Potential Scenarios for China's Future Grain Sorghum Excess Demand

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Abstract

China's sorghum imports have shown an unexpected increase since 2013 mainly due to the Chinese government "temporary reserve program" implemented on corn. The objective of this study is an attempt to provide a reference for sorghum exporters to prepare for China's future sorghum import trends when the Chinese government policy changes. This study developed a sorghum supply and demand structure model to estimate and forecast China's future sorghum excess demand. The results of this study suggested that China imports will decrease when government eliminates the subsidy policy for corn, but will not decrease to the levels that occurred before the year 2013.

Key Words: Excess Demand, Sorghum, Policy, China

Introduction

China has recently shown an explosive growth rate in sorghum imports for feed use. The quantity of Chinese imports of grain sorghum expanded from almost 0 to 10 million metric tons just within five years (2010-2014). China's sorghum import demand has remained above this high mark in 2015. This notable import demand attracted great attention from sorghum exporting countries. The United States has become the largest sorghum exporter to China, followed by Australia and Argentina. According to the USDA data, about 90% of the U.S. sorghum export has been sent to China in the market year 2014/2015, and this number was almost 0% before 2013.

The increasing demand for animal protein expanded the derived demand for feed grain in China where corn is the major feed grain. However, for food security purposes, the Chinese government included corn into the 95% self-sufficiency program since 1995 and placed a tariff rate quota (TRQs) on corn imports since 2001. In addition, the Chinese government started a "temporary reserve program" aimed at encouraging local corn production since 2008. The government paid farmers a corn price that was higher than

the market level predicted from previous years and stored the purchased corn in central government-owned storage facilities.

The Chinese government subsidy policy on corn pushed up the domestic corn price, and the trade restrictions limited the import quantity of cheaper international corn. Livestock industries start looking for alternatives feed grains. Sorghum is a cheap and close substitute for corn in China, but for the past two decades had not been considered as an important feed grain.

The dramatic increase in Chinese grain sorghum demand during the previous years may totally change the structure of international sorghum market. The USDA stated that this increasing demand may be caused by China's domestic subsidy policy on corn (USDA, 2015). An important question to explore is whether China would be able to keep this large import demand of sorghum in the future if the policy changes. In March 2016, the Chinese government announced that it would end this subsidy program on corn, which started in 2008. This action may bring additional uncertain changes to Chinese and international markets of corn and sorghum.

The sorghum excess demand, which refers to the difference between sorghum domestic demand and supply, is a good proxy to estimate China's sorghum import demand. Numerous previous studies suggested that a structural model consisting of both demand and supply side of a market would be more appropriate to measure and forecast excess demand. Exogenous variables included in this type of model could be used to forecast Chinese future excess demand under different scenarios.

The overall objective of this research is to estimate the potential sorghum excess demand of China in the future and simulate its level under plausible alternative scenarios. The more specific objectives are:

1) Establish a Chinese sorghum supply model includes variables of prices, planted area, harvested area, yields, beginning stocks of sorghum;

2) Establish a Chinese sorghum demand model includes variables of prices, feed use quantity, meat production, and ending stocks of sorghum;

3) Estimate sorghum excess demand by taking the difference of Chinese domestic sorghum demand and supply.

4) Perform a baseline projection and simulations to forecast future Chinese excess demand under different policy scenarios.

In order to understand Chinese sorghum production and distribution, the econometric model will consist of seven model equations. Those equations include: an equation of sorghum planted area, an equation of sorghum harvested area, an equation of sorghum domestic supply, an equation of sorghum feed consumption, an equation of sorghum domestic demand, and end equation of sorghum ending stocks. The last equation in the model captures the sorghum excess demand, which is a difference between domestic demand and domestic supply.

The models were estimated using annual marketing year data for the period 1991 to 2015 and have a total of 25 observations. Corn and sorghum producer prices were obtained from the China Grain Reserve Corporation (SINOGRAIN) website and were deflated to prices of 2010. Variables of China's sorghum planted area, harvested area,

and yield were obtained from National Bureau of Statistics of China (NBS). Other variables were from USDA PS&D.

The results and projections of this study could be a useful tool to understand and forecast Chinese sorghum supply and demand. The sorghum excess demand obtained from the difference between the domestic demand and supply could be used as a good reference for the sorghum exporting countries preparing for future Chinese sorghum import trends.

Literature Review

Compared to the use of corn, Chinese sorghum feed use in large quantity has occurred only in the last three to four years. Most studies related to China's grain market have analyzed the grain markets of corn, wheat, soybeans, and rice, but almost no research has focused on China's grain sorghum market. The most relevant analysis, which studied grain sorghum supply and demand, were based on U.S. and Mexican markets. The purpose of this literature review is to provide an understanding of the connection between this study and previous relevant research including its analytical methodology.

Roy and Ireland (1975) used a sorghum econometric model of simultaneous equations to identify and estimate the major structural relationships, which influenced U.S. sorghum prices. This study developed five simultaneous equations, and the dependent variables were U.S. sorghum feed demand, exports, stocks, and price. The last equation described an equilibrium situation. Results of this study showed that the free market forces of supply and demand in the U.S. sorghum sector played a stronger role in the price determination process than the government price support program. In addition, they found that structural relations in the grain sorghum market did not appear to be

entirely dominated by corn price or by the supply and demand situation in the corn sector. The authors indicated that the potential of higher total return of sorghum might be due to the increased domestic supply of sorghum.

Pandrangi and Malaga (2005) established a single equation sorghum import demand model and assessed the potential of Mexican market for U.S. sorghum. They estimated the import demand of sorghum mainly as a derived demand of livestock production. Livestock production has been used as a proxy for income to derive the feed demand. Prices of sorghum and corn were used in the form of a ratio in the model. The results of this study showed that price ratio and livestock production strongly related to the sorghum imports. A single equation to estimate the import demand model is preferable to use due to the ease of estimation as long as it yields unbiased or at least consistent elasticity estimates (Thursby and Thursby, 1984). However, this model did not account for the supply side of Mexico market. To estimate import demand of crops by considering both domestic demand and supply as a system may result in more accurate results.

The International Food Policy Research Institute developed an international model for policy analysis of agricultural commodities and trade (IMPACT) (Rosegran, Ringler, and Msangi, et al., 2008). Several published studies conducted by international organizations used this IMPACT modeling framework, such as the World Bank, the Asian Development Bank, the FAO, and national governments. This model demonstrated that the domestic crop production was determined by crop area and crop yields. They described the domestic demand for a commodity as the sum of its demand for food, feed, and other uses. In this model, the feed demand was a derived demand determined by the

changes in livestock production, feed ratios, and own and cross price effects of feed crops. In the IMPACT model, the authors defined the commodity trade by country as the difference between domestic supply and demand.

Duch-Carvallo and Malaga (2009) developed a partial equilibrium econometric and simulation international trade model to analyze the U.S. and Mexico sorghum market. They used a seemingly unrelated regression to estimate sixteen equations simultaneously as a system. Estimated results and projections of this study suggested that the dependency of the sorghum trade between U.S. and Mexico will continue. The specified simulation scenarios are increasing U.S. sorghum yield, changing domestic demand for industrial use of sorghum, and altering the world's remaining sorghum demand. Although results of this study confirmed that Mexican poultry production and the U.S. corn price were significant variables; this research did not project the effects of these two critical factors on the U.S.-Mexico sorghum trade market.

Bing and Malaga (2010) also used a partial equilibrium econometric and simulation international trade model to study the U.S. and Mexico sorghum markets. This study performed several alternative scenarios simulation and projection. They used FAPRI projections for exogenous variables to forecast the level of endogenous variables over the period of 2009 to 2017. Five scenarios were analyzed in this study by using the validated supply/demand/ trade simulation model. Specific scenarios included change on U.S. corn price, Mexican poultry production, sorghum yield in the U.S., U.S. sorghum export, and U.S. ethanol industry demand.

The reviewed papers showed that most previous studies related to the sorghum domestic market and trade were based on U.S. or Mexican markets. Rarely studies

discussed the sorghum demand, supply, and trade of Chinese market. Historically, China was a small country when came to sorghum imports and exports, and domestically considered a minor crop and a temporary substitute for corn for feed purposes. However, since 2013 China imported a large amount of sorghum from U.S. for the first time in history, China sorghum import demand became a popular topic among sorghum exporting countries. The USDA found that China's considerable and increased sorghum import demand was mainly caused by the government subsidy policy on corn, but there rarely future research discussed China's future sorghum import demand. The Chinese government announced on March 28, 2016 that it will end the corn subsidy, which started in 2008. This action may bring additional unexpected influences to China's corn and sorghum markets. As a result, it would be important to understand how China's sorghum demand and supply will react to the change in policy on corn and it's implication for sorghum imports.

Analytical Framework

This section describes the analytical framework of an agricultural commodity's production and distribution. In the past decades, several economic models have been developed and used for national and international projections and policy analysis, such as International Model for Policy Analysis of Agricultural Commodities and Trade IMPACT (Rosegrant et al., 2008) and the USDA Agricultural Projections to 2025 (USDA, 2016). The previous models suggested that crop supply equation mainly includes production and beginning stocks. The crop domestic demand equation, on the other hand, is the sum of its demands for food, feed, industry, and other uses. The net trade is the difference between the domestic demand and supply. The structure of the previous

models follows common microeconomic theory principles, which implies basic assumptions about consumer utility maximization behavior, producer profit maximization behavior, and market clearing conditions through price determination. Specifically, studies completed by Roy and Ireland (1975), Duch-Carvallo and Malaga (2009), Bing and Malaga (2010), etc. analyzed the grain sorghum market and policy influence by using supply and demand structured model.

The Crop Supply Structure

As suggested by the IMPACT model, the domestic crop production is determined by the area and yield response functions. It specified the harvested area as a function of crop's own price, prices of other competing crops, additional exogenous growth trends in harvested area, and water (Function 1). This model develops the yield as a function of the commodity price, the prices of labor and capital, water, and other exogenous trend factors (Function 2). The annual supply of a commodity is then estimated as the product of its area and yield plus the beginning stocks (Function 3).

Harvested area:

$$AH_t = f(P_{it}, P_{jt}, X, WAT) \quad (1)$$

Yield:

$$YD_t = f(P_{it}, PF_t, X, WAT) \quad (2)$$

Supply:

$$QS_t = AH_t \times YD_t + BSK \quad (3)$$

Where the AH, YD, QS, and BSK represent crop harvested area, yield, supply, and beginning stocks, respectively. P_{it}, P_{jt} , and PF_t are crop own price, price of the

competing crops, and prices of labor and capital, respectively. WAT represents the water variable. BSK represents the beginning stocks.

The Crop Demand Structure

Following previous studies, the demand for crops is broken into food, feed, and other uses. The IMPACT model defined the food demand as a function of the commodity's own price, prices of other competing commodities, per capita income, and total population (Function 4). The feed demand is a derived demand of livestock production, feed ratios, and own and cross price effects of feed crops (Function 5). The total demand is a sum of food demand, feed demand, ending stocks and other uses (Function 6).

Demand for food:

$$QI_t = f(P_{it}, P_{jt}, INC_t, POP_t) \quad (4)$$

Demand for feed:

$$QF_t = f(P_{it}, P_{jt}, MeatPD_t, FR_t) \quad (5)$$

Demand:

$$QD_t = QI_t + QF_t + QE_t + ESK \quad (6)$$

Where the QI_t, QF_t, QE_t, and QD_t represent crop demand for food, feed, other uses, and total demand. The $INC_t, POP_t, MeatPD_t, FR_t$ are income, population, meat production, and feed ratio, respectively. P_{it} and P_{jt}, are crop own price and price of competing crops. ESK represents the ending stocks.

Equilibrium Condition

Previous studies conducted by Roy and Ireland (1975), Rosegrant et al. (2008), Duch-Carvallo and Malaga (2009), and Bing and Malaga (2010) followed standard

microeconomic theory including a market price variable to satisfy the market-clearing condition. Models developled by Rosegrant et al. (20008), Duch-Carvallo and Malaga (2009), and Bing and Malaga (2010) were based on the international market, which assumed the exporting countries' excess supply matched the importing countries' excess demand, where a country's excess supply or excess demand is calculated as the difference between its domestic supply and demand.

Model Specification and Data

The objective of this study is to estimate and forecast the excess demand of China's grain sorghum. Excess demand refers to the difference between domestic demand and supply. Previous research provided a general framework for studying supply and demand of grain sorghum by developing a system of equations based on a market equilibrium condition. This system assumed that the exporting country's excess supply equaled the importing country's excess demand during the entire time period of estimation.

However, the equilibrium condition used by previous studies did not fit the Chinese grain sorghum market. China has been a small exporting country of sorghum since 1991, where it's participation on world's sorghum exports was below 5%. Historically, China also imported small amount of sorghum, but since 2013 it has become a large sorghum importing country and shared more than 50% of the world's sorghum total annual imports. Consequently, it would not be appropriate to use the market equilibrium condition to solve for China's sorghum demand and supply as a system.

This study specifically focuses on estimating the excess demand of China's grain sorghum. However, given the nature of the problem, instead of solving sorghum demand

and supply simultaneously by using the market equilibrium condition, this study estimated China's sorghum demand and supply separately and calculated the sorghum excess demand by taking the difference.

Model

Sorghum domestic supply is estimated as a product of yield and harvested area plus beginning stocks. The Sorghum harvested area is a function of sorghum planted area, and the sorghum planted area is a function of lagged sorghum price, lagged sorghum planted area, and a vector of other variables. The China sorghum supply model is specified as follows:

$$AP_t = f(PS_{t-1}, AP_{t-1}, \mu) \quad (1)$$

$$AH_t = f(AP_t, \mu) \quad (2)$$

$$QS_t = YD_t * AH_t + ESK_{t-1} \quad (3)$$

Where AP is the sorghum planted area in China; PS is the sorghum producer price in China; AH is the sorghum harvested area in China; QS is the supply of sorghum in China; YD is the sorghum yield per unit of area; ESK_{t-1} is the beginning stocks (previous years ending stocks) of sorghum in China; μ represents other impact factors.

China grain sorghum demand is disaggregated into feed use, food, seed, and industry use (FSI), and ending stocks. The feed demand of sorghum is considered as a derived demand of meat production and is estimated as a function of sorghum price, corn price, meat production, and other variables. Except for feed purposes, China's sorghum FSI use mainly consumed for hard liquor production (USDA). However, due to the limitation of information, it is hard to develop a function to estimate the sorghum FSI use. But the consumption trend of sorghum FSI use in China was relatively flat and

maintained at a level of 2 million metric tons in the most of previous 25 years. The China sorghum demand model could be written as:

$$QF_t = f(PS_t/PC_t, Swine_t, \eta) \quad (4)$$

$$QD_t = QF_t + QI_t + ESK_t \quad (5)$$

Where QF is the sorghum feed quantity in China; PS and PC are the producer prices of sorghum and corn in China, respectively; Swine is the swine production in China; QI is the sorghum food, seed, and industry (FSI) use; QD is China's sorghum demand; ESK is the ending stocks of sorghum.

In this study, a stock function, which is used to capture stock changes, has been developed as a function of sorghum producer price and previous year's ending stocks. The stocks function could be written as:

$$ESK_t = f(PS_t, ESK_{t-1}, \varepsilon) \quad (6)$$

The excess demand, which is a proxy of sorghum imports, could be solved as domestic demand minus domestic supply as shown in below:

$$ED_t = QD_t - QS_t \quad (7)$$

Where the ED represents the excess demand of China's grain sorghum.

Data

The models were estimated using annual marketing year data for the period 1991 to 2015 and have a total of 25 observations. Corn and sorghum producer prices were obtained from the China Grain Reserve Corporation (SINOGRAIN) website and were deflated to prices of 2010. Variables of China's sorghum planted area, harvested area, and yield were obtained from National Bureau of Statistics of China (NBS). Other variables were from USDA PS&D.

Forecast scenarios

The objective of this study is to forecast China's future sorghum excess demand under different government policy scenarios over the period from 2016 to 2020. In 2015, the USDA reported that the unexpected increase of China's sorghum imports were caused by the Chinese government subsidy policy, which was referred to as the "temporary reserve program" on domestic corn in 2008. The objective of this policy was to encourage domestic corn production. The government paid farmers a corn price that was higher than the market level predicted from previous years and stored the purchased corn in central government-owned storage facilities. The Chinese government subsidy policy on corn affected the domestic corn price as well as the sorghum price in recent years given that sorghum is an ideal substitute of corn for feed use. However, in March 2016, the Chinese government announced that it would end this subsidy program. This action may result in additional uncertainty about Chinese domestic and international markets for corn and sorghum.

This study is an attempt to forecast China's grain sorghum excess demand based on the potential changes of sorghum domestic demand and supply, which are directly affected by China's corn and sorghum producer prices and indirectly affected by the government subsidy policy on corn. In other words, changes in government subsidy policies on corn would result in differences in China's corn and sorghum producer prices and subsequently would impact the domestic sorghum demand and supply.

The government corn stocks-to-use ratio has been used to evaluate the effects of government policy on corn and sorghum markets. This study provided a one baseline projection and three simulations for sorghum excess demand based on corn and sorghum producer prices, which have been forecasted under different government corn stocks-to-

use ratio scenarios, over the period from 2016 to 2020. The baseline projection assumed that the government corn stocks-to-use ratio would keep the same level as in the year 2015. In the other three simulations, it is assumed that the government corn stocks-to-use ratio would: 1) decrease by 1% annually for the next five years; 2) decrease by 2% annually for the next five years; and 3) go to 0% for the next five years, which means the government will totally eliminate the temporary reserve program.

This research focused on China grain sorghum excess demand estimation and forecasting is the second part of a doctoral dissertation. In the first part of the dissertation, China corn and sorghum producer prices have been forecasted by using the relationship of price and stocks-to-use ratios, which followed the study of Labys (1973) and Westcott and Hoffman (1999). The variable government corn stocks-to-use ratio, which represents the government policy influence, has been used to simulate the different government policy effects on producer prices. Data used for producer prices estimation goes from 1991 to 2015, and the forecasted period was from 2016-2020. The detailed estimation models and forecasted producer price results are listed in Table 3 and Table 4, respectively. In addition, the Figure 3 displayed the graph of forecasted corn and sorghum producer prices under different policy scenarios.

Empirical Results

This section presents the parameter estimates of sorghum supply and demand model, the results of baseline projection, and the results of three simulated scenarios forecasts. The estimation for China sorghum supply and demand model based on annual data over the period 1991-2015 are presented in Table 1.

Sorghum supply is estimated as the product of yield and harvested area plus the previous year ending stocks. Sorghum harvested area is a function of the sorghum planted

area. Equation (1a) shows that the previous year sorghum price and sorghum planted area were positively related to the current year sorghum planted area. Equation (2a) indicates that the increase of the sorghum planted area would cause an increase of sorghum harvested area. Results of both equations have the expected signs and are significant.

Sorghum demand is the sum of sorghum feed consumption, sorghum food, seed, industry use (FSI), and sorghum ending stocks. Equation (4a), which was a function of sorghum feed consumption, used sorghum and corn producer prices as a ratio to eliminate the multicollinearity problem given that sorghum and corn are substitutes. A dummy variable D_1 was included to capture the sorghum feed consumption decline from 1999 to 2011 that may have been due to the increased consumption of corn for feed use during that period. Estimates of this equation have the expected signs and are significant. Equation (6a) indicates that the sorghum current year ending stocks was a function of current year sorghum producer price and previous year ending stocks. Sorghum ending stock was negatively related to sorghum producer price and was positively related to previous year ending stocks.

Table 2 provides a summary of the forecasted results of sorghum excess demand, which refers to the difference between sorghum domestic demand and domestic supply. In the baseline projection and the three simulation scenarios forecasts, the sorghum demand and supply were predicted over the period of 2016-2020. Values of the exogenous variables, which are sorghum yield, swine production, sorghum food, seed, and industry use (FSI), were assumed based on the previous five years' average (2011-2015). Sorghum and corn producer prices used for excess demand forecasting are listed in Table 4.

Figure 1 presents the model estimated and forecasted results, and it suggests that China's sorghum excess demand will decrease from its level in 2015, which was 7 million metric tons, to an approximate of 4.5 million metric tons in all forecasted scenarios in 2016, but it will not decrease to the levels that occurred prior to 2013. In addition, the forecasted results suggest that China's sorghum excess demand in all scenarios will slightly increase from around 4.5 million metric tons to about 5.5 million metric tons from 2016 to 2020.

Figure 2 shows the detailed results of sorghum excess demand baseline projection and three simulation scenarios over the period of 2016-2020 as a column graph. Scenario 3 assumed that the Chinese government would eliminate its corn subsidy policy over the period of 2016-2020. Comparing the scenario 3 with other scenarios, China's sorghum excess demand will decline to an approximate level of 4.4 million metric tons in 2016, which is lower than the levels of the other scenarios when assuming the government will not eliminate the corn subsidy policy. However, the results interestingly show that the increasing growth rate of sorghum excess demand in scenario 3 expanded slightly faster than the increasing rate in other scenarios. This may be because when the government eliminates the corn subsidy policy, which aims to encourage domestic corn production, prices of corn and sorghum declined to a lower level (see Figure 3) and declining prices may subsequently result in domestic corn and sorghum production decrease. Nevertheless, growing income and the transition to modern urban lifestyles are increasing China's demand for animal protein and expanding the derived demand for feed grain. Thus, when the domestic corn subsidy policy is eliminated, but TRQs on corn imports

remain, sorghum imports may tend to have a slightly faster increasing trend than in the other scenarios, which assume the existence of government policies.

Future Research

This research is an attempt to provide a reference for sorghum exporters to prepare for future Chinese sorghum import trends when Chinese government policy changes. One limitation of this study is the lack of information given that China large sorghum imports only began occurring in 2013. Therefore, it is challenging to solve China's sorghum supply and demand with traditional simultaneous equation models. The results of this study could be improved if more information and data became available in the future.

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Appendix

Table 1. Summary of the Econometric Results of the Structural Equations of China Sorghum Supply and Demand

Sorghum Supply

$$AP_t = -114.29 + 0.0713PS_{t-1} + 0.974AP_{t-1} + \mu_t \quad (1a)$$
(-1.62) (2.20)** (6.73)** Rsq=0.93

$$AH_t = -25.3 + 1.016AP_t + \mu_t \quad (2a)$$
(-1.05) (8.23)** Rsq=0.98

$$QS_t = YD_t * AH_t + ESK_{t-1} \quad (3a)$$

Sorghum Demand

$$QF_t = 1835.288 - 1273.647\, PS_t/PC_t + 0.0541Swine - 2623.27D_1 + \eta_t \quad (4a)$$
(2.22)** (-1.89)* (2.02)* (-5.08)** Rsq=0.78

$$QD_t = QF_t + QI_t + ESK_t \quad (5a)$$

Sorghum Ending Stocks

$$ESK_t = 332.86 - 0.0495PS_t + 0.4299ESK_{t-1} + \varepsilon_t \quad (6a)$$
(1.55) (-0.43) (2.33)** Rsq=0.55

$$ED_t = QD_t - QS_t \quad (7a)$$

Note: t values are in parentheses. *Significant at 90% level. **Significant at 95% level.

Table 2. Baseline Projections and Forecast Results of China Grain Sorghum Excess Demand under Different Scenarios

Variables	Scenarios	2016	2017	2018	2019	2020
Sorghum Excess Demand (1000MT)	Baseline	4490	4604	4714	4795	4884
	Scenario 1	4488	4603	4718	4806	4906
	Scenario 2	4486	4602	4722	4817	4927
	Scenario 3	4398	4625	4851	5042	5235

Table 3. Summary of the Estimated Results of the Corn and Sorghum Prices Model

Corn Price Model

$$\underset{}{\text{Ln}(p_c)} = \underset{(-6.43)^{**}}{-22.955} \underset{(-0.49)}{-0.0365\text{Ln(CSUR)}} + \underset{(9.02)^{**}}{7.3778\text{Ln(CFTU)}} \underset{(-2.64)^{**}}{-0.4191\text{Ln(USCSUR)}} + \underset{(3.46)^{**}}{0.011\text{GovSUR}} + \underset{(4.36)^{**}}{0.946D_1} \underset{(-2.50)^{*}}{-0.8276D_2} + \mu_c \quad \text{(a)}$$

Rsq=0.89

Durbin-Watson Statistic=2.1491

Sorghum Price Model

$$\underset{}{\text{Ln}(p_s)} = \underset{(1.81)^{*}}{3.2196} \underset{(-2.20)^{**}}{-0.1805\text{Ln(SSUR)}} + \underset{(0.42)}{0.0536\text{Ln(SFTU)}} + \underset{(0.11)}{0.0252\text{Ln(SFSITU)}} + \underset{(3.17)^{**}}{0.544\,\text{Ln}(p_c)} \underset{(-0.48)}{-0.035\,\text{Ln(USSSUR)}} \underset{(-2.33)^{**}}{-0.537D_1} + \mu_s \quad \text{(b)}$$

Rsq=0.89

Durbin-Watson Statistic=2.07

Summary of Variable Definition:

p_c	Annual China producer price of corn
p_s	Annual China producer price of sorghum
CSUR	Annual China stocks-to-use ratio (percent) for corn
SSUR	Annual China stocks-to-use ratio (percent) for sorghum
CFTU	Annual China feed-to-use ratio (percent) for corn
SFTU	Annual China feed-to-use ratio (percent) for sorghum
SFSITU	Annual China food, seed, and industry use ratio (percent) for sorghum
USCSUR	Annual U.S. stocks-to-use ratio (percent) for corn
USSSUR	Annual U.S. stocks-to-use ratio (percent) for sorghum
GovSUR	Government-owned stocks-to-use ratio (percent) for corn
D_1	Dummy for China's drought in 2000. It equals to 1 when year in 2000, and equals to 0 in other years.
D_2	Dummy for China's trade policy unexpected change on corn in 1995. It equals to 1 when year in 1995, and equals to 0 in other years.

Note: t values are in parentheses. *Significant at 90% level. **Significant at 95% level.

Table 4. Baseline Projections and Forecast Results of China Corn and Sorghum Producer Prices under Different Scenarios

Variables	Scenarios	2016	2017	2018	2019	2020
Corn Producer Price	Baseline	2224	2273	2461	2448	2367
(Yuan/MT)	Scenario 1	2199	2223	2380	2341	2238
	Scenario 2	2175	2174	2302	2239	2117
	Scenario 3	1448	1480	1602	1593	1541
Sorghum Producer Price	Baseline	2007	1997	2045	2008	1945
(Yuan/MT)	Scenario 1	1996	1974	2011	1963	1891
	Scenario 2	1985	1951	1977	1919	1838
	Scenario 3	1613	1604	1643	1614	1562

Figure 1. China Sorghum Excess Demand Estimate and Forecast (1991-2020)

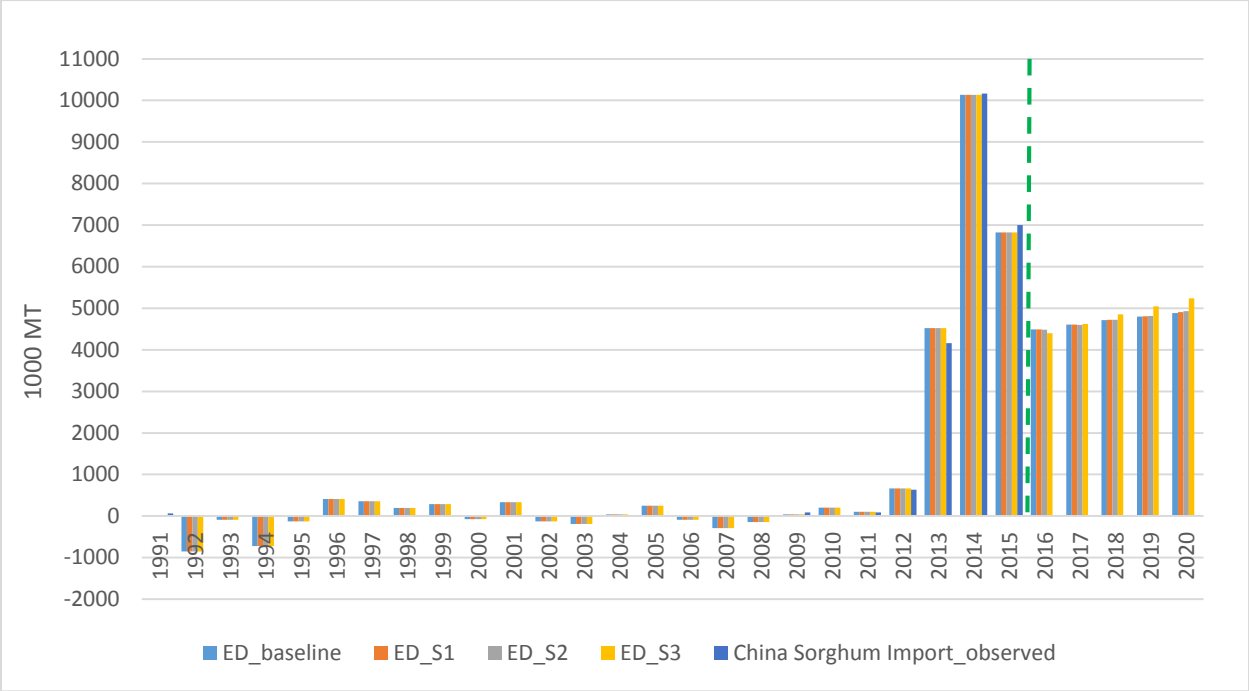

Figure 2. China Sorghum Excess Demand Forecasts (2016-2020)

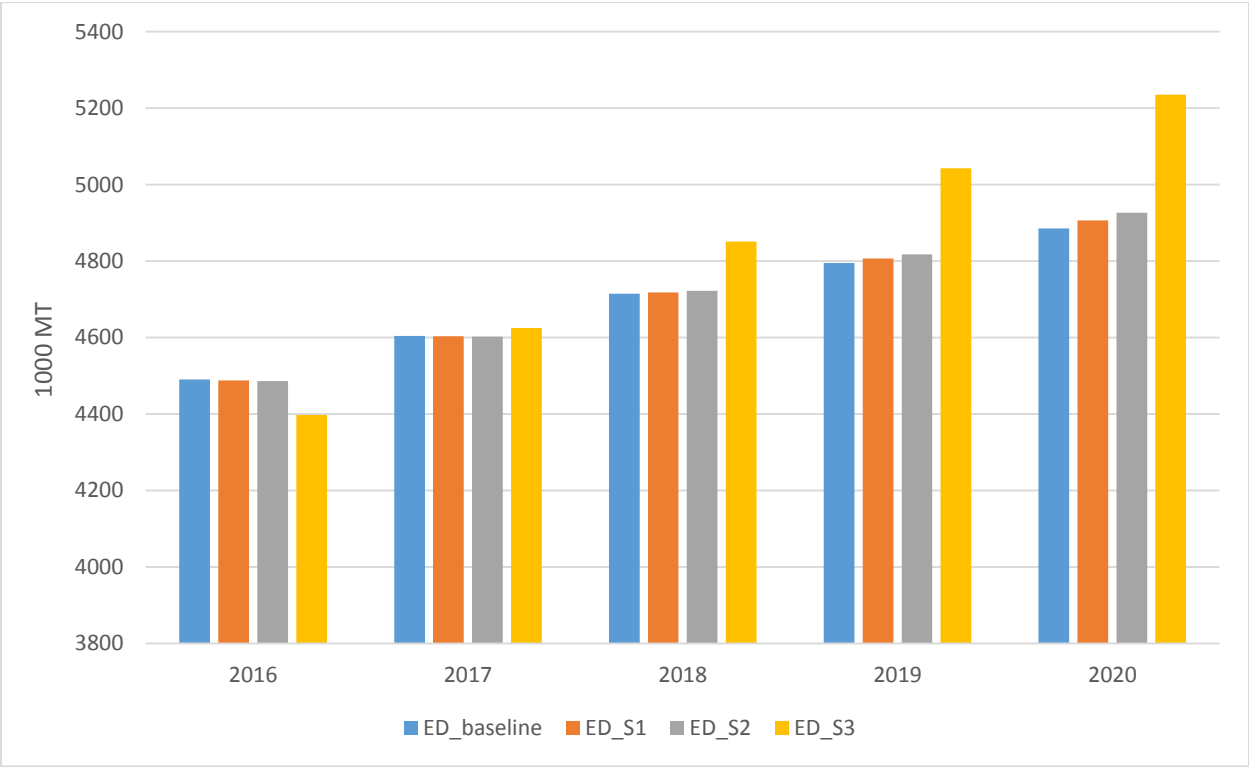

Figure 3. Forecasted China Corn and Sorghum Producer Prices