sorghum trade, and this study may enable U.S. government agencies to negotiate with the Chinese government from a stronger bargaining position by gaining critical information regarding Chinese sorghum
policies. This research could also be used as a reference for sorghum exporting countries (the U.S., Australia, Argentina) to prepare for changes in Chinese sorghum policies.

1.2 Objectives

This thesis aims to analyze the impacts on U.S. and global sorghum trade, and whether China will continue importing sorghum from the global sorghum market for feed use, if the Chinese government cancels its corn price support policy and corn temporary reserve program nationwide. To answer this question, this thesis will use the USDA-ERS China Model and the Country-Commodity Linked System (CCLS) to simulate the impacts of U.S. sorghum exports and the reduction of sorghum’s global price, global production, and global trade volumes. The simulation will be based on three scenarios: if China’s sorghum import volume decreased by 50% from USDA-ERS’s baseline projection; if China’s sorghum import volume decreased by 35% each year from the previous year; and if China’s sorghum import volume decreased by 70% from USDA-ERS’s baseline projection in year one and by 90% from the USDA-ERS’s baseline projection in subsequent years. Specific research objectives of this thesis are as follows:

1. Document China’s feed industry development and the increasing demand of sorghum in China.

2. Discover China’s possible reasons and ways of restricting global sorghum imports.
3. Simulate three potential scenarios that will impact U.S. and global sorghum price, production, as well as global trade volumes by using the USDA-ERS China model and the Country-Commodity Linked System (CCLS).

4. Analyze the empirical results of the simulations and evaluate the impacts for U.S.-China and global sorghum trade.

5. Project the impacts towards U.S. sorghum exports and the world’s sorghum market.

1.3 Organization of Thesis

This thesis is organized as follows: Chapter 2 reviews the most recent research on the demand for sorghum as feed in animal husbandry, U.S.-China sorghum trade, as well as the projection of sorghum trade trends in the future. Chapter 3 presents the USDA-ERS China model and the CCLS, used for simulation, and explains how the model was established, its logic and procedures. Chapter 4 interprets the scenarios and their corresponding empirical simulation results, as well as a discussion in response to the results. Chapter 5 summarizes the empirical results of the scenarios and the contributions of this thesis.
Chapter 2: Background Introduction and Literature Review

2.1 Current Situation of China’s Sorghum Market

Sorghum is a significant feed crop used throughout the world, which is drought tolerant and provides high-energy as a major animal feed (Tan, 2015). As important feed grains, sorghum and corn are usually used interchangeably to feed animals due to their similar production costs and nutritional content; therefore, farmers choose which to grow mainly based on the local growing environment. Compared to corn, sorghum is mainly grown in drier areas because of its characteristic in resisting drought (Tan, 2015).

Traditionally, sorghum is used for human consumption in Asia, Central America and Africa, while it is used as animal feed in Europe, North America and Australia (Garcia, 2004). China traditionally imports sorghum from Australia to produce rice wine, which is called baijiu. Chinese domestic sorghum mainly goes to food and baijiu industry. Up until recent years, because of corn’s tariff-rate quotas (TRQ) and the controversy over genetically modified organisms (GMOs) in China, sorghum became a perfect animal feed substitute for corn (Liu, 2016).

Figure 1 shows the rapid increase of sorghum use as a feed grain in China starting from marketing year (MY) 2012/13. China’s use of sorghum for feed has increased more than tenfold from MY 2012/13 to MY 2014/15 compared to low steady levels from MY
2006/07 to MY 2011/12 (PS&D, 2017). The significant change is mainly driven by the corn policy shift to the price support policy and temporary reserve program.

**Figure 1. Sorghum as Feed in China from MY 2000/01 to MY 2016/17**

Source: USDA, Foreign Agriculture Service (FAS), Production, Supply and Distribution (PS&D), 2017.

The Chinese government implemented the corn temporary reserve program in 2007 and the price support policy in 2011, which aims to increase rural income and guarantee the nation's grain safety. Based on these policies, the Chinese government purchased corn from farmers at a minimum support price and sold them to national storage facilities (Wu & Zhang, 2017). As shown in Figure 2 and Figure 3, because of increasing support price from 216 yuan in 2008 to 362.9 yuan in 2015, China’s corn stocks increased significantly from approximately 50 million metric tons (MMT) in 2008 to approximately 110 MMT in 2015.
Figure 2. China’s Corn Stocks From 2008 to 2016 (Dollar Per Metric Ton)

Source: Gale, 2013 and 2011-2015 data were collected from various USDA-GAIN reports.

Figure 3. China’s Corn Stocks From 2008 to 2016 (Million Metric Tons)

Source: USDA, Foreign Agriculture Service (FAS), Production, Supply and Distribution (PS&D), 2017.

China’s corn temporary reserve program and price support policy drove a higher corn price and decreased domestic corn consumption. Because of the increased corn price, Chinese feed companies substituted sorghum for corn for feed use. Thus, China’s
imports of sorghum increased significantly; and accordingly, the global sorghum price increased as well.

**Figure 4. China Sorghum Imports from MY 2000/01 to MY 2015/16**

![Graph showing sorghum imports from MY 2000/01 to MY 2015/16]

Source: USDA, Foreign Agriculture Service (FAS), Production, Supply and Distribution (PS&D), 2017.

As shown in Figure 4, before marketing year (MY) 2012/13, China imported a very small amount of sorghum. After MY 2012/13, Chinese sorghum imports increased significantly, and finally increased to 10 million metric tons (MMT) in MY 2014/15 (PS&D, 2017). From the global sorghum trade perspective, China, Mexico and Japan are major sorghum importers; and China ranks first among all sorghum importers in the world.

Figure 5 shows the comparison of sorghum import volumes among major sorghum importers in MY 2015/16, and it shows that China’s sorghum imports far exceed other major sorghum importers (PS&D, 2017). Figure 6 shows that China’s sorghum imports
account for 84% of the world total sorghum imports in MY 2014/15, which indicates China’s sorghum imports occupy an important place in global sorghum trade (PS&D, 2017).

**Figure 5. Top Three Sorghum Importers in the World in MY 2015/16**

Source: USDA, Foreign Agriculture Service (FAS), Production, Supply and Distribution (PS&D), 2017.

**Figure 6. The Proportion of China’s Sorghum Imports in Global Market in MY 2014/15**

Source: USDA, Foreign Agriculture Service (FAS), Production, Supply and Distribution (PS&D), 2017.
Figure 7 shows China’s production price ratio between sorghum and corn. Data prior to 2013 is actual data and data after 2013 is USDA baseline projections. As shown in this figure, China’s production price ratio of sorghum and corn is approximately 0.45 before MY 2012/13, which indicated an attractive sorghum price compared to corn price. Thus, the demand for sorghum increased significantly since MY 2012/13. According to USDA-ERS’s projection, this price ratio showed a significantly increase to 0.615 in MY 2017/18, which indicated a decrease demand of sorghum compared to corn.

![Figure 7. China’s Sorghum/Corn Production Price Ratio](image)

Source: USDA, Foreign Agriculture Service (FAS), Production, Supply and Distribution (PS&D), 2017. USDA, OCE, WAOB, USDA Agricultural Projections to 2026, OCE-2017-1, February 2017. (Note: Data prior to 2013 is actual data and data after 2013 is USDA baseline projections.)

Figure 8 shows sorghum imports for selected major sorghum importers. Data before MY 2016/17 is actual data, and data after MY 2016/17 is USDA-ERS’s baseline projection. Figure 8 shows that Chinese sorghum imports increased dramatically since MY 2012/13, and it increased up to a historical peak in MY 2014/15. In 2012/13, Chinese
sorghum imports reached 1.08 MMT, increased 114% compared to the import volume in 2011/12. In 2013/14, sorghum imports continued to increase, reached 5.78 MMT and increased by 435% compared to the previous year, and growth continued in 2014/15 (International Agricultural Trade Report, 2015).

**Figure 8. Sorghum Imports for Selected Countries (China, Mexico, Japan)**

However, growth of China’s sorghum imports started to change in 2016. In early 2016, China terminated its corn temporary reserve program in Northeastern provinces and Inner Mongolia as a pilot program. Instead, China implemented a new mechanism of “marketized purchases” and a direct payment subsidy policy towards corn, which is tied to corn planting acres (Kim, 2016). The change of China’s corn policy resulted in a lower Chinese domestic corn price, which brought higher corn demand. Thus, the demand for
sorghum, which is one of most important corn substitutes for feed use, decreased significantly.

As shown in Figure 8, China’s sorghum imports started to decrease in 2016 after four years of uninterrupted growth. The total imports of sorghum reached 7.218 MMT in 2016, a 32.54% year-on-year decline (Ministry of Agriculture of the People’s Republic of China). In China, sorghum is usually used in the food industry, brewing industry, and feed industry; and sorghum continued for feed use accounted for 79.44% of China’s total sorghum consumption in 2015. However, this ratio decreased to 63.74% in 2016. The decline of China’s sorghum feed demand and sorghum imports is mainly because of the drop of China’s domestic corn price in response to China’s corn policy reform (Ministry of Agriculture of the People’s Republic of China).

From another perspective, China’s new corn policy that ended its support price stimulated China’s sorghum production and lowered its price. Chinese sorghum planting areas started to increase in 2016. China’s sorghum planting area reached 733 million mu (MM) in 2016, an increase by 8.51% compared to 2015 (Ministry of Agriculture of the People’s Republic of China, 2017). The major planting areas of China’s sorghum are located in the three Northeast provinces of China: Heilongjiang, Jilin, and Liaoning, as well as Inner Mongolia. Sorghum planting areas in these provinces started to increase in 2016. Sorghum planting areas in Heilongjiang, Jilin, and Liaoning reached 52.73 MM, 206.17 MM, and 96.22 MM respectively, while the year-on-year growth rate compared to the
previous year reached 32.3%, 15%, and 22% accordingly. As for Inner Mongolia, the sorghum planting area in 2016 reached 117.14 MM, a decrease by 13.3% compared to the previous year (Ministry of Agriculture of the People’s Republic of China, 2017). Although China’s sorghum planting area increased in 2016, the total domestic output is 2.013 million metric tons (MMT), which declined by 6.69% compared to 2015. The decline is mainly because of extreme weather in northeast China and Inner Mongolia (Ministry of Agriculture of the People’s Republic of China, 2017).

2.2 Current Situation of the U.S. and Global Sorghum Market

Traditionally, sorghum ranks as the third largest cereal grain in the U.S., and it is grown throughout the central region on drylands. In 2015, U.S. sorghum planting areas reached 8.5 million acres, and 597 million bushels were harvested (Crop Production 2015 Summary, 2016). Figure 9 shows the top U.S. sorghum producing states in 2016, which Kansas and Texas accounts for most of the total U.S. sorghum production.

Figure 9. Top U.S. States in Sorghum Production for Grain in 2016 (in 1,000 bushels)
From a global perspective, the U.S. is the largest feed sorghum producer and exporter in the global sorghum market. In MY 2012/13, the U.S. accounts for 70% of the total global sorghum exports (Tran et al., 2015). In addition, U.S. sorghum has a lower price and a lower tannin content, which is more suitable for feed use compared to other countries’ sorghum, such as Australia and Argentina. Figure 10 shows that the U.S. sorghum exports far exceeds other major exporters in MY 2015/16. Figure 11 shows that the U.S. sorghum exports account for 73% of the world’s total sorghum exports in MY 2014/15.

**Figure 10. Major Sorghum Exporters in the World in MY 2015/16**

Source: USDA, Foreign Agriculture Service (FAS), Production, Supply and Distribution (PS&D), 2017.
Since 2013, U.S. sorghum has been widely accepted by China’s feed industry. China’s corn policy change was a great opportunity for U.S. sorghum exporters to open up China’s sorghum market. The U.S. seized the opportunity to get access to the Chinese sorghum market. China’s sorghum imports from the U.S. have risen enormously, making China the most important destination for U.S. sorghum exports since 2013. As shown in Figure 12 and Figure 13, from MY 2012/13 to MY 2014/15, China’s sorghum imports increased from almost zero to approximately 10 million metric tons (MMT), while the U.S. sorghum exports increased by approximately 350% during the same time period, from 2 MMT to 9 MMT (PS&D, 2017).
Figure 12. U.S. Sorghum Exports and Chinese Imports, MY 2000/01-2016/17.

![Graph showing U.S. Sorghum Exports and Chinese Imports, MY 2000/01-2016/17.](image)

Source: USDA, Foreign Agriculture Service (FAS), Production, Supply and Distribution (PS&D), 2017.

Figure 13. U.S. Sorghum Exports from MY 2000/01 to MY 2016/17

![Bar graph showing U.S. Sorghum Exports from MY 2000/01 to MY 2016/17.](image)

Source: USDA, Foreign Agriculture Service (FAS), Production, Supply and Distribution (PS&D), 2017.

Figure 14 shows the global sorghum price remained at a high level from MY 2011/12 to MY 2014/15 because of China’s increasing sorghum demand. It also shows the
decreasing trend of the global sorghum price after MY 2014/15 in response to China’s decreasing sorghum demand in response to China’s new corn policies in early 2016 that reduced the corn price.

![Figure 14. Global Sorghum Price from MY 2000/01 to MY 2016/17](image)

Source: USDA, Foreign Agriculture Service (FAS), Production, Supply and Distribution (PS&D), 2017.

### 2.3 China’s Demand for Sorghum

#### 2.3.1 Tannins

Sorghum contains tannins, which is an anti-nutritional and undesirable factor. Compared with no-tannin containing sorghum, tannin-containing sorghum is rarely used in Chinese feed industry because tannins lower sorghum nutritional value for non-ruminant animals by reducing retention of protein (Diao & Qi, 1999). In addition, the presence of tannins also decreases sorghum’s palatability, inhibits animal’s metabolism and depresses animal’s nutritional intake (Cannas, 2015). Thus, tannins are sorghum’s major restrictive factor in the feed industry. Take the poultry industry as an example. Higher tannin content
of sorghum reduces poultry’s feed intake, feed efficiency and egg production. In addition, higher tannin levels lead to the incidence of blood spots in poultry meat (Hassan, 2013).

China traditionally imports Australian sorghum, which is mainly used as raw material for edible alcohol production in liquor-making enterprises in the food industry. Australian sorghum has a high tannin content, which forms a unique aroma during fermentation, and this is the secret of the unique Chinese liquor flavor. Compared with Australian sorghum, American sorghum has a lower tannin content and a lower price, which is better suited for the feed industry (Liu, 2013). As a consequence, American sorghum became an important feed grain that is used in Chinese feed industry, and its low-tannin content became the important criteria to determine sorghum’s feed quality (China Agriculture, 2016). According to Florentino Lopez, Sorghum Checkoff marketing officer, “U.S. sorghum has a competitive advantage due to the United States’ dependable transportation lines, efficient production methods, and low tannin levels. High-tannin sorghum can be difficult to digest for certain animal varieties” (U.S. Grains Council, 2011).

2.3.2 Sorghum in Swine Production

Because of the significant increase of the Chinese income level, Chinese pork consumption increased more than seven times to 54 million metric tons (MMT) from 7 MMT in last 30 years (Schnitkey, 2013). Chinese pork consumption already accounts for more than half of total global consumption (Schnitkey, 2013). If the growth trend continues, Chinese pork consumption growth is projected to provide more opportunities
for Chinese feed industry. According to Gary Schnitkey, professor of the University of Illinois, Chinese pork consumption is over six times than that of the U.S. in 2013, which means that the potential growth of the Chinese pork market provides potential opportunities for U.S. feed exporters (Schnitkey, 2013).

Figure 15 shows increasing pork consumption in China. Between 1981 and 2013, Chinese pork consumption grew at the rate of 5.7% per year, while the U.S. yearly growth rate is around 1.3% (Schnitkey, 2013). Because of the difference in growth rate, Chinese pork consumption is over six times larger than U.S. pork consumption in 2013. Since the Chinese population increased by 49% while U.S. population grew by 45% during this period, the population growth is not the main reason for Chinese pork consumption growth relative to the U.S. (Schnitkey, 2013). Based on this, we can infer that the income growth is the primary reason for the increase of Chinese pork consumption (Schnitkey, 2013).

**Figure 15. Total Pork Consumption in China from 1981 to 2016 (Million Metric Tons)**
Sorghum contains starch, protein, cellulose, fat and minerals, which can be used as primary energy feed for swine. Protein is the essential nutritional ingredient in sorghum, accounting for 6.8%-19.6% of total nutritional substance (Brouk, 2011). Because of the existence of anti-nutritional factors in sorghum, such as tannins and the disulfide bond, the intake of protein by swine is decreased (Brouk, 2011). In addition, the proportion of amino acids exist in sorghum protein is in disequilibrium, the proportion of amino acids used for swine growth and development is relatively small compared to others. The amino acids used for digestibility in sorghum is lower than that of corn; thus, swine feed should be collated with high digestibility components. According to Yang’s report, high sorghum consumption may lead to constipation, unhairing, allotriophagy and cad pig; and sorghum should be restricted within 20% of swine feed because of poor palatability compared to corn (Yang & Liu, 2011).

However, this does not mean that sorghum is inferior to corn as a feed grain in the swine industry. Compared to corn, sorghum has the same proportion of starch and a higher proportion of protein; sorghum has a higher content of mineral elements than corn; sorghum has a lower content of lipid-soluble vitamins and higher content of water-soluble vitamins. Sorghum has a lower content of linoleic acid and higher content of linolenic acid and palmitoleic acid than corn (Brouk, 2011). Since the content of energy and the amino acids is the standard to evaluate grain feed’s quality, sorghum can substitute for corn as
a feed grain for swine. Gu Hongjuan, professor of Shenyang Agricultural University, stated that people could overcome the lack of limiting amino acids in sorghum by increasing protein content in swine feed, and sorghum can replace corn for feeding swine (no more than 50%) (Gu, 2010). Likewise, Xu Chuntang, professor of China Agricultural University, stated that sorghum is an excellent feed substitute for the reason that, compared to corn, sorghum gives higher lean meat for swine (Xu, 1990).

2.3.3 Sorghum in Beef and Dairy Production

China, behind Brazil and India, ranks the third largest cattle producing country in the world, by far the second largest in Asia. From 1978 to 2013, Chinese beef inventory increased by 115.3%, reached 113.5 million head in 2013 (Han, 2016). Economic growth in the past 30 years rapidly increased the average income for both urban and rural residents, which increased the demand for beef, where further increased the demand for animal feed (Han, 2016).

According to a survey of feedlot nutritionists, corn is traditionally accepted as the primary energy source for feeding cattle, and sorghum is a secondary energy source (Brouk, 2011). Corn is traditionally used in cattle feed instead of sorghum because it is more available and provides higher meat production. However, this does not mean that sorghum is inferior to corn as a feed grain. Sorghum has advantages in feeding cattle because of its higher protein content and drought resistance (Brouk, 2011).
Sorghum’s higher protein content is a distinct advantage for feed use compared to corn. It is estimated that sorghum contains around 10% higher crude protein than that of corn (Brouk, 2011). Thus, sorghum can be used as a replacement feed grain for corn, and the use of sorghum in cattle feed will decrease the use of protein supplements that is needed for corn. In addition, sorghum is a “nutrient-rich, water-sipping, high-yielding crop that offers essential nutrients for optimal milk production” (Hightower, 2010).

Drought resistance is the other advantage of sorghum for feed use. According to Steve Amasson, an Economist of Texas AgriLife Extension, “forage sorghum is a drought resistant forage that can yield similar milk production to corn in dairy cows when using high-quality varieties and managed properly. However, its profitability compared to corn is based on variables. For a dairy producer who lives in a dry region, where water is limited, sorghum forage is without a doubt a very economical feed. Sorghum forage requires lower input costs because it requires less water and seed costs are much lower” (Hightower, 2010).

2.3.4 Sorghum in Baijiu Production

Traditionally, one of the most common uses of sorghum in China is the production of baijiu. Baijiu is a distilled liquor with 30% to 60% alcohol content. Baijiu is considered as the most popular alcoholic beverage in China, and it has a long cultural history, dating approximately 4,000 years back to Xia Dynasty (Barris, 2013). In recent history, baijiu has
been widely accepted as the drink of politicians, generals, and businesspeople; it is served typically at official functions and celebrations.

_Baijiu_ is normally made from sorghum or “a mixture of barley, corn, rice, wheat, and sorghum, containing abundant volatile components such as esters and organic acids” (Zheng, 2016). The production of _baijiu_ involves four major steps: material preparation, fermentation, distillation, and aging (Zheng, 2016). _Baijiu_ has different names along with different flavors, and it can be categorized by different product flavors in terms of production techniques as well (Zheng, 2016). “Different types of _baijiu_ have their home microbiota and flavor because of their distinct production techniques” (Zheng, 2016).

The increasing demand of _baijiu_ is one of the most important reasons for China to import sorghum from the global market. Anna Bell, a researcher at the East-West Center, stated that the Chinese domestic sales of _baijiu_ increased by 6% in 2015 compared to 2014 (Bell, 2015). According to Tim Lust, CEO of National Sorghum Producers, “[The] demand is not just for livestock feed...A large portion of alcohol in China is made out of sorghum, and so that’s a significant market.” (Jibben, 2014).

### 2.4 China’s Feed Industry Development

China’s feed industry plays an important role in support of its livestock industry, as well as creating agricultural export opportunities for the United States. China is the leading importer of soybeans, sorghum and barley across the world, which the derived demands for these commodities are generated by the feed industry (Gale, 2015). The
Chinese government supported Chinese feed industry in the late 1970s, but now Chinese feed industry is consisting of private companies with strong competition in the global agricultural trade market (Gale, 2015).

According to the report by the Food and Agriculture Organization of the United Nations (FAO), China became the largest feed consumer in 2014 (FAO, 2014). Currently, China consumes about one-fifth of the world’s feed ingredients; however, compared to other industries, the Chinese feed industry is still an emerging industry (Gale, 2015). The Chinese feed industry started in 1978 along with China’s Reform and Opening-up Policy and grew with the implementation of this policy afterward. It consists of three phases: the start-up, rapid development, and integration phase.

**2.4.1 Start-up Phase**

From 1978-1984, the Chinese feed industry was at the start-up stage. China has a long agricultural history in feeding animals; however, animal feed was considered as a secondary activity with rural areas growing their own feed rather than buying it from industry (China Feed Industry Association, 2012).

After the establishment of the People’s Republic of China (PRC) in 1949, there was a greater demand for the feed industry because of faster agricultural development along with economic growth. Furthermore, some households started to specialize in producing animal feed at that time. However, the productivity level remained low because of China’s restrictive planned economy. In 1978, China initiated the Reform and Opening-up Policy
to fully stimulate economic development. The rapid development of China’s living standard and the changing diet structure forced the development of the feed industry (China Feed Industry Association, 2012). With rising living standards, households consume more meat, which in turn promotes the demand for animal feed.

2.4.2 Rapid Development Phase

From 1985, the Chinese feed industry began the rapid development stage. At the end of 1990, China had already built 6,045 feed companies with a production capacity of 1 metric ton (MT) of feed per hour, and 551 companies reached a production capacity of 5 MT per hour. Therefore, the total national annual feed production capacity reached 60.9 million metric tons (MMT) in 1990 (China Feed Industry Association, 2012). At the same time, China successfully developed feed research and relevant educational systems nationwide. Between 1990 and 2000, the Chinese feed industry kept growing at a fast rate and an integrated industrial system was finally built in 1999. 1,937 Chinese feed companies had a production capacity of 5 MT per hour in 1999, and China’s total feed production reached 68.71 MMT (China Feed Industry Association, 2012).

The rapid development of the Chinese feed industry was closely related to Chinese agricultural development. During this rapid development phase, the critical shortage of land was a fundamental reality of China. China has approximately 20% of the world’s population, but it only contains 10% of the world’s arable land and 6-7% of the world’s water resources (Hurley, 2015). Thus, there exists competition among different
agricultural products, and a challenge to decide how to efficiently use limited arable lands. However, China found its way to solve this problem by allocating arable lands efficiently and importing agricultural products from overseas. The Governor’s Grain Bag Policy and agricultural liberalization reform are two critical agricultural policies during this period of time.

From 1995, China implemented the Governor’s Grain Bag Policy to achieve a self-sufficiency rate of 95% for primary grains. This policy aimed to balance grain supply, grain demand and grain market prices in China (Crook, 1997 & 1999). Main guidelines of the Governor’s Grain Bag Policy are as follows: “1. Stabilize area sown to grain crops; 2. Guarantee investment in factories manufacturing agricultural inputs like chemical fertilizer to stimulate grain production; 3. Guarantee that certain quantities of grain are put into stocks; 4. Insure that transfers of grain in and out of a province are completed; 5. Stabilize urban residents’ concerns by supplying grains and edible oils; 6. Stabilize grain and edible oil prices; 7. Government should control 70 to 80% of commercial grain sales; 8. Develop means to control grain markets; 9. Raise the percentage of commercial grain sales; 10. Control grain imports and exports; and 11. Raise level of grain self-sufficiency” (Crook, 1997 & 1999).

A majority of the objectives were achieved, and grain production was boosted in the late 1990s. Although the Chinese central government eliminated this policy in 2004, high-ranking Chinese officials still believe that agricultural self-efficiency is very important
Simultaneously, China started a liberalization reform in the grain market and started to import a small amount of grain (Hansen, 2014). There also exists a great debate upon grain liberalization reform. Lou Jiwei, China’s Minister of Finance, “called for substantial reform of existing agricultural policies as a supplement to a reduction of agricultural subsidies, and proposed that China should prepare to gain the global market” (Hurley, 2015). COFCO Chairman, Ning Gaoning, “openly advocated for liberalized and transparent agricultural trade policy” (Hurley, 2015). The liberalization reform in the grain market continued. However, Niu Dun, former Vice Minister of Agriculture, “came out strongly against more liberalized grain imports” (Hurley, 2015). In contrast, Li Keqiang, the State Prime Minister, said: “In the past, we have focused on expanding production and grain quality, now we need reforms for better buying, selling, storage to contribute to national security” (Hurley, 2015).

2.4.3 Integration Phase

After stepping into the 21st century, the Chinese feed industry entered the integration phase. China is a country with massive consumption potential with a population of 1.35 billion, and China’s urbanization rate grew quickly in the past 30 years (Secretary-General of the OECD, 2013). Currently, 54% of the Chinese population lives in
urban area, and the Chinese central government is targeting this urbanization rate to reach 60% by 2020 (The Economist, 2014). China’s population is expected to reach 1.45 billion by 2030, and its increasing population will tremendously promote food demand (Lu, 2011). Meanwhile, because of climate change and the industrialization process, China’s cropland is projected to diminish as well (Lu, 2011). Because of high urbanization rates, the Chinese economic structure is transferring from a producer-driven economy to a consumer-driven economy (Sagami, 2011). Accordingly, the food consumption structure is shifting from grain food to meat food; thus, the high meat demand is promoting a fast-developing feed industry.

**Figure 16. Estimated Uses of Grains in China, 2004-2024**


According to Figure 16, China’s feed use of grains started to increase significantly from MY 2004/05, and projected to increase through until MY 2024/25. Figure 16 demonstrates the rapid development of the Chinese feed industry in the past 13 years and a positive projection for future development.

Although the feed industry has continued to expand, some negative issues developed during this integration phase. Because of excessive production capacity with higher costs, the benefits of the feed industry dropped significantly. Simultaneously, obtaining high quality and safe feed ingredients was gradually becoming a new challenge for feed companies (China Feed Industry Association, 2012). In addition, from the global market perspective, Chinese feed companies were facing fierce competition with foreign feed companies after China joined the World Trade Organization (WTO) (Weissmann, 2016). To survive in this situation, mergers and reorganization became the best choice for many Chinese feed enterprises. Because of this, numerous large feed companies with the production capacity of 1 MMT per year emerged in China since the beginning of the 21st century (China Feed Industry Association, 2012). In MY 2014/15, China finally became the world’s largest feed grain importer, livestock producer and the world’s largest feed manufacturer (Gale, 2015).

In summary, in the 1970s to 1980s, the Chinese government launched the feed industry because of the changing diet and the demand for food security. In the 1980s to 1990s, Chinese backyard producers used local feed grains, and animal feed imports were
very limited. In the 2000s, the Chinese government started to upgrade the feed industry by accelerating livestock production and construction of the feed industry infrastructure (Gale, 2015).
Chapter 3: Modeling

3.1 Methods and Procedure

Agricultural trade models, trade projections, and policy analysis play an important role for government officials and agricultural exporters in analyzing agricultural policies, trade negotiations, trade disputes, and long-term marketing strategy formulation. China is the world’s largest agricultural producing country, a strong force in international trade, and a critical component in international agricultural trade models. China’s fast-changing economy is driven by both rapid economic development and is transitioning to a market-oriented system. China affects global agricultural markets in a number of ways, from growing import demand for agricultural commodities, such as corn, meat, cotton, and soybeans, and a rising global presence in horticulture exports. However, China’s agricultural trade is often abruptly disrupted by changes in domestic market and trade policies, making it difficult for modeling and projecting China’s agricultural trade. In addition, the Chinese government continue to wield significant influence over trade decisions, although this influence is declining with WTO policy reforms.

Domestic and global agricultural trade policies are critical determinants of China’s involvement in international agricultural markets. At the same time, model integrity is dependent upon model structure, data quality and an in-depth understanding of the limits and issues with data. The uncertainty in China’s changing agricultural structure can have large impacts on domestic and international markets with respect to price
transmissions and the speed at which agriculture sectors adjust. Understanding and capturing changing market structure and pricing mechanisms are critical to a well-specified model.

The modeling system used in this thesis contains both USDA-ERS China model and the Country-Commodity Linked System (CCLS). The USDA-ERS China model is a large scale multi-country and multi-commodity partial equilibrium dynamic simulation model, and this model was developed for conducting scenarios at the national and regional level. The CCLS combines 42 country or regional models, and determines equilibrium prices and trade, to simultaneously clear 24 agricultural commodity markets and enable scenario projections by year, for 10 years into the future. The system as a whole contains about 15,000 equations. The CCLS includes supply, use, prices, and policies; and the CCLS is used for analyzing the impacts toward U.S. and international agricultural markets and trade driven by potential policy changes. Both the USDA-ERS China model and the CCLS use data from the USDA-FAS-PS&D, China's National Bureau of Statistics, and Chinese government agencies.

In an open economy, a simplified U.S.-China sorghum trade model can be expressed by equations as

\begin{align}
    ED_{CH}^{SG} &= D_{CH}^{SG} - S_{CH}^{SG} + STK_{CH}^{SG} \\
    ES_{W}^{SG} &= S_{W}^{SG} - D_{W}^{SG} + STK_{W}^{SG} \\
    ED_{CH}^{SG} &= ES_{W}^{SG}
\end{align}
Where

\[ ED_{CH}^{SG} = \text{China’s excess sorghum demand} \]

\[ D_{CH}^{SG} = \text{China’s domestic sorghum demand} \]

\[ S_{CH}^{SG} = \text{China’s domestic sorghum supply} \]

\[ STK_{CH}^{SG} = \text{China’s sorghum stock change} \]

\[ ES_{W}^{SG} = \text{Excess sorghum supply of all the world excluding China} \]

\[ S_{W}^{SG} = \text{Sorghum supply of all countries in the world excluding China} \]

\[ D_{W}^{SG} = \text{Sorghum demand of all countries in the world excluding China} \]

\[ STK_{W}^{SG} = \text{World’s sorghum stock change excluding China.} \]

Equation (3) is the market clearing equation in this simplified U.S.-China sorghum trade model. At the same time, Figure 17 describes the U.S.-China sorghum trade model in an open economy, assuming no other countries. The left panel represents the sorghum importing country, which is China, while the right panel represents the sorghum exporting country, which is the United States. Looking at China, the intersection represents the equilibrium of supply and demand, which results in an excess demand in the global market. The right panel, the intersection in the U.S. diagram represents the equilibrium of supply and demand as well, which results in an excess supply in the global sorghum market. In the global market, the intersection of the excess supply and excess demand result in the U.S.-China sorghum price (McCalla & Josling, 1985).
To examine the impacts of China’s policies on the market access of U.S. sorghum exports to China, a more detailed excess demand equation is represented for sorghum below

\[ ED_{CH}^{SG} = D_{CH}^{SG}(P_{CH}^{SG}, A, \alpha) - S_{CH}^{SG}(P_{CH}^{SG}, B, \beta) - \Sigma IM P_{CH}^{SG} + \Delta STK_{CH}^{SG} \]

Where previous definitions hold and

\[ P_{CH}^{SG} = \text{China’s domestic sorghum price} \]

\[ A = \text{The vector of demand shifters (population, income, price of substitutes and complements, etc.)} \]

\[ \alpha = \text{China’s sorghum policies (demographic factors, government policies and regulations)} \]

\[ S_{CH}^{SG} = \text{China’s domestic supply of sorghum} \]
\( B = \) The vector of supply shifters (input costs, price of substitutes, technological progress and number of producers, etc.)

\( \beta = \) The policy instruments that affect production decisions (farm size, yield, cost of production, etc.)

\( \Sigma IM\ell^{SG}_{CH} = \) The sum of China’s imports from other countries (excluding the U.S.)

\( \Delta STK^{SG}_{CH} = \) The change of sorghum stocks in China

### 3.2 Demand

As discussed in chapter two, sorghum demand is a derived demand from the demand for food and feed, and the primary demand is for feed. Total demand equals the sum of food demand and feed demand. Thus, China’s domestic demand for sorghum can be expressed as

\[
D^{SG}_{CH} = D^{\text{Food}} + D^{\text{Feed}}
\]

Where previous definitions hold and

\( D^{\text{Food}} = \) China’s domestic food demand for sorghum

\( D^{\text{Feed}} = \) The domestic feed demand for sorghum

Food demand is modeled by population and per capita consumption for both rural and urban areas, which is a function of its own consumer price, substitute food prices, and income. Feed demand is a function of derived feed demand, based on the quantity of pork and poultry produced in the commercial and specialized livestock sectors (Hansen, 2012).
From equation (5), each of the variables in the above equation of China’s domestic demand for sorghum are defined below—$D_t^{Food}$ and $D_t^{Feed}$. The food demand equation can be expressed as the sum of urban food demand ($D_t^{pcu} \cdot POP^u$) and rural food demand ($D_t^{pcr} \cdot POP^r$). Urban food demand equals per capita food demand in China’s urban areas ($D_t^{pcu}$) multiplied by China’s population in urban areas ($POP^u$). Rural food demand equals per capita food demand in China’s rural areas ($D_t^{pcr}$) multiplied by China’s population in rural areas ($POP^r$).

(6)  
$$D_t^{Food} = D_t^{pcu} \cdot POP^u + D_t^{pcr} \cdot POP^r$$

Where previous definitions hold and

$D_t^{pcu} =$ Per capita food demand for sorghum in China’s urban areas at time t  

$POP^u =$ China’s population in urban area at time t

$D_t^{pcr} =$ Per capita food demand for sorghum in China’s rural areas at time t  

$POP^r =$ China’s Population in rural areas at time t

From equation (6), per capita food demand for sorghum at time t in urban and rural areas are defined as $D_t^{pcu}$ and $D_t^{pcr}$ respectively. $D_t^{pcu}$ can be expressed as China’s per capita urban food demand for sorghum in the previous year ($D_{t-1}^{pcu}$) plus $D_{t-1}^{pcu}$ multiplied by the percentage change of food consumption for certain commodities in urban areas: sorghum, egg, poultry, pork, beef and veal, etc. The percentage change of food demand in urban areas ($\% \Delta Q$) equals the price elasticity ($\varepsilon = \frac{\% \Delta Q}{\% \Delta P}$) multiplied by the percentage change of price ($\% \Delta P$) for each of the above commodities, which can be
presented as \( \%\Delta P \cdot e \). This method of multiplying the elasticity and the percent change of price is used extensively in this model to obtain percentage change of quantities. For sorghum, we use the own-price elasticity. For other commodities, we use cross-price elasticities (e.g., \( \%Q^{SG}/\%P^{pork} \)).

\[(7) \quad D^p_{t-1} = D^p_{t-1} \times (1 + \%\Delta P_{SGU} \cdot e^{SG}_{SGU} + \%\Delta P_{Egg} \cdot e^{SG}_{Egg} + \%\Delta P_{Poultry} \cdot e^{SG}_{Poultry} + \%\Delta P_{(Beef & Veal)} \cdot e^{SG}_{(Beef & Veal)} + \%\Delta P_{Other} \cdot e^{SG}_{Other} + \%\Delta Per \text{ capita GDP urban} \cdot e^{SG}_{PC}) \]

Where previous definitions hold and

\( \%\Delta P_{SGU} = \) Percentage change of sorghum price in urban areas

\( e^{SG}_{SGU} = \) Own-price elasticity for sorghum food demand in urban areas

\( \%\Delta P_{Egg} = \) Percentage change of egg price in urban areas

\( e^{SG}_{Egg} = \) Cross-price elasticity between egg and sorghum food demand in urban areas

\( \%\Delta P_{Poultry} = \) Percentage change of poultry price in urban areas

\( e^{SG}_{Poultry} = \) Cross-price elasticity between poultry and sorghum food demand in urban areas

\( \%\Delta P_{(Beef & Veal)} = \) Percentage change of pork price in urban areas

\( e^{SG}_{(Beef & Veal)} = \) Cross-price elasticity between pork and sorghum food demand in urban areas

\( \%\Delta P_{Other} = \) Percentage change of other price in urban areas

\( e^{SG}_{Other} = \) Cross-price elasticity between other and sorghum food demand in urban areas

\( \%\Delta Per \text{ capita GDP urban} = \) Percentage change of per capita GDP in urban areas

\( e^{SG}_{PC} = \) Cross-price elasticity between per capita GDP and sorghum food demand in urban areas
\( e_{(Beef \ and \ Veal)}^{SG} \) = Cross-price elasticity between beef & veal and sorghum food demand in urban areas

\( \%\Delta P_{Otheru} \) = Percentage change of other commodities’ price in urban areas

\( e_{Otheru}^{SG} \) = Cross-price elasticity between other commodities and sorghum food demand in urban areas

\( \%\Delta Per \ capita \ GDP \ urban \) = Percentage change of per capita GDP in urban areas

\( e_{PC}^{SG} \) = Income elasticity of sorghum food demand in urban areas

A similar method is used to obtain per capita food demand in rural areas \( (D_{t}^{pcr}) \). However, in rural areas, commodities are limited to sorghum and pork. Equation (8) is similar to equation (7) by changing the percentage change of food demand to reflect this restriction in rural areas

\[ (8) \quad D_{t}^{pcr} = D_{t-1}^{pcr} \times (1 + \%\Delta P_{SGR} \cdot e_{SGR}^{SG} + \%\Delta P_{Porkr} \cdot e_{Porkr}^{SG} + \%\Delta P_{Otherr} \cdot e_{Otherr}^{SG} + \%\Delta Per \ capita \ GDP \ rural \cdot e_{PC}^{SG}) \]

Where previous definitions hold and

\( \%\Delta P_{SGR} \) = Percentage change of sorghum price in rural areas

\( e_{SGR}^{SG} \) = Own-price elasticity for sorghum food demand in rural areas

\( \%\Delta P_{Porkr} \) = Percentage change of pork price in rural areas

\( e_{Porkr}^{SG} \) = Cross-price elasticity between pork and sorghum food demand in rural areas

\( \%\Delta P_{Otherr} \) = Percentage change of other commodities’ price in rural areas
\[ e^{SG}_{Other} = \text{Cross-price elasticity between other commodities and sorghum food demand in rural areas} \]

\[ \%\Delta \text{Per capita GDP rural} = \text{Percentage change of per capita GDP in rural areas} \]

\[ e^{SC}_{PC} = \text{Income elasticity of sorghum food demand in rural areas} \]

Now we turn to **feed demand**. From equation (5), China’s domestic feed demand of sorghum at time t is defined as \( D_t^{Feed} \), which also can be expressed as China’s domestic feed demand of sorghum in previous year \( (D_{t-1}^{Feed}) \) plus the \( D_{t-1}^{Feed} \) multiplied by the sum of the percentage change of sorghum feed demand of certain commodities: sorghum and corn. The percentage change of sorghum feed demand for both sorghum and corn equals the respective price elasticities of sorghum and corn multiplied by their corresponding percentage change of price

\[
(9) \quad D_t^{Feed} = D_{t-1}^{Feed} \times (1 + \%\Delta P_{SG} \cdot e^{SG}_{SG} + \%\Delta P_{Corn} \cdot e^{SG}_{Corn} + \%\Delta GFR \cdot e^{SG}_{GFR})
\]

Where previous definitions hold and

\[ D_t^{Feed} = \text{China’s domestic feed demand of sorghum at time } t \]

\[ D_{t-1}^{Feed} = \text{China’s domestic feed demand of sorghum at time } t-1 \]

\[ \%\Delta P_{SG} = \text{Percentage change of domestic sorghum price} \]

\[ e^{SG}_{SG} = \text{Own-price elasticity for sorghum feed demand} \]

\[ \%\Delta P_{Corn} = \text{Percentage change of domestic corn price} \]

\[ e^{SG}_{Corn} = \text{Cross-price elasticity between corn and sorghum feed demand} \]

\[ \%\Delta GFR = \text{Percentage change of grain feeding requirement} \]
\( e_{GFR}^{SG} \) = Elasticity of sorghum feed demand with respect to a change in the grain feeding requirement

Table 1 listed the own-price elasticities and cross-price elasticities for feed demand of sorghum and corn

**Table 1. Own and Cross Price Elasticities for Sorghum Feed Demand**

<table>
<thead>
<tr>
<th>Percentage Change of Price</th>
<th>Sorghum</th>
<th>Corn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorghum</td>
<td>-1.1</td>
<td>0.02</td>
</tr>
<tr>
<td>Corn</td>
<td>1.1</td>
<td>-0.2</td>
</tr>
</tbody>
</table>


### 3.3 Supply

China’s domestic supply for sorghum \( S_{CH}^{SG} \) equals China’s domestic harvested areas \( HA_{CH}^{SG} \) multiplied by China’s domestic sorghum yields \( Y_{CH}^{SG} \), which can be expressed as

\[
S_{CH}^{SG} = HA_{CH}^{SG} \cdot Y_{CH}^{SG}
\]

\( S_{CH}^{SG} \) = China’s domestic supply of sorghum

\( HA_{CH}^{SG} \) = China’s domestic sorghum harvested areas

\( Y_{CH}^{SG} \) = China’s domestic sorghum yields

From equation (10), China’s domestic sorghum harvested areas at time \( t \) is defined as \( HA_{t}^{SG} \), which can be expressed as China’s domestic sorghum harvested areas in the
previous year \( (H_{A_{t-1}}^{SG}) \) plus the sum of \( HA_{t-1}^{SG} \) multiplied by the percentage change of sorghum harvested areas results from certain commodities: sorghum, corn and soybeans. This is because Chinese farmers can choose growing commodities with higher expected returns. The percentage change of harvested areas for these commodities equals their corresponding expected return elasticities of sorghum harvested areas multiplied by the percentage change of their expected returns accordingly

\[
(11) \quad HA_{t}^{SG} = HA_{t-1}^{SG} \times (1+%\Delta \text{Sorghum Expected Return} \cdot e_{SER} + %\Delta \text{Corn Expected Return} \cdot e_{CER}^{SG} + %\Delta \text{Soybeans Expected Return} \cdot e_{SoyER}^{SG})
\]

Where previous definitions hold and

\( %\Delta \text{Sorghum expected return} = \) Percentage change of sorghum expected returns

\( e_{SER} = \) Elasticity of sorghum harvested areas with respect to a change in the sorghum expected return

\( %\Delta \text{Corn expected return} = \) Percentage change of corn expected returns

\( e_{CER}^{SG} = \) Elasticity of sorghum harvested areas with respect to a change in the corn expected return

\( %\Delta \text{Soybean expected return} = \) Percentage change of soybean expected return

\( e_{SoyER}^{SG} = \) Elasticity of sorghum harvested areas with respect to a change in the soybean expected return
From equation (10), China’s domestic sorghum yields, $Y_{CH}^{SG}$, can be expressed as China’s domestic sorghum yields in the previous year ($Y_{t-1}^{SG}$) plus $Y_{t-1}^{SG}$ multiplied by the percentage change of three-year sorghum yields’ moving average.

$$Y_{t}^{SG} = Y_{t-1}^{SG} \times (1 + \%\Delta MA_{SR})$$

Where previous definitions hold and

$$\%\Delta MA_{SR} = \text{percentage change of three-year sorghum yields’ moving average}$$

### 3.4 Imports

China’s sorghum imports from the global market at time $t$ ($IMP_{t}^{SG}$) equals the sum of China’s sorghum imports from the global market in the previous year ($IMP_{t-1}^{SG}$), $IMP_{t-1}^{SG}$ multiplied by the percentage change of sorghum imports results from the price change of sorghum imports, and $IMP_{t-1}^{SG}$ multiplied by the percentage change of sorghum imports results from the change of China’s feed demand. The percentage change of the sorghum imports results from the price change of sorghum imports equals the price elasticity of China’s sorghum imports ($e_{IP}$) multiplied by the percentage change of sorghum import price ($\%\Delta IP$), while the percentage change of sorghum imports results from the change of China’s feed demand equals China’s feed demand elasticity of China’s sorghum imports ($e_{Feed}$) multiplied by the percentage change of China’s feed demand ($\%\Delta D_{Feed}$)

$$IMP_{t}^{SG} = IMP_{t-1}^{SG} \times (1 + \%\Delta IP \cdot e_{IP}^{SG} + \%\Delta D_{Feed} \cdot e_{Feed}^{SG})$$

44
\[ IMP_t^{SG} = \text{China’s sorghum imports from the global sorghum market at time } t \]
\[ IMP_{t-1}^{SG} = \text{China’s sorghum imports from the global sorghum market at time } t-1 \]
\[ \%\Delta IP = \text{Percentage change of China’s sorghum import price} \]
\[ e_{IP}^{SG} = \text{Price elasticity of China’s sorghum imports} \]
\[ \%\Delta D_{Feed} = \text{Percentage change of China’s feed demand} \]
\[ e_{Feed}^{SG} = \text{Elasticity of China’s sorghum imports with respect to a change in the China’s feed demand} \]

### 3.5 Stock Change

China’s domestic sorghum stock change \((STK_t^{SG})\) equals China’s domestic sorghum stock in the previous year \((STK_{t-1}^{SG})\) plus the product of \(STK_{t-1}^{SG}\) multiplied by the percentage change of sorghum stocks. The percentage change of sorghum stocks equals the price elasticity of sorghum stock \((e_{FMP})\) multiplied by the percentage change of sorghum price \((\%\Delta P_{FMP})\)

\[
(14) \quad STK_t^{SG} = STK_{t-1}^{SG} \times (1 + \%\Delta P_{FMP} \cdot e_{FMP}^{SG})
\]

Where

\[ STK_t^{SG} = \text{China’s domestic sorghum stock change at time } t \]
\[ STK_{t-1}^{SG} = \text{China’s domestic sorghum stock change at time } t-1 \]
\[ \%\Delta P_{FMP} = \text{Percentage change of sorghum price} \]
\[ e_{FMP}^{SG} = \text{Price elasticity of sorghum stock} \]
3.6 Anticipated Results

We discussed that China’s sorghum imports are related to China’s sorghum import price and China’s domestic feed demand (Equation 13). The shock of China’s domestic sorghum imports will directly affect China’s sorghum import price and China’s domestic feed demand. In economic terms, the expected results are as follows.

*From China’s sorghum market perspective*, as shown in figure 18, anticipated results expect that the decrease of sorghum imports will raise China’s domestic sorghum price. In figure 18, S is China’s domestic sorghum production plus imports. As China’s domestic sorghum supply shifts from S to $S^1$ that resulted from the decline of China’s sorghum imports, China’s domestic sorghum price increases from $P^1$ to $P^2$. Thus, China’s sorghum demand for feed use decreases accordingly from $Q^1$ to $Q^2$ because of the higher sorghum price $P^2$. Simultaneously, China’s sorghum planting areas and production will increase as well in response to this higher sorghum price.

*Figure 18. China’s Sorghum Market—When Imports Fall*
From the U.S. and the global sorghum market perspective, as shown in Figure 19, the decrease of China’s sorghum imports will result in less sorghum demand in global markets since China is such a large market. With the same global sorghum supply, less demand leads to a lower global sorghum price. In Figure 19, with the decrease of China’s sorghum imports, global sorghum demand shifts inward; thus, the global sorghum price moves down from \( P^1 \) to a lower price \( P^2 \). U.S. sorghum exports decreases as well because of the lower global sorghum price and less global sorghum demand. Figure 19 is repeated as the left panel in Figure 20, and the right panel is the U.S. market.

As shown in Figure 20, as the global sorghum price decreased from \( P^1 \) to \( P^2 \), U.S. sorghum exports decreased to a lower level as well from Exports 1 to Exports 2. However, other major sorghum importers, such as Japan and Mexico, will gain benefits from the lower global sorghum price, and their sorghum imports will increase.

Figure 19. Global Sorghum Market—Decrease in China’s Imports
Next, we return to China’s perspective, but now we focus on corn, a substitute for sorghum. *From China’s domestic corn market perspective*, as shown in Figure 21, anticipated results expect that China’s higher domestic sorghum price from Figure 18 will result in China’s higher domestic corn price in the short term. Because of the higher sorghum price, animal feed producers will substitute corn for sorghum. With the same domestic supply, higher domestic corn demand will lead to higher domestic corn prices. In Figure 21, China’s domestic corn demand shifts from \( D \) to \( D^1 \), and as a result, the domestic corn price increased from \( P^1 \) to \( P^2 \). Thus, we can anticipate that a higher sorghum price in China will in turn stimulate China’s domestic corn price to go up in the short term. In the long term, the corn price showed return to equilibrium because higher
corn prices will lead to a shift in corn supply, which means more corn planting areas and higher corn production in China.

However, since the magnitude of China’s sorghum market is very small compared with China’s corn market, the decrease of China’s sorghum imports may impose a slight impact towards China’s domestic corn market.

**Figure 21. China's Domestic Corn Market**

*From China’s domestic pork and poultry perspective*, assuming Chinese feed companies do not substitute corn for sorghum, anticipated results expect that the price of China’s pork and poultry will increase respectively. Because of the higher sorghum price in China (Figure 18), it will be more costly to feed animals in Chinese feed companies as the price of sorghum, an input, increases. Since sorghum demand is a derived demand for pork and poultry, the price of poultry and pork should be higher in China’s domestic market as the price of an input increases. However, feed companies may choose to
substitute corn for sorghum because of the increased sorghum price and the decreased corn price; thus, the price of poultry and pork may not change significantly.
Chapter 4: Empirical Results

This thesis aims to analyze the impacts on U.S. and global sorghum trade, and whether China will continue importing sorghum from the global sorghum market for feed use, if the Chinese government cancels its corn price support policy and corn temporary reserve program nationwide. To answer this question, this thesis used the USDA-ERS China Model and the Country-Commodity Linked System (CCLS) to simulate the impacts of a reduction of China’s imports on U.S. sorghum exports and the anticipated reduction of sorghum’s global price, global production, and global trade volumes. The simulation will be based on three scenarios:

1. If China’s sorghum import volume decreased by 50% from the USDA-ERS’s baseline projection;
2. If China’s sorghum import volume decreased by 35% each year from the previous year;
3. If China’s sorghum import volume decreased by 70% from USDA-ERS’s baseline projection in year one and by 90% from the USDA-ERS’s baseline projection in subsequent years.

4.1 Baseline Description

China’s domestic sorghum market from MY 2016/17 to MY 2026/27 is projected by USDA-ERS, which is treated as the baseline projection for all three scenarios in this thesis (Figure 22). Data before MY 2016/17 is actual data, and data after MY 2016/17 is USDA-ERS’s
baseline projection. The output base of sorghum and corn for all three scenarios are listed in Appendix 9 and Appendix 10.

**Figure 22. China’s Domestic Sorghum Demand and Imports (Million Metric Tons)**

![Graph showing China’s domestic sorghum demand and imports](image)

Source: USDA, Foreign Agriculture Service (FAS), Production, Supply and Distribution (PS&D), 2017. USDA, OCE, WAOB, USDA Agricultural Projections to 2026, OCE-2017-1, February 2017. (Note: Data prior to 2016 is actual data and data after 2016 is USDA baseline projections.)

Figure 22 describes the USDA-ERS’s baseline projection prior to any scenarios of China’s domestic sorghum market, including China’s sorghum demand (both food demand and feed demand) and imports. This USDA-ERS China model and the CCLS refer to the mathematical solution of a simultaneous set of differential equations in Chapter three (Pindyck and Rubinfeld, 1981), and this model is a mathematical model which combines both mathematical and logical concepts that emulate different scenarios (OLAP, 2017). All the variables involved in the USDA-ERS China model and the CCLS in Chapter three will be affected if we shock China’s sorghum imports (Equation 13) in terms of the different scenarios.
The simulation process includes: 1. Define the problem or system that is intended to simulate; 2. Formulate the model; 3. Test the model; compare its behavior with the behavior of the actual problem; 4. Identify and collect the data needed to test the model; 5. Run the simulation; 6. Analyze the results of the simulation; 7. Validate the simulation (Pandey, 2006). This chapter focuses on step 6.

Figure 22 shows the significant increase of China’s sorghum food demand, feed demand, and imports from marketing year (MY) 2012/13 to MY 2014/15. Figure 22 shows that China’s sorghum food demand has a small change after MY 1998/99, which has a slight impact toward China’s sorghum imports. This also indicates that the increase of China’s sorghum imports is from the increase of China’s feed demand. China’s sorghum feed demand was almost zero before MY 2012/13, but it reached 11,000 MT in MY 2014/15 (PS&D, 2017). Figure 22 also shows the actual data and projections of China’s sorghum imports. It shows that China rarely imported sorghum from the global market before MY 2012/13; however, imports increased to 10,000 MT in MY 2014/15 (PS&D, 2017).

Figure 22 also indicates that both China’s sorghum demand and imports started to decline in MY 2015/16. The decline of both China’s sorghum imports and China’s sorghum demand stems from China’s decreased corn price in MY 2015/16. In early 2016, China ended its price support policy and temporary reserve program for corn in two areas, Northeastern provinces and Inner Mongolia, as a pilot program to decrease China’s
excessive corn stockpiles. This new corn policy reduced China’s corn price, and China’s feed companies decreased substituting low-priced sorghum for high-priced corn. Thus, China’s sorghum imports and demand decreased as a result of the implementation of this new corn policy. According to USDA-ERS’s baseline projection, this declining trend will continue, and China’s sorghum imports will decline from 5,750 MT to 1,000 MT from MY 2016/17 to MY 2026/27.

4.2 Scenarios

Below list results of the three scenarios described above. For each scenario, there was a shock to the import equation. The shocks were implemented in MY 2018/19, and all scenarios started in MY 2018/19 in the time frame from MY 2018/19 to MY 2026/27. These scenarios were chosen because the end of these scenarios are near previous low levels of China’s sorghum imports before MY 2012/13, which is close to zero.

4.2.1 Scenario One: If China’s Sorghum Import Volume Decreased by 50% From USDA’s Baseline Projection

4.2.1.1 The Impacts Toward China’s Domestic Sorghum Market

As expected, the model simulation results show a decrease in global sorghum price and China’s domestic sorghum consumption. Table 2 shows that the global sorghum price decreased by 11.8% for the first year after the shock, and decreased by 8.47%, 5.12% and 3.75% for the following three years. Accordingly, China’s domestic sorghum consumption decreased by 21.51%, 20.73%, 18.07% for the first three years after the shock respectively.
Sorghum planting area and yields increased slightly, by 2.36% and 1.36% respectively for the next year.

Table 2. Result of Scenario One: China’s Sorghum Imports Decreased by 50% From USDA’s Baseline Projection.

<table>
<thead>
<tr>
<th>Crop year</th>
<th>Border price</th>
<th>Cons price</th>
<th>Area harvest</th>
<th>Yield</th>
<th>Production</th>
<th>Imports</th>
<th>Exports</th>
<th>consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>18/19</td>
<td>-11.8</td>
<td>27.41</td>
<td>0</td>
<td>0.947</td>
<td>0.947</td>
<td>-49.99</td>
<td>-25.73</td>
<td>-21.51</td>
</tr>
<tr>
<td>19/20</td>
<td>-8.47</td>
<td>22.02</td>
<td>2.359</td>
<td>1.564</td>
<td>3.96</td>
<td>-49.99</td>
<td>-24.06</td>
<td>-20.73</td>
</tr>
<tr>
<td>20/21</td>
<td>-5.12</td>
<td>14.21</td>
<td>3.914</td>
<td>2.018</td>
<td>6.01</td>
<td>-49.99</td>
<td>-18.75</td>
<td>-18.07</td>
</tr>
<tr>
<td>23/24</td>
<td>-4.3</td>
<td>5.8</td>
<td>3.146</td>
<td>1.076</td>
<td>4.256</td>
<td>-49.99</td>
<td>-13.15</td>
<td>-13.34</td>
</tr>
<tr>
<td>24/25</td>
<td>-3.52</td>
<td>3.13</td>
<td>2.565</td>
<td>0.749</td>
<td>3.333</td>
<td>-49.98</td>
<td>-10.4</td>
<td>-12.15</td>
</tr>
<tr>
<td>25/26</td>
<td>-2.69</td>
<td>1.51</td>
<td>1.721</td>
<td>0.469</td>
<td>2.198</td>
<td>-50.02</td>
<td>-8.31</td>
<td>-10.76</td>
</tr>
<tr>
<td>26/27</td>
<td>-2.22</td>
<td>0.54</td>
<td>1.009</td>
<td>0.294</td>
<td>1.306</td>
<td>-49.98</td>
<td>-6.63</td>
<td>-9.26</td>
</tr>
</tbody>
</table>


Figure 23 and Figure 24 show the comparison of scenario one and the baseline projection. After the 50% shock to imports from 3,340 MT to 1,620 MT, the decrease rate of China’s imports reached a lower level compared to the baseline projection for the subsequent years.
4.2.1.2 The Impacts Toward the U.S. and the Global Sorghum Markets

As expected, the model simulation results show a decrease in the global sorghum price. The result of the scenario shows that the global sorghum price decreased by 13.34%, 9.59%, and 5.8% for the first three years after the shock respectively. The U.S., Argentina and Australia sorghum exports decreased by 17.58%, 26.38% and 9.76% respectively after the shock (Figure 25). Simultaneously, Japan and Mexico sorghum imports increased by 2.8% and 46.26% respectively.
4.2.1.3 The Impacts Toward China’s Domestic Corn Market

As expected, the model simulation results show an increase in China’s domestic corn price. Table 3 shows the impacts toward corn for scenario one, which shows that China’s domestic corn price increased slightly by 0.46%, 0.58%, and 0.50% for the first three years after the shock. Then the increase rate of China’s corn price gradually dropped to almost zero as time goes by. China’s corn planting area increased a small amount, which is 0.05%, 0.11%, and 0.17% for the first three years respectively.

Table 3. The Impact Toward Corn for Scenario One.

<table>
<thead>
<tr>
<th>Crop year</th>
<th>Ref. price</th>
<th>Cons price</th>
<th>Prod price</th>
<th>Area harvest</th>
<th>Yield</th>
<th>Production</th>
<th>Imports</th>
<th>Exports</th>
<th>%SCEN-BASE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: USDA, Foreign Agriculture Service (FAS), Production, Supply and Distribution (PS&D), 2017. USDA, OCE, WAOB, USDA Agricultural Projections to 2026, OCE-2017-1, February 2017. (Note: Data prior to 2016 is actual data and data after 2016 is USDA baseline projections.)
4.2.1.4 The Impacts Toward China’s Domestic Pork and Poultry Markets

As expected, the model simulation results show a price increase in China’s domestic pork and poultry markets. The result of the scenario shows that the pork price came across a very slight change for the first year and then it increased a small amount for the following years until 2027 (Appendix 3 and Appendix 4). China’s domestic poultry price changed slightly for the first year and then increased a small amount subsequently as well. The results indicate that China’s feed companies substituted corn for sorghum for feed use with an increased sorghum price.

4.2.2 Scenario Two: If China’s Sorghum Import Volume Decreased by 35% Each Year from the Previous Year

4.2.2.1 The Impacts Toward China’s Domestic Sorghum Market

As expected, China’s domestic sorghum price increased and its domestic production increased as well. Table 4 shows the result of scenario two that the global sorghum price decreased by 6.55%, 7.73%, and 7.33%, compared to the previous year, for the first three

<table>
<thead>
<tr>
<th></th>
<th>16/17</th>
<th>17/18</th>
<th>18/19</th>
<th>19/20</th>
<th>20/21</th>
<th>21/22</th>
<th>22/23</th>
<th>23/24</th>
<th>24/25</th>
<th>25/26</th>
<th>26/27</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>1.66</td>
<td>-2.31</td>
<td>0.26</td>
<td>0.46</td>
<td>0.05</td>
<td>-0.00</td>
<td>0.11</td>
<td>0.71</td>
<td>-0.77</td>
<td>0.08</td>
<td>-2.31</td>
<td>0.26</td>
</tr>
<tr>
<td>1.38</td>
<td>-1.91</td>
<td>0.14</td>
<td>0.59</td>
<td>0.05</td>
<td>-0.00</td>
<td>0.17</td>
<td>0.72</td>
<td>-0.77</td>
<td>0.08</td>
<td>-2.31</td>
<td>0.26</td>
</tr>
<tr>
<td>0.94</td>
<td>-0.6</td>
<td>0.13</td>
<td>0.20</td>
<td>0.05</td>
<td>-0.00</td>
<td>0.17</td>
<td>0.93</td>
<td>-0.99</td>
<td>0.11</td>
<td>-2.31</td>
<td>0.26</td>
</tr>
<tr>
<td>0.69</td>
<td>-0.84</td>
<td>0.09</td>
<td>0.08</td>
<td>0.12</td>
<td>-0.00</td>
<td>0.17</td>
<td>0.93</td>
<td>-0.99</td>
<td>0.11</td>
<td>-2.31</td>
<td>0.26</td>
</tr>
<tr>
<td>0.12</td>
<td>-0.78</td>
<td>0.08</td>
<td>0.07</td>
<td>0.08</td>
<td>-0.00</td>
<td>0.07</td>
<td>0.31</td>
<td>-0.29</td>
<td>0.07</td>
<td>-2.31</td>
<td>0.26</td>
</tr>
<tr>
<td>0.04</td>
<td>-0.10</td>
<td>0.06</td>
<td>0.06</td>
<td>0.04</td>
<td>-0.00</td>
<td>0.04</td>
<td>0.13</td>
<td>-0.05</td>
<td>0.03</td>
<td>-2.31</td>
<td>0.26</td>
</tr>
<tr>
<td>0.02</td>
<td>-0.05</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>-0.00</td>
<td>0.02</td>
<td>0.02</td>
<td>-0.05</td>
<td>0.03</td>
<td>-2.31</td>
<td>0.26</td>
</tr>
</tbody>
</table>

years respectively. Accordingly, China’s domestic sorghum consumption decreased by 11.69% for the first year, 18.6% for the second year, and 21.98% for the third year. The planting area and yields increased by 1.28% and 1.25% respectively for the first year, and increased by 3.12% and 2.12% for the second year. Thus, this showed an expanding sorghum planting area for sorghum.

**Table 4. Result of Scenario Two: China’s Sorghum Imports Decreased by 35% Each Year from the Previous Year.**

<table>
<thead>
<tr>
<th>Crop year</th>
<th>Border price</th>
<th>Cons price</th>
<th>Area harvest</th>
<th>Yield</th>
<th>Production</th>
<th>Imports</th>
<th>Exports</th>
<th>Total cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>16/17</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>17/18</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>18/19</td>
<td>-6.55</td>
<td>14.9</td>
<td>0</td>
<td>0.515</td>
<td>0.51</td>
<td>-27.18</td>
<td>-14.14</td>
<td>-11.69</td>
</tr>
<tr>
<td>19/20</td>
<td>-7.729</td>
<td>25.23</td>
<td>1.282</td>
<td>1.251</td>
<td>2.55</td>
<td>-45.75</td>
<td>-21.12</td>
<td>-18.6</td>
</tr>
<tr>
<td>20/21</td>
<td>-7.332</td>
<td>30.8</td>
<td>3.124</td>
<td>2.12</td>
<td>5.31</td>
<td>-60.25</td>
<td>-22.16</td>
<td>-21.98</td>
</tr>
<tr>
<td>21/22</td>
<td>-6.175</td>
<td>37.73</td>
<td>5.277</td>
<td>2.78</td>
<td>8.2</td>
<td>-70.16</td>
<td>-21.06</td>
<td>-22.43</td>
</tr>
<tr>
<td>22/23</td>
<td>-5.479</td>
<td>31.24</td>
<td>6.919</td>
<td>2.938</td>
<td>10.06</td>
<td>-77.25</td>
<td>-18.75</td>
<td>-20.52</td>
</tr>
<tr>
<td>23/24</td>
<td>-5.691</td>
<td>24.22</td>
<td>7.324</td>
<td>2.796</td>
<td>10.32</td>
<td>-83.61</td>
<td>-16.84</td>
<td>-19.91</td>
</tr>
<tr>
<td>25/26</td>
<td>-3.802</td>
<td>16.51</td>
<td>5.696</td>
<td>1.935</td>
<td>7.74</td>
<td>-89.95</td>
<td>-10.47</td>
<td>-16.44</td>
</tr>
<tr>
<td>26/27</td>
<td>-2.891</td>
<td>14.07</td>
<td>4.606</td>
<td>1.64</td>
<td>6.32</td>
<td>-91.75</td>
<td>-7.66</td>
<td>-13.95</td>
</tr>
</tbody>
</table>


Figure 26 and Figure 27 show the comparison of scenario two and the baseline projection. The decrease rate of sorghum imports continued to decrease after the shock. Finally, China’s sorghum imports reached almost zero in MY 2026/27.
Figure 26. China’s Sorghum Imports for Scenario Two (1,000 Metric Tons)

Source: USDA, Foreign Agriculture Service (FAS), Production, Supply and Distribution (PS&D), 2017.

Figure 27. Projected Sorghum Imports for Selected Countries for Scenario Two

Source: USDA, Foreign Agriculture Service (FAS), Production, Supply and Distribution (PS&D), 2017.
(Note: Data prior to 2016 is actual data and data after 2016 is USDA baseline projections.)
4.2.2.2 The Impacts Toward the U.S. and the Global Sorghum Markets

As expected, the global sorghum price decreased, and sorghum exports increased for major exporters (U.S., Argentina, Australia). The result of scenario two shows that the global sorghum price decreased by 7.4%, 8.76%, and 8.3% compared to the previous year respectively. The U.S., Argentina and Australia sorghum exports decreased by 9.38%, 14.66% and 5.44% respectively for the first year after the shock (Figure 28). Simultaneously, Japan and Mexico sorghum imports increased by 1.46% and 25.66% respectively.

Figure 28. Projected Sorghum Exports for Selected Countries for Scenario Two

Source: USDA, Foreign Agriculture Service (FAS), Production, Supply and Distribution (PS&D), 2017. USDA, OCE, WAOB, USDA Agricultural Projections to 2026, OCE-2017-1, February 2017. (Note: Data prior to 2016 is actual data and data after 2016 is USDA baseline projections.)
4.2.2.3 The Impacts Toward China’s Domestic Corn Market

As expected, China’s corn price increased after the shock. The result of scenario two (Table 5) shows that China’s domestic corn price increased by 0.25% for the first year after the shock, and it increased by 0.53%, 0.75%, 0.89% for the following years respectively. China’s corn planting area increased slightly, which is 0.02%, 0.08% and 0.17% for the first three years respectively.

Table 5. The Impacts Toward Corn for Scenario Two

<table>
<thead>
<tr>
<th>Year</th>
<th>Crop price</th>
<th>Ref. price</th>
<th>Cons price</th>
<th>Prod price</th>
<th>Area harvest</th>
<th>Yield</th>
<th>Production</th>
<th>Imports</th>
<th>Exports</th>
<th>Total consensus</th>
</tr>
</thead>
<tbody>
<tr>
<td>16/17</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>17/18</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>18/19</td>
<td>-0.924</td>
<td>0.2495</td>
<td>0.2533</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.906</td>
<td>-1.259</td>
<td>0.1434</td>
<td></td>
</tr>
<tr>
<td>19/20</td>
<td>-1.007</td>
<td>0.5364</td>
<td>0.5444</td>
<td>0.0274</td>
<td>-0.0001</td>
<td>0.0274</td>
<td>1.31</td>
<td>-1.877</td>
<td>0.19</td>
<td></td>
</tr>
<tr>
<td>20/21</td>
<td>-0.702</td>
<td>0.7516</td>
<td>0.7625</td>
<td>0.0877</td>
<td>-0.0002</td>
<td>0.0876</td>
<td>1.313</td>
<td>-1.624</td>
<td>0.1989</td>
<td></td>
</tr>
<tr>
<td>21/22</td>
<td>-0.444</td>
<td>0.8948</td>
<td>0.9076</td>
<td>0.1704</td>
<td>-0.0003</td>
<td>0.1701</td>
<td>2.576</td>
<td>-1.481</td>
<td>0.2555</td>
<td></td>
</tr>
<tr>
<td>22/23</td>
<td>-0.493</td>
<td>0.7288</td>
<td>0.7391</td>
<td>0.2404</td>
<td>-0.0005</td>
<td>0.24</td>
<td>2.067</td>
<td>-1.445</td>
<td>0.2159</td>
<td></td>
</tr>
<tr>
<td>23/24</td>
<td>-0.653</td>
<td>0.4743</td>
<td>0.4809</td>
<td>0.2587</td>
<td>-0.0005</td>
<td>0.2582</td>
<td>1.552</td>
<td>-1.197</td>
<td>0.2117</td>
<td></td>
</tr>
<tr>
<td>24/25</td>
<td>-0.508</td>
<td>0.3014</td>
<td>0.3057</td>
<td>0.2278</td>
<td>-0.0004</td>
<td>0.2274</td>
<td>0.991</td>
<td>-0.666</td>
<td>0.2034</td>
<td></td>
</tr>
<tr>
<td>25/26</td>
<td>-0.257</td>
<td>0.2771</td>
<td>0.281</td>
<td>0.1662</td>
<td>-0.0003</td>
<td>0.1659</td>
<td>0.692</td>
<td>-0.208</td>
<td>0.1759</td>
<td></td>
</tr>
<tr>
<td>26/27</td>
<td>-0.149</td>
<td>0.3059</td>
<td>0.3102</td>
<td>0.1199</td>
<td>-0.0002</td>
<td>0.1197</td>
<td>0.633</td>
<td>-0.054</td>
<td>0.1416</td>
<td></td>
</tr>
</tbody>
</table>


4.2.2.4 The Impacts Toward China’s Domestic Pork and Poultry Markets

As expected, the model simulation results show an increase in China’s domestic pork and poultry markets. The result of scenario two shows that pork price came across a very slight change for the first year and then it increased a small amount for the following years until 2027 (Appendix 5 and Appendix 6). China’s domestic poultry price changed slightly for the
first year and then increased a small amount subsequently as well. The results indicate that China’s feed companies substituted corn for sorghum for feed use with increased sorghum price.

4.2.3 Scenario Three: If China’s Sorghum Import Volume Decreased by 70% for Year One from USDA-ERS’s Baseline Projection and by 90% from the USDA-ERS’s Baseline Projection in Subsequent Years

4.2.3.1 The Impacts Toward China’s Domestic Sorghum Market

As expected, the model simulation results show a decrease in China’s domestic sorghum price and consumption. The result of scenario three (Table 6) shows that the global sorghum price decreased by 18.3%, 17.38%, and 11.9% for the first three years. Accordingly, domestic consumption decreased by 30.12% for the first year, 37.06% for the second year and 32.38% for the third year. The planting area and yields increased by 3.3% and 2.73% respectively for the first year, and increased by 6.86% and 3.52% for the second year, showing an expanding planting area for sorghum.

Table 6. Result of Scenario Three: China’s Sorghum Imports Decreased by 70% in Year One from USDA-ERS’s Baseline Projection and by 90% from the USDA-ERS’s Baseline Projection in Subsequent Years.

<table>
<thead>
<tr>
<th>Crop year</th>
<th>Ref. price</th>
<th>Cons price</th>
<th>Area harvest</th>
<th>Yield</th>
<th>Production</th>
<th>Imports</th>
<th>Exports</th>
<th>Total cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>16/17</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>17/18</td>
<td>-18.3</td>
<td>38.37</td>
<td>0</td>
<td>1.326</td>
<td>1.33</td>
<td>-69.99</td>
<td>-35.63</td>
<td>-30.12</td>
</tr>
<tr>
<td>18/19</td>
<td>-17.38</td>
<td>51.44</td>
<td>3.302</td>
<td>2.732</td>
<td>6.12</td>
<td>-89.98</td>
<td>-42.46</td>
<td>-37.06</td>
</tr>
<tr>
<td>19/20</td>
<td>-11.9</td>
<td>27.73</td>
<td>6.862</td>
<td>3.524</td>
<td>10.63</td>
<td>-89.98</td>
<td>-34.62</td>
<td>-32.38</td>
</tr>
</tbody>
</table>

CHINA’S SORGHUM IMPORTS DECREASED BY 70% IN YEAR ONE AND BY 90% FROM THE BASELINE PROJECTION IN SUBSEQUENT YEARS

%SCEN-BASE = [S(t)/B(t)-1] *100
23/24  -8.42  7.33  5.789  1.888  7.79  -89.96  -23.04  -23.85
24/25  -7.28  2.08  4.481  1.168  5.7  -89.97  -18.63  -22.03
25/26  -5.65  -0.8  2.614  0.63  3.26  -90.02  -15.14  -19.84
26/27  -4.54  -2.48  1.243  0.301  1.55  -89.95  -12.11  -17.28


Figure 29 and Figure 30 show the comparison of scenario three and the baseline projection. Sorghum imports decreased significantly after the shock for the first two years, and China’s sorghum imports maintained a low level afterwards. Finally, China’s sorghum imports reached almost zero by MY 2026/27.

**Figure 29. China’s Sorghum Imports for Scenario Three (1,000 Metric Tons)**

Figure 30. Projected Sorghum Imports for Selected Countries for Scenario Three

Source: USDA, Foreign Agriculture Service (FAS), Production, Supply and Distribution (PS&D), 2017. USDA, OCE, WAOB, USDA Agricultural Projections to 2026, OCE-2017-1, February 2017. (Note: Data prior to 2016 is actual data and data after 2016 is USDA baseline projections.)

4.2.3.2 The Impacts Toward the U.S. and the Global Sorghum Markets

As expected, the model simulation results show a decrease in global sorghum price and trade. The result of scenario three shows that the global sorghum price decreased by 18.3%, 17.38%, and 11.9% respectively for the first three years. The U.S., Argentina and Australia sorghum exports decreased by 25.04%, 36.16% and 13.36% respectively for the first year after the shock (Figure 31). Simultaneously, Japan and Mexico sorghum imports increased by 4.07% and 63.49% respectively.
4.2.3.3 The Impacts Toward China’s Domestic Corn Market

As expected, the model simulation results show an increase in China’s domestic corn market. The result of scenario three (Table 7) shows that China’s domestic corn price increased by 0.64% for the first year after the shock, and it increased by 1.12%, 0.96%, 0.78% for the following years respectively. China’s corn planting area increased slightly, which is 0.07%, 0.20% and 0.30% for the first three years respectively.

Table 7. The Impacts Toward Corn for Scenario Three.

<table>
<thead>
<tr>
<th>Crop year</th>
<th>Ref. price</th>
<th>Cons price</th>
<th>Prod price</th>
<th>Area harvest</th>
<th>Yield</th>
<th>Production</th>
<th>Imports</th>
<th>Exports</th>
<th>Total cons</th>
<th>%SCEN-BASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>16/17</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-3.232</td>
</tr>
<tr>
<td>17/18</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-3.232</td>
</tr>
<tr>
<td>18/19</td>
<td>-2.37</td>
<td>0.643</td>
<td>0.653</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2.329</td>
<td>-3.232</td>
<td>0.3694</td>
<td></td>
</tr>
<tr>
<td>Year</td>
<td>Change in Corn Price</td>
<td>Change in Sorghum Price</td>
<td>Change in Pork Price</td>
<td>Change in Poultry Price</td>
<td>Corn Export</td>
<td>Sorghum Export</td>
<td>Pork Import</td>
<td>Poultry Import</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>----------------------</td>
<td>-------------------------</td>
<td>----------------------</td>
<td>-------------------------</td>
<td>-------------</td>
<td>---------------</td>
<td>------------</td>
<td>---------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19/20</td>
<td>-1.993</td>
<td>1.12</td>
<td>1.137</td>
<td>0.0706</td>
<td>-0.0001</td>
<td>0.0704</td>
<td>2.675</td>
<td>-3.747</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20/21</td>
<td>-0.659</td>
<td>0.961</td>
<td>0.975</td>
<td>0.1971</td>
<td>-0.0004</td>
<td>0.1968</td>
<td>1.561</td>
<td>-1.942</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21/22</td>
<td>-0.195</td>
<td>0.782</td>
<td>0.793</td>
<td>0.3041</td>
<td>-0.0006</td>
<td>0.3035</td>
<td>2.043</td>
<td>-1.231</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22/23</td>
<td>-0.697</td>
<td>0.364</td>
<td>0.369</td>
<td>0.3206</td>
<td>-0.0006</td>
<td>0.32</td>
<td>1.473</td>
<td>-1.535</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23/24</td>
<td>-1.005</td>
<td>0.087</td>
<td>0.088</td>
<td>0.2359</td>
<td>-0.0004</td>
<td>0.2355</td>
<td>1.086</td>
<td>-1.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24/25</td>
<td>-0.611</td>
<td>-0.008</td>
<td>-0.008</td>
<td>0.1411</td>
<td>-0.0003</td>
<td>0.1408</td>
<td>0.496</td>
<td>-0.626</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25/26</td>
<td>-0.169</td>
<td>0.049</td>
<td>0.049</td>
<td>0.06</td>
<td>-0.0001</td>
<td>0.0599</td>
<td>0.218</td>
<td>-0.023</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26/27</td>
<td>-0.141</td>
<td>0.096</td>
<td>0.097</td>
<td>0.0296</td>
<td>0</td>
<td>0.0296</td>
<td>0.268</td>
<td>-0.02</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


### 4.2.3.4 The Impacts Toward China’s Domestic Pork and Poultry Markets

As expected, the model simulation results show an increase in China’s domestic pork and poultry markets. The result of scenario three shows that the pork price had a very slight change throughout the forecast (Appendix 7 and Appendix 8). Similarly, China’s domestic poultry price changed slightly throughout the forecast as well. The results indicate that China’s feed companies substituted corn for sorghum but only slightly for feed use with an increased sorghum price.

### 4.3 Summary of The Scenarios

The results of the scenarios all showed significant impacts toward China’s sorghum imports resulting from the change of China’s corn policy, which lowered the price of corn in China. Figure 32 shows the comparison among the USDA-ERS baseline projection and all three scenarios.
For scenario one, the 50% decrease in imports shock, imposed significant impacts on both China’s sorghum food consumption (21.51% decline) and sorghum feed demand (28.97% decline), global sorghum price (13.34% decline), and China’s sorghum stocks (45.63% decline) for the first year (Table 2). Afterwards, this decreasing rate for imports slowed compared to the baseline projection starting from year two (Figure 23). As for the major sorghum exporters, the U.S., Argentina and Australia, their sorghum exports decreased by 17.58%, 26.38% and 9.76% respectively after the shock. And as for the major sorghum importers, Japan and Mexico, their sorghum imports increased by 2.8% and 46.26% respectively.

For scenario two, the 35% decline in China’s sorghum imports from the previous year, imposed significant impacts on China’s sorghum food demand (11.69% decline),
sorghum feed demand (15.75% decline), global sorghum price (7.4% decline), and China’s sorghum stocks (24.8% decline) as well (Table 4). Afterwards, the rate of decline for sorghum imports slowed for the following years. Sorghum exports the U.S., Argentina and Australia decreased by 9.38%, 14.66% and 5.44% respectively for the first year after the shock. Mexico sorghum imports increased by 25.66%. Japan’s sorghum imports did not increase by a significant amount in the first year, in scenario two.

For scenarios three, a 70% decrease of sorghum imports from the USDA-ERS’s baseline projection in year one and 90% in all subsequent years, affected China’s sorghum food demand (30.12% decline), sorghum feed demand (40.56% decline), global sorghum price (18.3% decline), and China’s sorghum stocks (63.88% decline) significantly (Table 6). After the first two years of the shock, the rate of decline for sorghum imports decreased to a very low level for the following years and sorghum was rarely traded. Sorghum exports for the U.S., Argentina and Australia decreased by 25.04%, 36.16% and 13.36% respectively for the first year after the shock. Mexico sorghum imports increased by 63.49%. Again, Japan’s sorghum imports did not increase by a significant amount, in scenario three.

4.4 Discussion

From China’s domestic sorghum market perspective, as predicted, the results show that both China’s sorghum food demand and feed demand decreased significantly in all three scenarios. China’s domestic sorghum price increased dramatically in all three scenarios.
Simultaneously, China’s sorghum planting areas and production increased as well in response to the higher sorghum price. As sorghum’s feed substitute in China, China’s corn price increased results from China’s higher domestic sorghum price in the short term. The results also show that the price of poultry and pork increased slightly in China’s domestic market with an increased sorghum price for the reason that sorghum demand is a derived demand for pork and poultry.

From the U.S. and the global sorghum market perspective, as predicted, the decrease of China’s sorghum imports resulted in less sorghum demand and lower sorghum price in the global market. Sorghum exports for U.S. and other major sorghum exporters (Australia, Argentina) decreased significantly. However, sorghum imports increased significantly for Mexico.

In both scenario two and scenario three, China’s sorghum imports returned to the previous level prior to the policy shock as the corn price in China fell. The rate of China’s sorghum imports declined faster in scenario three than that of scenario two. However, scenario two shows a gradual change of sorghum imports.

In terms of the simulation results, U.S.-China sorghum trade is a temporary success story, and it is risky for those U.S. sorghum exporters who rely on China’s sorghum market. The results show the necessity to seek new sorghum export opportunities worldwide for U.S. sorghum exporters. Meanwhile, U.S. sorghum exporters may change their cropping patterns to continue making profits by switching out of sorghum.
Chapter 5: Summary and Conclusion

The beginning and current sorghum story stems from changes in China’s corn policy because corn and sorghum are feed substitutes. China’s higher domestic corn price resulted in higher sorghum demand with relatively lower price as a feed substitute in 2013. Prior to this, China implemented a corn temporary reserve program in 2007 and a price support policy in 2011 nationwide to guarantee national food security and increase rural incomes. The Chinese government purchased corn from farmers at a minimum support price and accumulated corn in national storage facilities as stocks. The corn support price increased each year, which further encouraged corn production. This policy increased corn stockpiles and distorted the market with a high corn price (Wu & Zhang, 2016). In addition, China imposed TRQs on corn imports, which is a 65% out-of-quota duty. In 2015, China imposed a TRQs of 7.2 million metric tons (MMT) on corn (Andrew et al., 2015). The TRQs helped to keep China’s domestic corn price at a high level because it increased the cost of corn imports. Due to the higher domestic corn price, domestic corn consumption decreased significantly, and China started to import feed substitutes for corn; thus, sorghum imports started to increase. This is the temporary sorghum success story.

From the global sorghum exporter perspective, the U.S. is the largest feed sorghum producer and exporter in the global sorghum market. In MY 2012/13, the U.S. accounted for 70% of total global sorghum exports (Tran et al., 2015). In addition, U.S. sorghum has a lower price and a lower tannin content, which is more suitable for feed use compared
to other countries’ sorghum, such as Australia and Argentina. Due to the increasing demand of China’s sorghum imports, the U.S. became a major sorghum exporter to China in marketing year (MY) 2012/13. From the global sorghum importer perspective, In MY 2014/15, China’s sorghum imports accounted for 84% of the world total sorghum imports, which indicates China’s sorghum imports occupy an important place in global sorghum trade.

Changes in China’s corn policy once again affected the global sorghum market. China terminated its corn temporary reserve program and price support policy in 2016. Instead, China implemented a direct payment subsidy policy towards corn, which is tied to corn planting acres (Wu & Zhang, 2016). This change of China’s corn policy resulted in lower Chinese domestic corn price, which increased corn demand. Thus, the demand for sorghum, which is one of most important corn substitutes for feed use, decreased significantly afterwards. Simultaneously, the Chinese government is taking multiple measures to decrease corn storage and production: 1. The Chinese government permitted state-owned companies to export corn to neighboring countries. 2. The Chinese government is trying to switch corn planting areas to other commodities, such as soybeans. 3. The Chinese government plans to use stored corn for biofuel production (Wu & Zhang, 2016).

Thus, China’s sorghum imports started to decrease in 2016 after four years of uninterrupted growth because of the reform of China’s corn policies. This reform
increased corn’s competitiveness in both domestic and global markets for feed use, which further weakened China’s sorghum demand as a feed substitute. China’s corn price decreased significantly and, thus, Chinese feed companies switched to corn instead of sorghum. In 2016, China’s total imports of sorghum decreased by 32.54% compared to the previous year, and this trend is projected to continue (PS&D, 2017).

U.S.-China sorghum trade is important because sorghum trade is a thin market, which means that the magnitude of sorghum trade is relative small compared to other commodities, and China’s sorghum imports accounts for most of global sorghum exports. Thus, a significant change of China’s sorghum imports imposes a dramatic impact towards the U.S. and global sorghum exports. In addition, U.S.-China sorghum trade from MY 2012/13 to MY 2015/16 is a temporary success story. Since then, due to China’s recent changes to its corn policy, sorghum exporters should consider changing their cropping patterns to continue making profits by switching out of sorghum. This study may enable U.S. government agencies to negotiate with the Chinese government from a stronger bargaining position by gaining critical information regarding Chinese sorghum policies.

The scenarios of this thesis were set up based on China’s probable sorghum import shock results from the change of China’s corn policy. Finding the impacts of these scenarios for U.S. and global community helps to project the trend of sorghum global trade in terms of price and volume.
Figure 32 in Chapter Four shows the comparison among the baseline projection and three scenarios for China’s sorghum imports. For the baseline projection, we found a steady decline of China’s sorghum imports, and the imports is projected to decline to less than 1,000 thousand metric tons (MT) in MY 2026/27. For scenario one, after a significant shock, which is a 50% sorghum imports decrease in China’s sorghum imports, the decrease rate kept steady but at a lower level for the following years up until MY 2026/27. China’s sorghum imports are projected to decrease to less than 500 thousand MT. For scenario two, which is sorghum imports decreased by 35% each year from the previous year, the decrease rate kept decreasing as time goes by and China’s sorghum imports finally reached almost zero in this scenario. For scenario three, China’s sorghum imports declined tremendously for the first two years, and the imports level kept at a low level afterwards. The imports finally go to zero as time goes by as well. All three scenarios showed the risks of significant decline of both global sorghum price and trade volume results from the change of China’s corn policy. The scenarios also showed a significantly decline of U.S. sorghum exports. The result is a reminder for U.S. sorghum exporters that it is important to diversify cropping patterns to hedge the potential risks, and it is necessary to seek new sorghum export opportunities worldwide.

In addition, according to the China-Australia Free Trade Agreement, 85% of Australian commodities have free zero tariff treatment. Concerning sorghum trade in this agreement, “Australia’s trade to China in barley and sorghum will benefit from the
immediate elimination of the three percent tariff on barley and two percent tariff on sorghum” (USDA-FAS, 2015). That means the import tariff of sorghum from Australia decreases up to 2% for Chinese sorghum importers (Australian Trade and Investment Commission, 2015). With the trade liberalization agreement, Australia-China’s agricultural trade will deepen and broaden. Thus, China is likely to import higher volume of sorghum from Australia with lower tariffs instead of the U.S., further decreasing the U.S. sorghum exports.

However, there are some positive indications in the results as well. For example, Mexico ranks the second sorghum importer in the world in 2016, and its sorghum imports increased by 46.26%, 25.66% and 63.49% separately for the three scenarios, which indicates a new market opportunity for U.S. sorghum exporters. Japan is another important sorghum importer, and its sorghum imports increased significantly as well. U.S.-Mexico and U.S.-Japan sorghum trade could become new success stories if U.S. sorghum exporters could seize the opportunity and gain access to their sorghum markets in time.
Reference


http://www.progressivedairy.com/topics/feed-nutrition/sorghum-an-economical-forage-for-dairy-producers


Appendix

Appendix A Model

USDA-ERS China Model — Sorghum

1. Demand (4087, Code: CRDMSRTO)
   - Food Demand (4090, Code: CRDMSRFD)
     o Urban Demand (4091, Code: CRDMSRFDUR)
       ▪ =Per Capita Food Urban (4118, Code: CRDMSRFDUR) * Population (103, POPUR)
     o Rural Demand (4092, Code: CRDMSRFDRU)
       ▪ =Per Capita Food Rural (4148, Code: CRDMSRFDRU) * Population (104, POPRU)
   - Feed Demand (4104, Code: CRDMSRFSE)
     o Sorghum Producer Price (4096, Code: PRWPSR)
     o Corn Producer Price (4097, Code: PRWPCO)
     o Grain Feeding Requirement (1790, Code FEDMMTGR)

*Per Capita Influencing Factors:
   - Sorghum consumer price (4130)
   - Substitute food prices (4119-4142)
   - Income (Not listed)

2. Supply (4059, Code: CRPRSRT0) = Area Harvested (4057, Code: CRAHSRT0) * Yield (4058, Code: CRYLRSRT0)
   - Influencing Factor of yield: Three year moving average (499, Code: PRwpSR3)
   - Influencing Factor of Area Harvested:
     o Sorghum Expected Returns (4054, Code: CRERSRT0)
     o Substitutes Expected Return (4070-4080)

3. Imports
   Influencing Factor of imports:
   - Feed Demand (4104, Code: CRDMSRFSE)
   - Import Price (4025, Code: PRMPSR)

4. Stock Change
   Influencing Factor of Stock: Free Market Price (4038, Code: PRppSR)
Word Form

Demand:
Demand = Food demand + Feed demand
• Food demand = Per capita food urban × Population urban + Per capita food rural × Population rural
  o Per capita food urban_t = Per capita food urban_t-1 × (1 + %ΔP_{SRU} · ε_{SRU} + %ΔP_{Egg} · ε_{Egg} + %ΔP_{Poultry} · ε_{Poultry} + %ΔP_{Pork} · ε_{Pork} + %ΔP_{Beef & Veal} · ε_{Beef and Veal} + %ΔPer capita GDP urban · ε_{PC})
  o Per capita food rural_t = Per capita food rural_t-1 × (1 + %ΔP_{SR} · ε_{SR} + %ΔP_{Corn} · ε_{Corn} + %ΔGFR · ε_{GFR})
• Feed demand_t = Feed demand_t-1 × (1 + %ΔP_E · ε_{E} + %ΔP_C · ε_{C} + %ΔGFR · ε_{GFR})

Supply:
Supply = Area harvested × Yield
• Area harvested_t = Area harvested_t-1 × (1+ΔSorghum expected return · ε_{SER} + ΔCorn expected return · ε_{CER} + ΔSoybean expected return · ε_{SER})
• Yield_t = Yield_t-1 × (1+ΔMA_{SR})

Imports:
Imports = Imports_t-1 × (1+ΔImport price · ε_{IP} + %ΔDemand · ε_{Feed})

Stock Change :
Stock Change_t = Stock change_t-1 × (1+ΔFMP · ε_{FMP})

Variables
Demand:
Demand: China’s domestic demand for sorghum (4087, Code: CRDMSRTO)
Food Demand: China’s domestic food demand for sorghum (4090, Code: CRDMSRFD)
Feed Demand: China’s domestic feed demand for sorghum (4104, Code: CRDMSRFE)
Per capita food urban: Per capita food demand in urban area (4118, Code: CRPCSRFDUR)
Population urban: Population in urban area (103, Code: POPUR)
Per capita food rural: Per capita food demand in rural area (4148, Code: CRPCSRFDRU)
Population rural: Population in rural area (104, Code: POPRU)
%ΔP_{SRU}: Percentage change of sorghum price in urban areas (4130, 4049, Code: PRCPSR)
ε_{SRU}: Own-price elasticity for sorghum food demand in urban areas
%ΔP_{Egg}: Percentage change of egg price in urban areas (4123, 1386, Code: PRCPEG)
ε_{Egg}: Cross-price elasticity between egg and sorghum food demand in urban areas
%ΔP_{Poultryu}: Percentage change of poultry price in urban areas (4122, 1244, Code: PRCPPL)

ε_{Poultryu}: Cross-price elasticity between poultry and sorghum food demand in urban areas

%ΔP_{Porku}: Percentage change of pork price in urban areas (4120, 1916, Code: PRCPPK)

ε_{Porku}: Cross-price elasticity between pork and sorghum food demand in urban areas

%ΔP_{(Beef & Veal)u}: Percentage change of beef & veal price in urban areas (4119, 760, Code: PRCPBV)

ε_{(Beef and Veal)u}: Cross-price elasticity between beef & veal and sorghum food demand in urban areas

%ΔPer capita GDP urban: Percentage change of per capita GDP in urban areas (4142, 89, Code: (PCCONSUR)

ε_{PC}: Income elasticity of sorghum food demand in urban areas

Per capita food rural: Per capita food demand in urban area (4148, Code: CRPCSRFDRU)

%ΔP_{SRR}: Percentage change of sorghum price in rural areas (4160, 4049, Code: PRCPSR)

ε_{SRR}: Own-price elasticity for sorghum food demand in rural areas

%ΔP_{Porkr}: Percentage change of pork price in rural areas (4150, 916, PRCPPK)

ε_{Porkr}: Cross-price elasticity between pork and sorghum food demand in rural areas

%ΔPer capita GDP rural: Percentage change of per capita GDP in rural areas (4172, 90, Code: PCCONSRU)

ε_{PC}: Income elasticity of sorghum food demand in rural areas

Feed Demand: China’s domestic feed demand of sorghum (4104, Code: CRDMSRFE)

%ΔP_{SR}: Percentage change of domestic sorghum price (4096, 4047, Code: PRWPSR)

ε_{SR}: Own-price elasticity for sorghum feed demand

%ΔP_{Corn}: Percentage change of domestic corn price (4097, 3161, Code: PRWPCO)

ε_{Corn}: Cross-price elasticity between corn and sorghum feed demand

%ΔGFR: Percentage change of grain feeding requirement (4098, 1790, Code: FEDMMTGR)

ε_{GFR}: Elasticity of sorghum feed demand with respect to a change in the grain feeding requirement

Supply:

Supply: China’s domestic supply of sorghum (4059, Code: CRPRSRT0)

Area harvested: China’s domestic sorghum harvested areas (4057, Code: CRAHSRTO)

Yield: China’s domestic sorghum yield (4058, Code: CRYLSRTO)

%ΔSorghum expected return: Percentage change of sorghum expected returns (4074, 4054, Code: CRERSRT0)

ε_{SER}: Elasticity of sorghum harvested areas with respect to a change in the sorghum expected return
\%ΔCorn expected return: Percentage change of corn expected returns (4073, 3174, Code: CRERCOTO)

ε_{CER} : Elasticity of sorghum harvested areas with respect to a change in the corn expected return

\%ΔSoybean expected return: Percentage change of soybean expected return (4077, 4838, Code: CRERSBTO)

ε_{SER} : Elasticity of sorghum harvested areas with respect to a change in the soybean expected return

\%ΔMA_{SR} : percentage change of three-year sorghum yields’ moving average (4063, 499, Code: PRwpSR3)

**Imports:**
Imports: China’s sorghum imports from the global sorghum market (4179, Code: CRIMSRTO)

\%ΔImport price: Percentage change of China’s sorghum import price (4181, 4025, Code: PRMPSR)

ε_{IP} : Price elasticity of China’s sorghum imports

\%ΔDemand_{Feed} : Percentage change of China’s feed demand (4180, 4104, Code: CRDMSRFE)

ε_{Feed} : Elasticity of China’s sorghum imports with respect to a change in the China’s feed demand

**Stock Change :**
Stock Change: China’s domestic sorghum stock change (4198, CRESSRTO)

\%ΔP_{FMP} : Percentage change of sorghum price (4199, 4038, Code: PRPPSR)

ε_{FMP} : Price elasticity of sorghum stock
Variable Form

Demand:

\[ D^S_G = D^{Food} + D^{Feed} \]

- \[ D^{Food} = Y_{Urban}/P_{Urban} \times P_{Urban} + Y_{Rural}/P_{Rural} \times P_{Rural} \]
  - \[ Y_{Urban}/P_{Urban} = Y_{T-1} \times (1 + \Delta P_{SGU}/P_{SGU} \cdot \Delta Y_{SGU}/\Delta P_{SGU} \cdot P_{SGU}/Y_{SGU} + \Delta P_{Egg}/P_{Egg} \cdot \Delta Y_{SRU}/\Delta P_{Egg} \cdot P_{Egg}/Y_{SRU} + \Delta P_{Poultry}/P_{Poultry} \cdot \Delta Y_{SRU}/\Delta P_{Poultry} \cdot P_{Poultry}/Y_{SRU} + \Delta P_{Beef & Veal}/P_{Beef & Veal} \cdot \Delta Y_{SRU}/\Delta P_{Beef & Veal} \cdot P_{Beef & Veal}/Y_{SRU} + \%\Delta Per capita GDP urban \cdot \%\Delta P_{PC}) \]
  - \[ Y_{T-1} \times (1 + \Delta P_{SGR}/P_{SGR} \cdot \Delta Y_{SGR}/\Delta P_{SGR} \cdot P_{SGR}/Y_{SGR} + \Delta P_{Pork}/P_{Pork} \cdot \Delta Y_{SRU}/\Delta P_{Pork} \cdot P_{Pork}/Y_{SRU} + \%\Delta Per capita GDP rural \cdot \%\Delta P_{PC}) \]

- \[ D^{Feed} = D^{(T-1)Feed} \times (1 + \Delta P_{SG}/P_{SG} \cdot \Delta Y_{SG}/\Delta P_{SG} \cdot P_{SG}/Y_{SG} + \Delta P_{Corn}/P_{Corn} \cdot \Delta Y_{SR}/\Delta P_{Corn} \cdot P_{Corn}/Y_{SR} + \%\Delta GFR_{SG}/GFR_{SG} \cdot \%\Delta GFR_{SG}/GFR_{SG} \cdot \%\Delta GFR_{SG}/GFR_{SG}) \]

Supply:

\[ S^S_{CH} = H^S_{CH} \times Y^S_{CH} \]

- \[ H^S_{CH} = H^S_{T-1} \times (1 + \%\Delta MA) \]

Import:

\[ \text{IMP}_t = \text{IMP}_{t-1} \times (1 + \Delta P_{IP}/P_{IP} \cdot \Delta Y_{SG}/\Delta P_{IG} \cdot P_{IP}/Y_{SR} + \%\Delta D^{Feed} \cdot \%\Delta Feed) \]

Stock Change:

\[ \text{STK}^S_{t} = \text{STK}^{S}_{t-1} \times (1 + \Delta P_{FMP}/P_{FMP} \cdot \%\Delta SC_{FMP}/\Delta P_{FMP} \cdot P_{FMP}/SC_{FMP}) \]

Variables

Demand:

- \[ D^S_{CH} \]: China’s domestic demand for sorghum (4087, Code: CRDMSRTO)
- \[ D^{Food} \]: China’s domestic food demand for sorghum (4090, Code: CRDMSRFD)
- \[ D^{Feed} \]: China’s domestic feed demand for sorghum (4104, Code: CRDMSRFE)
- \[ Y_{Urban} \]: Sorghum food demand in China’s urban areas
- \[ P_{Urban} \]: Population in urban area
- \[ Y_{Rural} \]: Sorghum food demand in China’s rural areas
- \[ P_{Rural} \]: Population in rural area
- \[ Y_{Turban} \]: Sorghum food demand in China’s urban areas at time t
$P_{Urban}$: Sorghum price in urban area at time $t$
$P_{(T-1)Urban}$: Sorghum price in urban area at time $t-1$
$Y_{(T-1)Urban}$: Sorghum food demand in China’s urban areas at time $t-1$
$\Delta P_{SGU}$: Price change of sorghum in urban area
$P_{SGU}$: Price of sorghum in urban area
$\Delta Y_{SGU}$: Yield change of sorghum in urban area
$Y_{SGU}$: Yield of sorghum in urban area
$\Delta P_{Egg}$: Price change of egg
$P_{Egg}$: Price of egg
$\Delta P_{Poultry}$: Price change of poultry
$P_{Poultry}$: Price of poultry
$\Delta P_{Pork}$: Price change of poultry
$P_{Pork}$: Price of poultry
$\Delta P_{Beef & Veal}$: Price change of Beef and veal
$P_{Beef & Veal}$: Price of Beef and veal
$Y_{TRural}$: Sorghum food demand in China’s rural areas at time $t$
$P_{TRural}$: Sorghum price in rural area at time $t$
$P_{(T-1)Rural}$: Sorghum price in rural area at time $t-1$
$Y_{(T-1)Rural}$: Sorghum food demand in China’s rural areas at time $t-1$
$\Delta P_{SGR}$: Price change of sorghum in rural area
$P_{SGR}$: Price of sorghum in rural area
$\Delta Y_{SGR}$: Yields change of sorghum in rural area
$Y_{SGR}$: Yields of sorghum in rural area
$D_{TFeed}$: China’s domestic feed demand of sorghum at time $t$
$D_{(T-1)Feed}$: China’s domestic feed demand of sorghum at time $t-1$
$\Delta P_{SG}$: Price change of sorghum for feed demand
$P_{SG}$: Price of sorghum for feed demand
$\Delta Y_{SG}$: Yields change of sorghum for feed demand
$Y_{SG}$: Yields change of sorghum for feed demand
$\Delta P_{Corn}$: Price change of corn
$P_{Corn}$: Price of corn
$\Delta GFR_{SG}$: Sorghum feeding requirement change
$GFR_{SG}$: Sorghum feeding requirement

**Supply:**
$S_{Ch}^{SG}$: China’s domestic supply for sorghum
$HA_{Ch}^{SG}$: China’s domestic sorghum harvested areas
$Y_{Ch}^{SG}$: China’s domestic sorghum yields
$HA_{t}^{SG}$: China’s domestic sorghum harvested areas at time $t$
$HA_{t-1}^{SG}$: Domestic sorghum harvested areas at time $t-1$
$\Delta \text{ER}_{SG}$: Sorghum expected return change
$\text{ER}_{SG}$: Sorghum expected return
$\Delta \text{AH}_{SG}$: Change of sorghum harvested area
$\text{AH}_{SG}$: Sorghum harvested area
$\Delta \text{ER}_{\text{Corn}}$: Change of corn expected return
$\text{ER}_{\text{Corn}}$: Corn expected return
$\Delta \text{ER}_{\text{Soybean}}$: Change of soybean expected return
$\text{ER}_{\text{Soybean}}$: Soybean expected return
$Y^S_t$: Domestic sorghum yields at time t
$Y^S_{t-1}$: Domestic sorghum yields at time t-1
$\% \Delta \text{MA}$: Increase rate of sorghum moving average

**Imports:**
$\text{IMP}_t$: Sorghum imports from global market at time t
$\text{IMP}_{t-1}$: Sorghum imports from global market at time t-1
$\Delta \text{P}_{IP}$: Change of sorghum import price
$\text{P}_{IP}$: Sorghum import price
$\% \Delta \text{D}_{\text{Feed}}$: Increase rate of feed demand
$\varepsilon_{\text{Feed}}$: Elasticity of China’s sorghum imports with respect to a change in the China’s feed demand

**Stock Change:**
$\text{STK}_t$: Sorghum domestic stock at time t
$\text{STK}_{t-1}$: Sorghum domestic stock at time t-1
$\Delta \text{P}_{FMP}$: Change of sorghum free market price
$\text{P}_{FMP}$: Sorghum free market price
$\Delta \text{SC}_{FMP}$: Change of sorghum domestic stock
$\text{SC}_{FMP}$: Sorghum domestic stock
Appendix B. Baseline Projected Sorghum Exports for Select Countries (United States, Argentina, Australia)

### Appendix C. The Impacts Toward Pork for Scenario One.

<table>
<thead>
<tr>
<th>Calendar year</th>
<th>Ref. price</th>
<th>Ref. price</th>
<th>Cons. price</th>
<th>Prod. price</th>
<th>Slaught. price</th>
<th>Produc. Total Imports</th>
<th>Exports consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2018</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2019</td>
<td>-0.1294</td>
<td>-0.1272</td>
<td>-0.0134</td>
<td>-0.0134</td>
<td>-0.0004</td>
<td>0.1827</td>
<td>-0.0705</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>-0.2009</td>
<td>-0.1976</td>
<td>0.0478</td>
<td>0.0478</td>
<td>-0.0591</td>
<td>0.3844</td>
<td>-0.0765</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2021</td>
<td>-0.138</td>
<td>-0.1358</td>
<td>0.0505</td>
<td>0.0505</td>
<td>-0.0554</td>
<td>0.2661</td>
<td>-0.0455</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2022</td>
<td>-0.0481</td>
<td>-0.0473</td>
<td>0.0352</td>
<td>0.0352</td>
<td>-0.0359</td>
<td>0.0877</td>
<td>-0.0097</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2023</td>
<td>-0.0376</td>
<td>-0.037</td>
<td>0.0286</td>
<td>0.0286</td>
<td>-0.0288</td>
<td>0.0543</td>
<td>-0.0079</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2024</td>
<td>-0.0808</td>
<td>-0.0796</td>
<td>0.0067</td>
<td>0.0067</td>
<td>-0.0118</td>
<td>0.0851</td>
<td>-0.0394</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2025</td>
<td>-0.0862</td>
<td>-0.0848</td>
<td>0.0019</td>
<td>0.0019</td>
<td>-0.0081</td>
<td>0.0806</td>
<td>-0.0438</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2026</td>
<td>-0.0547</td>
<td>-0.0539</td>
<td>0.0042</td>
<td>0.0042</td>
<td>-0.0085</td>
<td>0.0285</td>
<td>-0.0277</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2027</td>
<td>-0.0261</td>
<td>-0.0257</td>
<td>0.0087</td>
<td>0.0087</td>
<td>-0.0105</td>
<td>-0.0114</td>
<td>-0.0118</td>
</tr>
</tbody>
</table>

Appendix D. The Impacts Toward Poultry for Scenario One.

<table>
<thead>
<tr>
<th>Calendar year</th>
<th>Ref. Border</th>
<th>Cons Prod</th>
<th>Produc-Imports</th>
<th>Exports</th>
<th>Total consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2018</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2019</td>
<td>-0.6067</td>
<td>-0.5995</td>
<td>0.0119</td>
<td>0.0119</td>
<td>0.6058</td>
</tr>
<tr>
<td>2020</td>
<td>-0.3065</td>
<td>-0.3028</td>
<td>0.0641</td>
<td>0.0641</td>
<td>0.3677</td>
</tr>
<tr>
<td>2021</td>
<td>-0.0995</td>
<td>-0.0983</td>
<td>0.0725</td>
<td>0.0725</td>
<td>0.1824</td>
</tr>
<tr>
<td>2022</td>
<td>-0.0501</td>
<td>-0.0495</td>
<td>0.0589</td>
<td>0.0589</td>
<td>0.1261</td>
</tr>
<tr>
<td>2023</td>
<td>-0.1523</td>
<td>-0.1503</td>
<td>0.0284</td>
<td>0.0284</td>
<td>0.1987</td>
</tr>
<tr>
<td>2024</td>
<td>-0.1787</td>
<td>-0.1764</td>
<td>0.0031</td>
<td>0.0031</td>
<td>0.206</td>
</tr>
<tr>
<td>2025</td>
<td>-0.0891</td>
<td>-0.0879</td>
<td>-0.0036</td>
<td>-0.0036</td>
<td>0.1187</td>
</tr>
<tr>
<td>2026</td>
<td>-0.0209</td>
<td>-0.0207</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0588</td>
</tr>
<tr>
<td>2027</td>
<td>-0.027</td>
<td>-0.0266</td>
<td>0.0024</td>
<td>0.0024</td>
<td>0.067</td>
</tr>
</tbody>
</table>

Appendix E. The Impacts Toward Pork for Scenario Two.

<table>
<thead>
<tr>
<th>Calendar year</th>
<th>%SCEN-BASE = [S(t)/B(t)-1] *100</th>
<th>Total consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ref. price</td>
<td>Border price</td>
<td>Cons price</td>
</tr>
<tr>
<td>Prod price</td>
<td>Slaughter price</td>
<td>Production</td>
</tr>
<tr>
<td>Imports</td>
<td>Exports</td>
<td>2017</td>
</tr>
<tr>
<td>2018</td>
<td></td>
<td>0.0002</td>
</tr>
<tr>
<td>2019</td>
<td>-0.0704</td>
<td>-0.0692</td>
</tr>
<tr>
<td>2020</td>
<td>-0.1454</td>
<td>-0.143</td>
</tr>
<tr>
<td>2021</td>
<td>-0.1536</td>
<td>-0.1512</td>
</tr>
<tr>
<td>2022</td>
<td>-0.1091</td>
<td>-0.1074</td>
</tr>
<tr>
<td>2023</td>
<td>-0.0759</td>
<td>-0.0747</td>
</tr>
<tr>
<td>2024</td>
<td>-0.0908</td>
<td>-0.0894</td>
</tr>
<tr>
<td>2025</td>
<td>-0.0992</td>
<td>-0.0976</td>
</tr>
<tr>
<td>2026</td>
<td>-0.0802</td>
<td>-0.0789</td>
</tr>
<tr>
<td>2027</td>
<td>-0.0464</td>
<td>-0.0457</td>
</tr>
</tbody>
</table>

Appendix F. The Impacts Toward Poultry for Scenario Two.

<table>
<thead>
<tr>
<th>Calendar year</th>
<th>Ref. price</th>
<th>Border price</th>
<th>Cons price</th>
<th>Prod price</th>
<th>Production</th>
<th>Imports</th>
<th>Exports</th>
<th>Total consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2018</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2019</td>
<td>-0.3303</td>
<td>-0.3264</td>
<td>0.0064</td>
<td>0.0064</td>
<td>-0.0467</td>
<td>0.3297</td>
<td>-0.6739</td>
<td>-0.0086</td>
</tr>
<tr>
<td>2020</td>
<td>-0.3325</td>
<td>-0.3285</td>
<td>0.0487</td>
<td>0.0487</td>
<td>-0.1042</td>
<td>0.3717</td>
<td>-0.6789</td>
<td>-0.0631</td>
</tr>
<tr>
<td>2021</td>
<td>-0.2677</td>
<td>-0.2644</td>
<td>0.0897</td>
<td>0.0897</td>
<td>-0.1519</td>
<td>0.3465</td>
<td>-0.5466</td>
<td>-0.1152</td>
</tr>
<tr>
<td>2022</td>
<td>-0.1765</td>
<td>-0.1743</td>
<td>0.1209</td>
<td>0.1209</td>
<td>-0.1837</td>
<td>0.2862</td>
<td>-0.3655</td>
<td>-0.1548</td>
</tr>
<tr>
<td>2023</td>
<td>-0.1787</td>
<td>-0.1765</td>
<td>0.1103</td>
<td>0.1103</td>
<td>-0.1684</td>
<td>0.2813</td>
<td>-0.3537</td>
<td>-0.1409</td>
</tr>
<tr>
<td>2024</td>
<td>-0.2221</td>
<td>-0.2192</td>
<td>0.0714</td>
<td>0.0714</td>
<td>-0.1198</td>
<td>0.295</td>
<td>-0.4045</td>
<td>-0.0919</td>
</tr>
<tr>
<td>2025</td>
<td>-0.167</td>
<td>-0.1648</td>
<td>0.0418</td>
<td>0.0418</td>
<td>-0.0744</td>
<td>0.2233</td>
<td>-0.267</td>
<td>-0.055</td>
</tr>
<tr>
<td>2026</td>
<td>-0.0912</td>
<td>-0.0899</td>
<td>0.0337</td>
<td>0.0337</td>
<td>-0.0559</td>
<td>0.1483</td>
<td>-0.1071</td>
<td>-0.0448</td>
</tr>
<tr>
<td>2027</td>
<td>-0.0508</td>
<td>-0.0501</td>
<td>0.0379</td>
<td>0.0379</td>
<td>-0.057</td>
<td>0.1148</td>
<td>-0.0277</td>
<td>-0.0495</td>
</tr>
</tbody>
</table>

Appendix G. The Impacts Toward Pork for Scenario Three.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2018</td>
<td>0.1789</td>
<td>-0.1759</td>
<td>-0.0185</td>
<td>-0.0185</td>
<td>-0.0006</td>
<td>0.2526</td>
<td>-0.0975</td>
<td>0.0096</td>
</tr>
<tr>
<td>2019</td>
<td>-0.3235</td>
<td>-0.3182</td>
<td>0.0634</td>
<td>0.0634</td>
<td>-0.083</td>
<td>0.5989</td>
<td>-0.1293</td>
<td>-0.0564</td>
</tr>
<tr>
<td>2020</td>
<td>-0.2606</td>
<td>-0.2565</td>
<td>0.1075</td>
<td>0.1075</td>
<td>-0.1154</td>
<td>0.5329</td>
<td>-0.079</td>
<td>-0.0907</td>
</tr>
<tr>
<td>2021</td>
<td>-0.1204</td>
<td>-0.1184</td>
<td>0.0703</td>
<td>0.0703</td>
<td>-0.0722</td>
<td>0.2273</td>
<td>-0.0298</td>
<td>-0.061</td>
</tr>
<tr>
<td>2022</td>
<td>-0.0701</td>
<td>-0.069</td>
<td>0.0588</td>
<td>0.0588</td>
<td>-0.0584</td>
<td>0.1127</td>
<td>-0.0112</td>
<td>-0.0521</td>
</tr>
<tr>
<td>2023</td>
<td>-0.1272</td>
<td>-0.1252</td>
<td>0.0089</td>
<td>0.0089</td>
<td>-0.0176</td>
<td>0.1179</td>
<td>-0.0628</td>
<td>-0.0124</td>
</tr>
<tr>
<td>2024</td>
<td>-0.15</td>
<td>-0.1477</td>
<td>-0.0002</td>
<td>-0.0002</td>
<td>-0.0111</td>
<td>0.1326</td>
<td>-0.0774</td>
<td>-0.0054</td>
</tr>
<tr>
<td>2025</td>
<td>-0.1068</td>
<td>-0.1051</td>
<td>0.0031</td>
<td>0.0031</td>
<td>-0.0115</td>
<td>0.0598</td>
<td>-0.0552</td>
<td>-0.0087</td>
</tr>
<tr>
<td>2026</td>
<td>-0.0541</td>
<td>-0.0532</td>
<td>0.0129</td>
<td>0.0129</td>
<td>-0.0165</td>
<td>-0.012</td>
<td>-0.0251</td>
<td>-0.0163</td>
</tr>
<tr>
<td>2027</td>
<td>-0.0518</td>
<td>-0.0517</td>
<td>0.0128</td>
<td>0.0128</td>
<td>-0.0165</td>
<td>-0.012</td>
<td>-0.0251</td>
<td>-0.0163</td>
</tr>
</tbody>
</table>

## Appendix H. The Impacts Toward Poultry for Scenario Three.

<table>
<thead>
<tr>
<th>Calendar Year</th>
<th>Reference Price</th>
<th>Border Price</th>
<th>Cons Price</th>
<th>Prod Price</th>
<th>Production</th>
<th>Imports</th>
<th>Exports</th>
<th>Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2018</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2019</td>
<td>-0.845</td>
<td>-0.835</td>
<td>0.0169</td>
<td>0.0169</td>
<td>-0.1203</td>
<td>0.844</td>
<td>-1.724</td>
<td>-0.0227</td>
</tr>
<tr>
<td>2020</td>
<td>-0.6364</td>
<td>-0.6287</td>
<td>0.1102</td>
<td>0.1102</td>
<td>-0.224</td>
<td>0.7311</td>
<td>-1.319</td>
<td>-0.1431</td>
</tr>
<tr>
<td>2021</td>
<td>-0.2749</td>
<td>-0.2716</td>
<td>0.1371</td>
<td>0.1371</td>
<td>-0.2217</td>
<td>0.4157</td>
<td>-0.59</td>
<td>-0.1786</td>
</tr>
<tr>
<td>2022</td>
<td>-0.1056</td>
<td>-0.1042</td>
<td>0.1189</td>
<td>0.1189</td>
<td>-0.1798</td>
<td>0.2431</td>
<td>-0.234</td>
<td>-0.1567</td>
</tr>
<tr>
<td>2023</td>
<td>-0.2212</td>
<td>-0.2183</td>
<td>0.0589</td>
<td>0.0589</td>
<td>-0.11</td>
<td>0.3059</td>
<td>-0.421</td>
<td>-0.0809</td>
</tr>
<tr>
<td>2024</td>
<td>-0.3045</td>
<td>-0.3006</td>
<td>0.0015</td>
<td>0.0015</td>
<td>-0.0405</td>
<td>0.3432</td>
<td>-0.537</td>
<td>-0.009</td>
</tr>
<tr>
<td>2025</td>
<td>-0.1891</td>
<td>-0.1866</td>
<td>-0.0185</td>
<td>-0.0185</td>
<td>-0.0026</td>
<td>0.2226</td>
<td>-0.283</td>
<td>0.0152</td>
</tr>
<tr>
<td>2026</td>
<td>-0.0607</td>
<td>-0.0599</td>
<td>-0.0105</td>
<td>-0.0105</td>
<td>-0.001</td>
<td>0.1102</td>
<td>-0.031</td>
<td>0.0051</td>
</tr>
<tr>
<td>2027</td>
<td>-0.0405</td>
<td>-0.04</td>
<td>-0.0003</td>
<td>-0.0003</td>
<td>-0.0124</td>
<td>0.1003</td>
<td>0.004</td>
<td>-0.0074</td>
</tr>
</tbody>
</table>

## Appendix I. Sorghum Output Baseline for The Three Scenarios.

<table>
<thead>
<tr>
<th>Crop year</th>
<th>Border price</th>
<th>Cons price</th>
<th>Area harvest</th>
<th>Yield</th>
<th>Production</th>
<th>Imports</th>
<th>Exports</th>
<th>Total cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>16/17</td>
<td>1075</td>
<td>1492</td>
<td>650</td>
<td>4.923</td>
<td>3200</td>
<td>5500</td>
<td>10</td>
<td>9300</td>
</tr>
<tr>
<td>17/18</td>
<td>1080</td>
<td>1840</td>
<td>666</td>
<td>4.945</td>
<td>3294</td>
<td>3630</td>
<td>8</td>
<td>6920</td>
</tr>
<tr>
<td>18/19</td>
<td>1094</td>
<td>1663</td>
<td>675</td>
<td>4.972</td>
<td>3354</td>
<td>3240</td>
<td>7</td>
<td>6554</td>
</tr>
<tr>
<td>19/20</td>
<td>1064</td>
<td>1533</td>
<td>681</td>
<td>4.982</td>
<td>3394</td>
<td>2829</td>
<td>6</td>
<td>6194</td>
</tr>
<tr>
<td>20/21</td>
<td>1054</td>
<td>1434</td>
<td>688</td>
<td>4.988</td>
<td>3433</td>
<td>2509</td>
<td>5</td>
<td>5924</td>
</tr>
<tr>
<td>21/22</td>
<td>1031</td>
<td>1588</td>
<td>695</td>
<td>4.986</td>
<td>3466</td>
<td>2172</td>
<td>5</td>
<td>5642</td>
</tr>
<tr>
<td>22/23</td>
<td>1011</td>
<td>1524</td>
<td>704</td>
<td>4.991</td>
<td>3513</td>
<td>1850</td>
<td>5</td>
<td>5366</td>
</tr>
<tr>
<td>23/24</td>
<td>995</td>
<td>1320</td>
<td>710</td>
<td>4.985</td>
<td>3541</td>
<td>1670</td>
<td>4</td>
<td>5197</td>
</tr>
<tr>
<td>24/25</td>
<td>975</td>
<td>1237</td>
<td>718</td>
<td>4.983</td>
<td>3577</td>
<td>1421</td>
<td>4</td>
<td>4982</td>
</tr>
<tr>
<td>25/26</td>
<td>949</td>
<td>1226</td>
<td>721</td>
<td>4.994</td>
<td>3600</td>
<td>1157</td>
<td>4</td>
<td>4788</td>
</tr>
<tr>
<td>26/27</td>
<td>933</td>
<td>1283</td>
<td>725</td>
<td>4.997</td>
<td>3624</td>
<td>913</td>
<td>4</td>
<td>4569</td>
</tr>
</tbody>
</table>

### Appendix I. Sorghum Output Baseline for The Three Scenarios (CTD).

<table>
<thead>
<tr>
<th>Ending stocks</th>
<th>Feed use</th>
<th>Food Sd Ind=FSI</th>
<th>EndStk% Cons+Ex</th>
<th>Cons/ capita</th>
<th>FoodSl/ capita</th>
<th>Net exports</th>
<th>Import% Cons</th>
<th>Export% Prod</th>
</tr>
</thead>
<tbody>
<tr>
<td>357</td>
<td>7200</td>
<td>2100</td>
<td>3.83</td>
<td>6.743</td>
<td>1.522</td>
<td>-5490</td>
<td>59.14</td>
<td>0.31</td>
</tr>
<tr>
<td>353</td>
<td>4852</td>
<td>2068</td>
<td>5.09</td>
<td>4.997</td>
<td>1.493</td>
<td>-3622</td>
<td>52.46</td>
<td>0.25</td>
</tr>
<tr>
<td>387</td>
<td>4473</td>
<td>2080</td>
<td>5.89</td>
<td>4.716</td>
<td>1.497</td>
<td>-3233</td>
<td>49.44</td>
<td>0.22</td>
</tr>
<tr>
<td>409</td>
<td>4089</td>
<td>2105</td>
<td>6.6</td>
<td>4.443</td>
<td>1.51</td>
<td>-2823</td>
<td>45.66</td>
<td>0.17</td>
</tr>
<tr>
<td>422</td>
<td>3795</td>
<td>2128</td>
<td>7.11</td>
<td>4.238</td>
<td>1.523</td>
<td>-2503</td>
<td>42.35</td>
<td>0.16</td>
</tr>
<tr>
<td>413</td>
<td>3493</td>
<td>2149</td>
<td>7.32</td>
<td>4.027</td>
<td>1.534</td>
<td>-2167</td>
<td>38.5</td>
<td>0.15</td>
</tr>
<tr>
<td>406</td>
<td>3203</td>
<td>2163</td>
<td>7.56</td>
<td>3.823</td>
<td>1.541</td>
<td>-1845</td>
<td>34.47</td>
<td>0.13</td>
</tr>
<tr>
<td>415</td>
<td>2997</td>
<td>2200</td>
<td>7.99</td>
<td>3.697</td>
<td>1.565</td>
<td>-1665</td>
<td>32.12</td>
<td>0.12</td>
</tr>
<tr>
<td>427</td>
<td>2770</td>
<td>2212</td>
<td>8.57</td>
<td>3.541</td>
<td>1.572</td>
<td>-1417</td>
<td>28.52</td>
<td>0.12</td>
</tr>
<tr>
<td>392</td>
<td>2561</td>
<td>2227</td>
<td>8.19</td>
<td>3.401</td>
<td>1.582</td>
<td>-1153</td>
<td>24.16</td>
<td>0.11</td>
</tr>
<tr>
<td>356</td>
<td>2335</td>
<td>2234</td>
<td>7.79</td>
<td>3.246</td>
<td>1.587</td>
<td>-909</td>
<td>19.99</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Appendix J. The Impacts Towards Corn (Output Baseline).

<table>
<thead>
<tr>
<th>Crop year</th>
<th>Ref. price</th>
<th>Cons price</th>
<th>Prod price</th>
<th>Area harvest</th>
<th>Yield</th>
<th>Production</th>
<th>Imports</th>
<th>Exports</th>
<th>Total cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>16/17</td>
<td>135.1</td>
<td>2606</td>
<td>2091</td>
<td>36000</td>
<td>6</td>
<td>216001</td>
<td>3000</td>
<td>20</td>
<td>226008</td>
</tr>
<tr>
<td>17/18</td>
<td>132.4</td>
<td>2627</td>
<td>2107</td>
<td>34926</td>
<td>6.146</td>
<td>214657</td>
<td>3373</td>
<td>18</td>
<td>228659</td>
</tr>
<tr>
<td>18/19</td>
<td>131.6</td>
<td>2670</td>
<td>2140</td>
<td>34401</td>
<td>6.282</td>
<td>216087</td>
<td>3641</td>
<td>19</td>
<td>231336</td>
</tr>
<tr>
<td>19/20</td>
<td>128.9</td>
<td>2710</td>
<td>2170</td>
<td>34212</td>
<td>6.411</td>
<td>219320</td>
<td>3793</td>
<td>16</td>
<td>233340</td>
</tr>
<tr>
<td>20/21</td>
<td>130</td>
<td>2731</td>
<td>2186</td>
<td>34000</td>
<td>6.539</td>
<td>222321</td>
<td>4190</td>
<td>18</td>
<td>235210</td>
</tr>
<tr>
<td>21/22</td>
<td>129.2</td>
<td>2755</td>
<td>2204</td>
<td>33913</td>
<td>6.667</td>
<td>226100</td>
<td>4638</td>
<td>18</td>
<td>238240</td>
</tr>
<tr>
<td>22/23</td>
<td>128.4</td>
<td>2768</td>
<td>2212</td>
<td>33849</td>
<td>6.8</td>
<td>230157</td>
<td>5016</td>
<td>18</td>
<td>240754</td>
</tr>
<tr>
<td>23/24</td>
<td>127.5</td>
<td>2740</td>
<td>2187</td>
<td>33917</td>
<td>6.931</td>
<td>235066</td>
<td>5319</td>
<td>22</td>
<td>243761</td>
</tr>
<tr>
<td>24/25</td>
<td>126.7</td>
<td>2691</td>
<td>2146</td>
<td>33957</td>
<td>7.067</td>
<td>239983</td>
<td>5638</td>
<td>29</td>
<td>247437</td>
</tr>
<tr>
<td>25/26</td>
<td>124.2</td>
<td>2666</td>
<td>2125</td>
<td>33903</td>
<td>7.197</td>
<td>243986</td>
<td>5892</td>
<td>39</td>
<td>250852</td>
</tr>
<tr>
<td>26/27</td>
<td>123.4</td>
<td>2663</td>
<td>2121</td>
<td>33816</td>
<td>7.33</td>
<td>247863</td>
<td>6104</td>
<td>51</td>
<td>253989</td>
</tr>
</tbody>
</table>

Source: USDA, Foreign Agriculture Service (FAS), Production, Supply and Distribution (PS&D), 2017.
Appendix J. The Impacts Towards Corn (Output Baseline) (CTD).

<table>
<thead>
<tr>
<th>Ending stocks use</th>
<th>Feed use</th>
<th>Food Sd use</th>
<th>Indust. use</th>
<th>Food + Seed</th>
<th>EndStk%</th>
<th>Cons/ capita</th>
<th>FoodSI/ capita</th>
<th>Net exports</th>
<th>Import%</th>
<th>Export%</th>
</tr>
</thead>
<tbody>
<tr>
<td>103753</td>
<td>159008</td>
<td>67000</td>
<td>57029</td>
<td>9971</td>
<td>45.9</td>
<td>163.9</td>
<td>48.58</td>
<td>-2980</td>
<td>1.327</td>
<td>0.01</td>
</tr>
<tr>
<td>93106</td>
<td>162939</td>
<td>65721</td>
<td>57469</td>
<td>8252</td>
<td>40.7</td>
<td>165.1</td>
<td>47.46</td>
<td>-3354</td>
<td>1.475</td>
<td>0.01</td>
</tr>
<tr>
<td>81480</td>
<td>165677</td>
<td>65659</td>
<td>57890</td>
<td>7769</td>
<td>35.2</td>
<td>166.5</td>
<td>47.25</td>
<td>-3623</td>
<td>1.574</td>
<td>0.01</td>
</tr>
<tr>
<td>71237</td>
<td>167701</td>
<td>65639</td>
<td>58276</td>
<td>7363</td>
<td>30.5</td>
<td>167.4</td>
<td>47.09</td>
<td>-3777</td>
<td>1.626</td>
<td>0.01</td>
</tr>
<tr>
<td>62520</td>
<td>169563</td>
<td>65646</td>
<td>58724</td>
<td>6922</td>
<td>26.6</td>
<td>168.3</td>
<td>46.96</td>
<td>-4172</td>
<td>1.781</td>
<td>0.01</td>
</tr>
<tr>
<td>55000</td>
<td>172743</td>
<td>65497</td>
<td>58987</td>
<td>6510</td>
<td>23.1</td>
<td>170</td>
<td>46.75</td>
<td>-4620</td>
<td>1.947</td>
<td>0.01</td>
</tr>
<tr>
<td>49401</td>
<td>175353</td>
<td>65401</td>
<td>59251</td>
<td>6150</td>
<td>20.5</td>
<td>171.5</td>
<td>46.59</td>
<td>-4999</td>
<td>2.083</td>
<td>0.01</td>
</tr>
<tr>
<td>46004</td>
<td>178418</td>
<td>65343</td>
<td>59518</td>
<td>5825</td>
<td>18.9</td>
<td>173.4</td>
<td>46.48</td>
<td>-5297</td>
<td>2.182</td>
<td>0.01</td>
</tr>
<tr>
<td>44159</td>
<td>182161</td>
<td>65275</td>
<td>59787</td>
<td>5489</td>
<td>17.8</td>
<td>175.9</td>
<td>46.39</td>
<td>-5609</td>
<td>2.279</td>
<td>0.01</td>
</tr>
<tr>
<td>43146</td>
<td>185653</td>
<td>65199</td>
<td>60058</td>
<td>5141</td>
<td>17.2</td>
<td>178.2</td>
<td>46.32</td>
<td>-5853</td>
<td>2.349</td>
<td>0.02</td>
</tr>
<tr>
<td>43073</td>
<td>188862</td>
<td>65127</td>
<td>60331</td>
<td>4796</td>
<td>17</td>
<td>180.4</td>
<td>46.27</td>
<td>-6052</td>
<td>2.403</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Appendix K. Comparison of China’s Sorghum and Corn Feed-to-use Ratio