What would be the Corn and Sorghum Price Gap Allowing China to Continue Importing Sorghum?

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Abstract

The large volume of sorghum imports for feed use since 2013 has rapidly made China the largest export destination for sorghum, especially sorghum from the U.S., which has sent about 90% of its sorghum exports to China by MY 2014/2015. The main reason for China's increasing imports of sorghum may be related to its corn domestic and trade policies, which pushed up domestic corn prices. Because sorghum is a cheap close substitute for corn, the large price gap between these two grains attracted livestock industries to shift part of their feed grain use from corn to sorghum as the price of corn continued to rise. In order to estimate and forecast the prices of sorghum and corn in China, this study developed a price determination model by using a stocks-to-use ratio formulation to capture market supply and demand factors. The government policy effect has also been included in the model. A baseline projection and three simulation scenarios were performed to forecast the Chinese corn and sorghum prices from 2015 to 2019. Results of the study indicated that prices for Chinese corn and sorghum may be declining in the next five years and the price of sorghum would be lower than the price of corn. In addition, the three simulation scenarios suggested that price differences between these two grains would be smaller if the Chinese government would eliminate its temporary corn reserve program.

Keywords: Sorghum, Corn, China, Price, Stocks-to-use ratio.

Introduction

In recent years, the unexpectedly large amount of sorghum imported by China has attracted a great deal of attention from international sorghum exporters. USDA data shows that China imported about 0.6 million metric tons of grain sorghum in 2012, raised that quantity to 4 million metric tons in 2013 and then to 10 million metric tons in 2014. China's sorghum imports increased more than 10 times within only three years. The United States became the top exporter of grain sorghum and sent almost 90% of its sorghum exports to China by the market year 2014/2015. Many reports indicate that the U.S. is facing a huge sorghum demand from China, but rarely do studies clearly explain if this market would keep growing in the future.

Understanding the reasons that explain why China imports large amounts of sorghum is crucial to predicting its future sorghum market demand. USDA data shows

that the increase in sorghum imports in China is related to the sudden growth of sorghum feed consumption. Sorghum feed to use ratio is a percentage measuring the proportion of sorghum domestic consumption for feed over sorghum total domestic use, and this ratio in China has increased from 37% in 2012 to 83% in 2014, as calculated by using USDA data. Historically, corn was the major feed grain in China and on average about 70% of Chinese corn has been used for feed each year. However, the Ministry of Agriculture of China (MOA) stated that domestic corn prices have been increasing since 2008 under the pressure of continued growth in meat production as well as domestic and trade policies interventions.

In order to encourage the production of corn, beginning in 2008, Chinese farmers received a price above the market price due to government purchasing. This policy is called the "government temporary reserve program". After implementing this policy on corn, the price gap between domestic corn and cheaper imported corn and sorghum became larger. Additionally, China has imposed tariff rate quotas (TRQ) on corn and a restrictive government policy on genetically modified corn. As the USDA grain and feed annual report on China stated, the livestock industry has been shifting their feed use towards low-priced imported sorghum which has no TRQs or GMO restrictions. Since the livestock industry finds sorghum can largely be used as a cheaper substitute for corn, the price of domestic sorghum even increased above the price of corn in 2013 and the sorghum import demand growth trend is going upward sharply.

For food security purposes, China has implemented a 95% self-sufficient policy on grain production with emphasis on corn, wheat and rice since 1995. This policy has been considered as a long-term goal in the government's plan. Agricultural policies in

China such as TRQs and temporary reserve programs are methods used to achieve the 95% self-sufficiency. Recently, MOA officers mentioned that the Chinese government noticed the feed grain market had been distorted by the temporary reserve program to some extent and has started thinking about changing the current situation. But how the policy change will affect the corn and sorghum markets is ambiguous.

The objective of this study is to estimate the potential sorghum and corn wholesale prices for China in the future and simulate their levels under different policy change scenarios. This study performs annual price determination models which are based on market factors as well as government agricultural policies for Chinese corn and sorghum. Price determination models use stocks-to-use ratios to capture the effects of market supply and demand factors. International market variables as well as feed use and cross commodity pricing considerations are also included. Data used for the estimations are from USDA, FAO, and Chinese official sources. In particular, the price determination model has been used by USDA's short-term market analysis and long-term baseline projections to forecast prices and check for the consistency of its supply, demand, and price forecasting.

Results of this study could be very relevant for U.S. sorghum producers and exporters. Most of China's corn and sorghum imports have come from the U.S. in recent years. However, policy interventions sometimes cause unexpected changes in the market. The forecasted price under different simulation scenarios will provide relevant information for sorghum producers and exporters and help them make strategic plans.

Literature Review

Previous Studies

Van Meir (1983) and Baker and Menzie (1988) have studied the relationship between prices and ending stocks for corn. Hoffman and Westcott carried out many studies related to annual price forecasting and policy affecting of U.S. farm price on wheat and corn by using the relationship between prices and stocks-to-use ratios from1997 to 1999. They used stocks-to-use ratio formulation to capture the effects of market supply and demand factors on price determination and augmented the formulation by factors that represent the changing role of agricultural policies. In particular, there are a large number of unpublished annual pricing models for corn and wheat using stocks-to-ratios have been used by USDA in its forecasts. The results of previous studies showed that the stocks-to-use ratio variable is negatively related to prices.

Factors Affecting China's Wholesale Price of Corn and Sorghum

Prices are determined by the interaction of both supply and demand functions which are influenced by government policies. This section briefly discusses supply and demand components of China's corn and sorghum markets that affect the stocks. Agricultural policies, in particular, the temporary reserve program for corn, have affected the pricing of corn more directly and only during certain periods. This policy factor beyond the effects on supply and demand has been discussed separately.

Supply Factors for Corn and Sorghum

The supply variables include beginning stocks, imports, and production. The Chinese government placed a high priority on 95% self-sufficiency in food grains (wheat, rice, and corn), which is reflected in policies encouraging domestic production and limiting imports. China was a net exporter of corn from the late 1990s until 2007, but has

become a consistent importer of corn since 2008, and its exports have declined. China's shift from net exporter to importer of corn reflects its growing demand for animal protein and the derived demand of feed grain. Historical data suggests that China's consumption of corn is outpacing growth in domestic supply and the limitation of corn import incentivizes livestock industries to use sorghum as a substitute of corn. However, the huge demand for sorghum for feed use cannot be met by domestic sorghum production. Imports of grain sorghum have increased more than 10 times from year 2012 to 2014. A comparison of China's corn and sorghum imports is given in figure 1.

Beginning Stocks

The previous year's carryover becomes the current year's beginning stocks. The beginning stocks plus the current year's production defines total supply. Large stocks can be used as a cushion in a low production year.

Imports

China's agricultural imports reflect its growing demand for animal feed and the relative scarcity of its land resources. China used to be a corn net exporter and had an export subsidy on corn. After China entered the WTO in 2001, China agreed to eliminate the export subsidy but applied tariff rate quotas (TRQs) on corn imports. Before 2004 the tariff was 1% to 10% within quota and 74% above quota, and the quota was 5.85 million metric tons. In 2004, China decreased the tariff from 74% to 65% and increased the quota to 7.2 million metric tons.

China's sorghum imports have risen dramatically in recent years and have mainly been used as a corn substitute for feed purposes. Sorghum is a cheaper substitute for corn, and the advantage of importing sorghum is that it has no TRQ limitations and no trade

barrier restrictions, such as an exclusion on GMO basis. Historically, China imported sorghum for hard liquor (Bai Jiu) production, but in three recent years China's sorghum feed to use ratio increased from about 37% in 2012 to about 83% in 2014 and in comparison the corn feed to use ratio changed from 72% in 2012 to 69% in 2014 (USDA PS&D).

Production

Corn plays an important role in Chinese agriculture. The size of the area planted with corn has expanded from approximately 5.5 million hectares in the 1940s to 35 million hectares in 2012. In 2012, corn became the largest single crop produced in China, surpassing rice. China is the second largest corn producer in the world after the United States and has a 20% share of the global corn output. The key factor in China's growth in corn production should have been improving corn yields because of the growing competition for a limited land supply. However, Li and Wang (2009) pointed out that yield improvements were a factor behind China's corn output growth through 1980s but in recent decades that 70% increase in corn output was achieved primarily by expanding the area planted. They provided data showing that corn area planted grew 42% from 2002 to 2012 but the yield only improved 19% during that time period. In China, corn production was 121 million metric tons in year 2002 and then increased to 216 million metric tons in 2014. China and the U.S. plant roughly equal areas of corn now, but China's corn output is still only half as large as that of the United States.

China has a long history of planting sorghum. In 1952, sorghum planted area shared 7.5% of the total grain planted area and was mainly used for food. Most of the sorghum was planted in arid and barren land. After 1980 sorghum production decreased

and the use of sorghum shifted from food to hard liquor production and feed use. Based on data from China's National Bureau of Statistics (NBS), sorghum planted area decreased to 1.04% in 1990 then to 0.38% in 2013. Sorghum yields increased from 2.87 mt/hectare to 4 mt/hectare from 1986 to 2013. Sorghum production in China was 5.7 million metric tons in 1990 and decreased to 2.7 million metric tons in 2014.

Demand Factors for Corn and Sorghum

Components of demand for corn and sorghum are food use, feed and residual, seed, exports, and ending stocks. In China, approximately 70% of corn is used for animal feed, 20% is used in industrial processing, and less than 10% is consumed directly as human food and seed. Historically, sorghum in China was used for food, feed, and hard liquor production. As the animal protein consumption increases, sorghum for feed use represents most of the sorghum consumption in recent years.

Food, Seed, and Industrial Use

Before the 1980s, corn was mainly consumed as food in China. In the middle of the 1980s, the consumption of corn started shifting from food use to feed use and industry processing, as domestic income was increasing and consumer preference was changing. From 1992 to 2001, China's domestic corn consumption rose from 87.83 million metric tons to 115.9 million metric tons. Yang and Lu (2011) stated in their study that the proportions of food, feed, industry processing, and other uses of corn were 24:65:8:3 in 1992 and then changed to 15:72:11:2 in 2002.

Sorghum played an important role in food consumed in China before the 1980s and its use in the production of hard liquor increased after the 1980s. USDA forecasts that China's sorghum food, seed and industrial consumption is declining due to a large

slowdown in hard liquor production, which is likely related to the government's anti-corruption program starting in 2012.

Feed and Residual

About 70% of China's corn is used for feed purpose as the country's appetite for meat rapidly rises, and the rest is processed into syrups or starches. The USDA baseline projects China's corn consumption will be increasing in average 8.8 million metric tons annually over the 10 years projection period to 2023/24. This projection reflects the rising demand for meat in China, which based on continued robust income growth and an increasing urban share of population that alters consumption patterns.

From 1991 to 2005, more than 20% of sorghum was used as feed grain but this ratio decreased to about 5% on average from 2006 to 2010. High domestic corn prices in the most recent three years have pushed livestock industries to search for alternative ingredients. But import TRQs for corn had made importation of this grain more difficult. Sorghum, which is a cheap close substitute for corn, has been perceived by the livestock industries for alternative feed grain. Then, the sorghum feed to use ratio increased from 17.89% in 2010 to 83.17% in 2014. A comparison of China’s sorghum and corn feed to use ratio from 1991-2014 is shown in figure 2.

Export

China joined WTO in 2001 and agreed to eliminate its export subsidies. In 2007, due to continuing increasing domestic corn consumption, the government eliminated all export subsidies and shifted to a corn importing country since 2008. In 1995, China suddenly stopped almost all corn exports but increased its imports, which caused large price increase in the international market as well as the domestic market.

As Asian countries have been decreasing their import demand for sorghum, China's sorghum exports have been decreasing. In 1991, China's sorghum export share was 4.86% of the world's total sorghum exports and this number fell to 0.18% in 2015. Compare to the U.S., China is a small country in sorghum exports.

Ending Stocks

China placed a temporary reserve program on corn starting in 2008 and this policy encourages the production of corn. In 2014, China's corn stocks-to-use ratio reached almost 50%. The continued growth in corn stocks is straining government storage facilities. As mentioned in the USDA grain and feed annual report of China, the Chinese government is renting storage facilities from corn processors to help hold temporary corn reserves. The inadequate storage facilities are leading to deteriorating corn quality and the government is trying to release its excess stocks.

Since the price of corn in China has been stable at a high level in recent years, sorghum as a cheap close substitute for corn has been largely used for feed production and the sorghum stocks-to-use ratio has fallen from 22.44% in 2008 to 4.06% in 2014.

Temporary Reserve Program

Over the last decades, except for the 95% self-sufficient policy and TRQs on corn, China has used subsides to expand the production of corn to meet growing domestic demand. The central component of China's subsidy policy for corn is its price support program started in 2008. The price support program for corn is referred to as a "temporary reserve program", with the announcement of the price support taking place during the marketing year, based on supply and demand conditions. When support prices are announced, the funding for the program is provided from the central government to provincial authorities for implementation. The support prices and government purchased

quantity of corn are listed in table 1. The essential objective of this program is to ensure a minimum price level for the grain producer. In recent years, the Chinese government has intervened in the domestic corn market on a large scale to support corn prices. The government had purchased 30.83 million MT, 69.19 million MT, and 81.07 million MT of corn in 2012, 2013, and 2014, respectively. High support prices have had a dramatic effect on production. Since China first implemented this program for corn in 2008, production has increased from 165 million metric tons to 220 million metric tons. This is about a 33% increase in corn production over five years.

Unlike corn, sorghum has not been included with other grain for the purpose of achieving 95% self-sufficiency. Sorghum used to be considered a minor crop in China and the production of sorghum has been decreasing over the years. In addition, the grain price support program has not included sorghum. A comparison of policies implemented for corn and sorghum is listed in table 2.

Analytical Framework

This section illustrates how to derive the relationship of prices and ending stocks within a partial equilibrium model. Prices are determined by the interaction of both supply and demand aspects. A partial equilibrium model as noted by Westcott and Hoffman (1999) will relate prices to factors that influence supply and demand. These factors are often summarized in the stocks-to-use ratio as Westcott and Hoffman stated.

Following Labys (1973) and Westcott and Hoffman (1999), a partial equilibrium model for competitive markets with inventories generally consists of a supply function, a demand function, a stock function, and an identity describing equilibrium. Supply (S) is a function of the previous year's price and demand (D) is a function of prices in current and

previous years. In their simple form, stocks (K) are a function of price when there is no government price support. Market equilibrium requires that supply equals demand plus stocks. The following functions (1-4) display the supply, demand, stocks, and market equilibrium. The p is the market price, z is a set of exogenous variables, and t-1 represents prices in the previous year.

$$S = s(p_{t-1}, z) \quad (1)$$

$$D = d(p, p_{t-1}, z) \quad (2)$$

$$K = k(p, z) \quad (3)$$

$$S - D - K = 0 \quad (4)$$

The equilibrium condition allows us to solve the price as the inverse of the stocks function. In this function, prices are negatively related to stocks as noted by Westcott and Hoffman (1999).

$$p = k^{-1}(K, z) \quad (5)$$

Westcott and Hoffman used stocks-to-use ratio as an indicator of market supply and demand conditions and it has become common to consider stocks in terms of their size relative to total usage. Stocks are positively related to production, and the total use, which includes domestic consumption and exports, is generally more stable and tends to shift gradually over time. Supply and demand shifters also include variables that capture the effect of policy as well as factors affecting weather and demand shocks. In addition, Chinese corn and sorghum prices are, to some extent influenced by the international market, especially by the U.S., which is the world largest corn and sorghum exporting country. U.S. corn and sorghum stocks-to-use ratios are also included in the models developed in this study. Function 5 can be rewritten as

$$p = k^{-1}(K, GovSTU, FTU, USSTU, DUM, z) \quad (6)$$

The price function 6 has additional variables GovSTU for government temporary reserve stocks (price support policy), FTU for feed share of annual use, USSTU for U.S. stocks-to-use ratios of corn and sorghum, and DUM for dummies indicating exceptional weather changes or other shocks. Prices are negatively related to total stocks, but positively related to government owned stocks. This means the larger total stocks would relate to lower prices and larger government owned stocks would push prices up.

Model Specification and Data

Following by Westcott and Hoffman (1999), most of the explanatory variables used in function 6 are in logarithmic (double-log) form, but the government-owned stocks variable in corn price model was not transformed to logarithms. To estimate corn and sorghum prices, function 6 can be rewritten as follows:

Corn price model:

$$Ln(p_c) = \alpha_0 + \alpha_1 Ln(CSUR) + \alpha_2 Ln(CFTU) + \alpha_3 Ln(USCSUR) + \alpha_4 GovSUR + \alpha_5 D_1 + \alpha_6 D_2 + \mu_c \quad (6a)$$

Sorghum price model:

$$Ln(p_s) = \beta_0 + \beta_1 Ln(SSUR) + \beta_2 Ln(SFTU) * D_3 + \beta_3 Ln(p_c) + \beta_4 Ln(USSSUR) * D_4 + \beta_5 D_5 + \beta_6 D_1 + \mu_s \quad (6b)$$

Variables p_c and p_s are China's annual wholesale prices for corn and sorghum, respectively. Sorghum is a close substitute of corn, so when the price of corn is increasing, the demand for sorghum will also increase, which could result in an increasing sorghum price. Hence, the coefficient β_3 is hypothesized to be positive. The stocks variable (K) is transformed to reflect stocks relative to total domestic use plus

exports according to Westcott (1999). CSUR and SSUR represent corn and sorghum stocks-to-use ratios. The expected signs of Chinese corn and sorghum stocks-to-use ratio variables are negative. USCSUR and USSSUR indicate U.S. corn and sorghum stocks-to-use ratios. Historically, China is a large export destination for U.S. corn, and in the most recent three years more than 70% of U.S. sorghum was exported to China. The lower U.S. stocks-to-use ratio for corn and sorghum indicate more grains are available for the market place, which may cause the price of Chinese domestic corn and sorghum to decrease. The expected signs of U.S. corn and sorghum stocks-to-use ratios are positive. GovSUR is the government stocks-to-use ratio. Larger government owned stocks indicates that a greater share of stocks would not be accessible in the market and would increase the grain prices. The expected sign of the government stocks-to-use ratio is positive. CFTU and SFTU are corn and sorghum feed to use ratios. The feed to use ratios are domestic feed use divided by annual total use. Larger feed consumption may result in higher prices, thus, the sign of corn and sorghum feed to use ratios are positive. Each ratio is multiplied by 100 to express the result as a percentage.

D_1 represents a dummy variable equal to 1 in 2000 and equals to 0 in other years. China had its worst drought since 1949 in 2000 and the production of crops in that year decreased dramatically. D_2 is the dummy variable that captures China's sudden halt to almost all corn export and imports large amounts of corn in 1995, which affected both domestic and international prices for corn. D_3 is the dummy variable for year 2005 and 2006 when sorghum feed consumption suddenly and dramatically decreased from 500,000 metric tons to 150,000 metric tons. D_4 is the dummy variable that represents the significant effect of U.S. sorghum exports on the Chinese sorghum market during 2012 to

2014. D_5 is the dummy variable that represents the period from 2003 to 2009 when China largely decreased the planted acreage and production of sorghum. Production declined at this time period causing hard liquor production industries to expect higher sorghum prices and they expanded their stocks of sorghum. The α_i and β_i are parameters to be estimated. The μ_c and μ_s are error terms for the corn and sorghum models, respectively. Variable definitions are summarized in table 3.

Validation of the model uses Theil's inequality coefficient (*U*), with the proportions of inequality U^M, U^S, U^C which are called the bias, the variance, and the covariance proportions of *U*, respectively.

The models were estimated using annual marketing year data for the period 1991 to 2014 and a total of 24 observations. Corn and sorghum annual wholesale prices are obtained from China Grain Reserves Corporation (SINOGRAIN) website. Other expletory variables are from USDA PS&D. The Durbin-Watson test indicates that there exists second-order autocorrelation in the corn price model. Thus, the autoregressive error correction with AR (2) has been used to correct the regression estimates for autocorrelation. The Durbin-Watson test shows that first-order autocorrelation is not a problem for the sorghum price model and the OLS regression has been used for the estimation. Both corn and sorghum price models were estimated and simulated in SAS 9.4.

Empirical Results

In this section, detailed results of Chinese corn and sorghum price models estimations are presented. The estimation results for corn (equation 7a) and sorghum

(equation 7b) price models based on annual data over the period 1991-2014 are presented in table 4. Both price models showed acceptable goodness of fit as indicated by the R^2 statistic.

The estimated corn price equation 7a in table 4 shows that the coefficient for corn stocks-to-use variable is negative, and coefficients for the feed to use variable and the government-owned stocks variable are positive. All signs of these three variables are as hypothesized and all coefficients are significant at the 95% level. The coefficient for dummy variable D_1, which represents the worst drought in 2000, is positive and significant at the 99% level. The coefficient for dummy $D_{2,}$ which indicates an unexpected halt in exports, but large corn imports in 1995, is negative and significant at the 90% level.

Only the U.S. corn stocks-to-use ratio failed to show the expected sign and is not significant at less than the 90% level. The sign for this variable was expected to be positive. In most of the years from 1991 to 2014, China share was less than 7% of the world's total imports of corn and less than 6% of the world's total exports of corn. This indicates that China was a small country with respect to corn imports as well as a small country with respect to corn exports during the past twenty-four years. China is a price taker of corn in the international corn market. The larger stocks relative to total use of the U.S. mean a smaller supply of corn in the market place, and this may push up China's domestic corn price. However, the estimated coefficient of the U.S. corn stocks-to-use ratio variable is negative, which indicates the larger corn stocks U.S. reserved will lead to a lower price for Chinese domestic corn. One reasonable explanation of this result is that China established a policy of 95% self-sufficiency in the mid-90s for grain security

purposes and grains included in this policy are rice, wheat, and corn. In order to better achieve this 95% self-sufficiency objective, the Chinese government applied TRQs on corn imports and sometimes also used bio-tech reasons such as genetically modified organisms (GMO) to reject other countries' exports of corn to China. To some extent, policies placed on corn imports distort the market and also make the Chinese corn market hard to predict. However, the U.S. is the world largest corn exporting country and has the power to affect the international corn market, so this variable has been kept for corn price forecasting in this study.

Sorghum price model 7b in table 4 shows that the coefficient for sorghum stocks-to-use ratio is negative as expected. But this variable is not significant at the 90% level. Sorghum is a minor crop in China and only shared a very small proportion of the grain market in China before 2012. Lack of data and information in the data collection process may be one of the reasons this variable is not statistically significant. However, this stocks variable started having a better influence of the market price since 2012 as more and more sorghum has been introduced into the grain market as a corn substitute. The sorghum stocks-to-use ratio is still an important variable that could be used for future price forecasting, assuming that sorghum will maintain its current role in the grain market.

Coefficients for sorghum feed to use ratio, corn wholesale price, and U.S. sorghum stocks-to-use ratio are all positive as expected, and are all significant at 95% level. Dummy variables D_1 and D_5 have negative signs and are significant at the 95% level.

The corn and sorghum price models are validated using the Theil's inequality coefficient, with its proportions of inequality U^M, U^S, and U^C corresponding to characteristic sources of the simulation error. The ideal distribution of the Theil's inequality coefficient over the three proportions is U^M=U^S=0, and U^C=1. A summary of these validation statistics is listed in table 5. The statistics results suggest that both established models are suitable for further projections and simulations.

Price Forecasting Applications

In this section, one baseline projection and three simulations for corn and sorghum prices in different scenarios based on validated price models are presented. This study performs forecasting over the period from 2015 to 2019. Values of the exogenous variables represent the Chinese market planned using FAPRI World Trade Outlook. However, the obtainable FAPRI World Trade Outlook projections have only been updated until year 2012. Previous years' projections seem not to have included the corn temporary reserve program effect and the phenomenon of China gradually importing large amounts of sorghum since 2012 in its updates. FAPRI projections, compared to actual data, overestimated Chinese corn total domestic use and underestimate corn ending stocks and feed use (see in figure 3). In addition, sorghum projections were not included in FAPRI World Trade Outlook. It is hard to find appropriate reference information for sorghum price forecasting from official data.

Baseline Projection

For corn price forecasting, the most recent five years (2010-2014) average data have been used as exogenous values for the Chinese corn stocks-to use ratio and feed to

use ratio. In the baseline projection, the government-owned stocks for the next five years are assumed to be the same as in year 2014. The U.S. corn stocks-to-use ratio for the next five years use projections from USDA Agricultural Projections to 2024. The sorghum price forecasting model uses an average of the most recent three years (2012-2014) data as the value for Chinese sorghum stocks-to-use ratio. The reason for using the previous three years' averages for forecasting is that the data during this time period better reflects the current reality of the Chinese sorghum market. The feed to use ratio of sorghum was 83.33% in 2014, a high level from which it seems unlikely to increase very much more in the future. Thus, the sorghum feed to use ratio assumes a 0.5% increase each year starting with year 2014 for the next five years. The U.S. sorghum stocks-to-use ratio for the next five years used projections from USDA Agricultural Projections to 2024. The variable of corn wholesale price in the sorghum price model used the baseline projected corn price from the corn price model.

According to the baseline projected results, the price difference between China's domestic corn and sorghum is getting larger. Results of estimated and baseline projected results are listed in table 7 and a descriptive graph is shown in figure 4. During 1991 to 2014, the price of Chinese corn was above the price of sorghum most of the time. However, in 2013, the price of sorghum exceeded the price of corn by 848 yuan (about 133 US dollars) per metric tons due to the large demand for sorghum for feed use and reached a peak over the previous 24 years. The baseline projected results show that starting from year 2015 the domestic sorghum price will go below the domestic corn price and the price difference could be as large as about 1000 yuan ($157) per metric tons.

Model Simulation and Forecasts

Three scenarios were analyzed using the established corn and sorghum price models. For the corn price forecasts model, all other variables remain at the same values as in the baseline projection but the government-owned stocks-to-use ratio will change by: 1) decreasing by 1% each year from 2014 (40.13%) for the next five years; 2) decreasing by 2% each year from 2014 (40.13%) for the next five years; and 3) going to zero percent for the next five years, which means the government will eliminate the temporary reserve program. For the sorghum price forecasts model, all other variables remain at the same values as in the baseline projection but the corn wholesale price will change as the forecasted prices changed under the simulated three scenarios in the corn model. A summary of the scenarios simulated for forecasting has been listed in table 6.

The simulated results are compared to the baseline projections. Details of the baseline projection and three forecasted prices are shown in table 7. In all three simulations, the wholesale prices of corn and sorghum trended downward, which indicated that corn and sorghum prices in China are decreasing in the next five years. In the cases of scenario one and scenario two with government-owned stocks decreasing by 1% and 2% each year, respectively, the forecasted corn prices and sorghum prices are close to the prices forecasted in the baseline projection. The third scenario, which represents elimination of the government's temporary corn reserve program, deserves special attention. In this scenario, the corn and sorghum wholesale prices also trended downward after 2015, but the price differences between the two crops were smaller than all other cases before. In previous cases, the price of sorghum was about 800-1200 yuan/metric tons cheaper than the price of corn, but in the case when the government

eliminates the temporary corn reserve program, the sorghum price is only about 400-600 yuan/metric tons cheaper than the price of corn. Figures 5, 6, and 7 display the results in graphs.

A comparison of the three simulated scenarios indicates that the advantage of using sorghum as a cheaper substitute for corn would be more obvious if China keep its temporary reserve program instead of eliminating it. Chinese feed grain consumption is increasing at a rate of about 6.18% per year, which is much higher than the rate at which world feed grain consumption is rising, 2.07%. This implies that over the long-term, China feed grain consumption is on an upward trend. Lower domestic sorghum prices are one of the most important incentives for livestock industries to choose sorghum as the feed substitute for corn. The cheaper price of sorghum may bring about a larger market demand. It is hard to predict when the Chinese government will eliminate the temporary reserve program of corn, but under the simulated scenarios one and two, the results showing that sorghum is still a cheap close substitute for corn may sustain the current huge demand for the next five years.

The wholesale price of Chinese sorghum was 3098 yuan/mt and 2418 yuan/mt in 2013 and 2014, respectively. The U.S. sorghum FOB gulf price was 1509 yuan/mt and 1272 yuan/mt in 2013 and 2014, respectively. U.S. sorghum price is about 1200-1500 yuan/mt less than Chinese sorghum and China imported around 86% of its sorghum from the U.S. in those two years. Compared to corn, Chinese sorghum has no TRQs and 95% self-sufficiency limitations. Even in scenarios one and two, the price of Chinese sorghum is expected to fall in the next five years. There will still be room for U.S. sorghum if the

price difference between Chinese sorghum and U.S. sorghum is large enough. The detail of import demand for Chinese sorghum needs further analysis.

Conclusion

Models presented in this study for corn and sorghum prices use a stocks-to-use ratio formulation to capture the market supply and demand factors that affect price determination. The effect of government policy has also been included in the model. This study estimated the corn and sorghum prices model by using annual data during years 1991 to 2014 and used the established model to perform a baseline projection and three scenarios simulations. Results of the study indicate that prices of Chinese corn and sorghum will be decreasing in the next five years (2015-2019) and the price of sorghum would be less than the price of corn. In addition, the three scenarios simulated suggested that price differences between Chinese corn and sorghum will shrink if the government eliminates the temporary reserve program of corn for the next five years.

Although both corn and sorghum prices models showed strong statistical properties, further efforts are needed to explain the unexpected negative sign of the U.S. corn stocks-to-use variable in the corn price model and the insignificance of the sorghum stocks-to-use variable in the sorghum price model. Furthermore, to better estimate and forecast China's future excess sorghum demand, more study with both supply and demand functions for Chinese sorghum is needed. Nevertheless, models built in this study are simple, reasonably accurate, and easy to use. Forecasts based on this study could be used as reference for further analysis related to the supply and demand for Chinese sorghum and may also prove useful for sorghum exporting countries.

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Appendix

Table 1. China Corn Annual Temporary Reserve Price and Quantity

Year	Purchase price from Liaoning (Yuan/mt)	Purchase price from Jiling (Yuan/mt)	Purchase price from Heilongjiang (Yuan/mt)	Price of current year minus last year	Quantity (million tons)
2008	1520	1500	1480	NA	35.74
2009	1520	1500	1480	0	0.60
2010	1820	1800	1780	300	0.00
2011	2000	1980	1960	180	1.27
2012	2140	2120	2100	140	30.83
2013	2260	2240	2220	120	69.19
2014	2260	2240	2220	0	81.07
2015	2000	2000	2000	-220-260	Unknown[1]

Note: [1] Temporary reserved quantity of 2015 has not been published yet until this time point.

Table 2. Chinese Agriculture Policy: Corn vs. Sorghum

	Corn	Sorghum
Domestic Subsidy	• Government temporary reserve policy since 2008 • Corn considered as food grain and be included in the 95% self-sufficiency for grains since 1995	• No production assistance and financial support • Not include in the 95% self-sufficiency for grains
Trade Policy	• Tariff rate quota (7.2 million MT), within TRQ is 1-10% and out of the TRQ is 60% • Bio-tech barrier(GMO)	• No TRQ • No Bio-tech barrier

Table 3. Summary of Variable Definition

Variable Name	Definition
p_c	Annual China wholesale price of corn
p_s	Annual China wholesale 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
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.
D_3	Dummy for sorghum feed consumption suddenly decrease in 2005 and 2006. It equals to 1 when years in 2005 and 2006, and equals to 0 in other years.
D_4	Dummy for significant influence of U.S. sorghum export on Chinese market during 2012-2014. It equals to 1 when years in 2012, 2013, and 2014, and equals to 0 in other years.
D_5	Dummy for China's large decrease of sorghum production during 2003-2009. It equals to 1 when years during 2003-2009, and equals to 0 in other years.

Note: Stocks-to-use ratio=ending stocks/total domestic consumption (domestic use + export); Feed-to-use ratio=domestic feed use/ total domestic consumption (domestic use + export).

Table 4. Summary of the Estimated Results of the Corn and Sorghum Prices Model

Corn Price Model

$$\underset{}{\text{Ln}(p_c)} = \underset{(-5.61)^{**}}{-19.447} \underset{(-2.28)^{**}}{-0.158\text{Ln(CSUR)}} + \underset{(8.27)^{**}}{6.598\text{Ln(CFTU)}} \underset{(-1.69)}{-0.274\text{Ln(USCSUR)}} + \underset{(2.30)^{**}}{0.01\text{GovSUR}} + \underset{(4.53)^{**}}{0.874D_1} \underset{(-1.96)^{*}}{-0.565D_2} + \mu_c \quad \text{Rsq=0.89} \quad (7a)$$

Durbin-Watson Statistic=2.102

Sorghum Price Model

$$\underset{}{\text{Ln}(p_s)} = \underset{(2.98)^{**}}{2.379} \underset{(-0.63)}{-0.042\text{Ln(SSUR)}} + \underset{(2.17)^{**}}{0.126\text{Ln(SFTU)}} * D_3 + \underset{(6.83)^{**}}{0.677\ \text{Ln}(p_c)} + \underset{(4.89)^{**}}{0.346\text{Ln(USSSUR)}} * D_4 \underset{(-2.25)^{**}}{-0.274D_5} \underset{(-3.32)^{**}}{-0.69D_1} + \mu_s \quad \text{Rsq=0.91} \quad (7b)$$

Durbin-Watson Statistic=1.993

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

Table 5. Validation Statistics for Estimations of Corn and Sorghum Price Model

Variables	Bias (U^M)	Var (U^S)	Covar (U^C)	Theil's U
$\text{Ln}(P_c)$	0.00	0.00	1.00	0.012
$\text{Ln}(P_s)$	0.00	0.02	0.98	0.302

Table 6. A Summary of Scenarios Simulated for Forecasts (2015-2019)

Model	Scenarios	Variables
Corn Price Model	Baseline Projections	CSUR,CFTU (use five years average during 2010-2014); USCSUR (use USDA long-term projections); GovSUR (assume same data as year 2014 which is 40.13%)
	Scenario 1	CSUR,CFTU (use five years average during 2010-2014); USCSUR (use USDA long-term projections); GovSUR (assume decrease by 1% each year from 40.13%)
	Scenario 2	CSUR,CFTU (use five years average during 2010-2014); USCSUR (use USDA long-term projections); GovSUR (assume decrease by 2% each year from 40.13%)
	Scenario 3	CSUR,CFTU (use five years average during 2010-2014); USCSUR (use USDA long-term projections); GovSUR (assume policy has been eliminated and the government stock-to-use ratio equal to 0%)
Sorghum Price Model	Baseline Projections	SSUR(use three years average during 2012-2014); SFTU (assume 0.5% increase each year); USSSUR (use USDA long-term projections); P_c (use price forecasted by corn price baseline projection)
	Scenario 1	SSUR(use three years average during 2012-2014); SFTU (assume 0.5% increase each year); USSSUR (use USDA long-term projections); P_c (use price forecasted by corn price scenario 1)
	Scenario 2	SSUR(use three years average during 2012-2014); SFTU (assume 0.5% increase each year); USSSUR (use USDA long-term projections); P_c (use price forecasted by corn price scenario 2)
	Scenario 3	SSUR(use three years average during 2012-2014); SFTU (assume 0.5% increase each year); USSSUR (use USDA long-term projections); P_c (use price forecasted by corn price scenario 3)

Table 7. Baseline Projections and Forecast Results of China Corn and Sorghum Wholesale Prices under Different Scenarios

Variables	Scenarios	2015	2016	2017	2018	2019
Corn Wholesale Price	Baseline	2861	2393	2335	2548	2632
(Yuan/mt)	Scenario 1	2831	2343	2262	2442	2496
	Scenario 2	2801	2294	2191	2341	2368
	Scenario 3	1872	1565	1528	1667	1722
Sorghum Wholesale Price	Baseline	1659	1470	1446	1533	1568
(Yuan/ mt)	Scenario 1	1647	1449	1415	1490	1512
	Scenario 2	1635	1428	1385	1448	1459
	Scenario 3	1245	1103	1085	1151	1176

Figure 1. Comparison of China's Corn and Sorghum Import

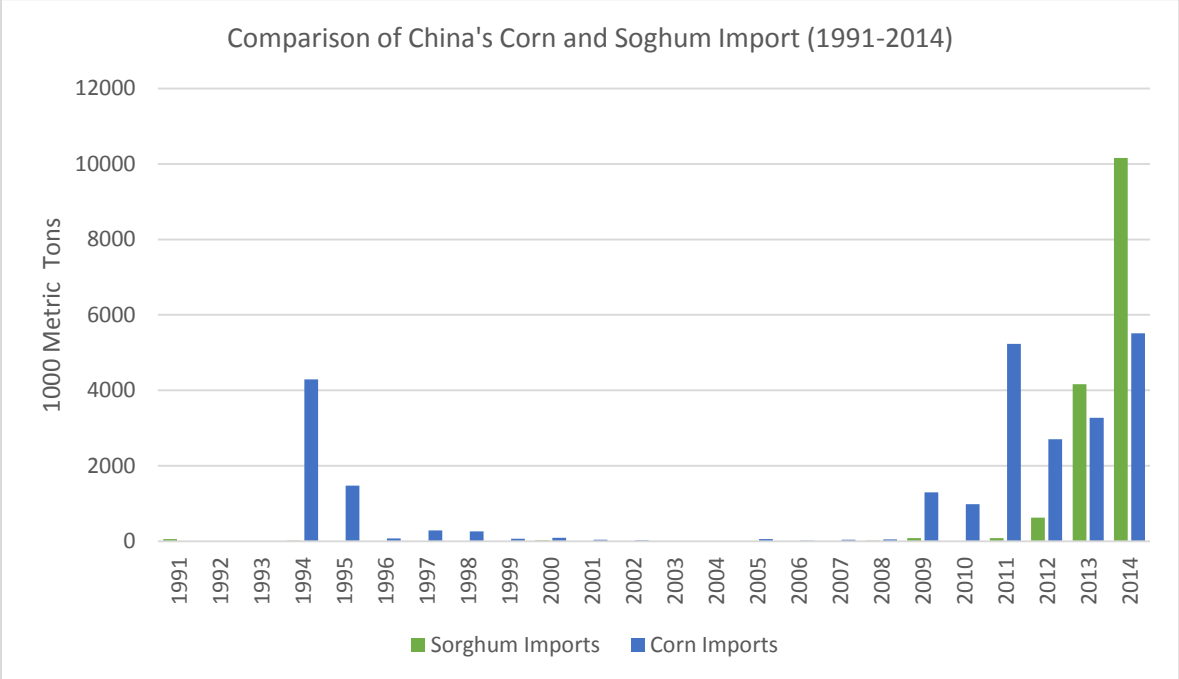

Figure 2. Comparison of China's Sorghum and Corn Feed-to-use Ratio

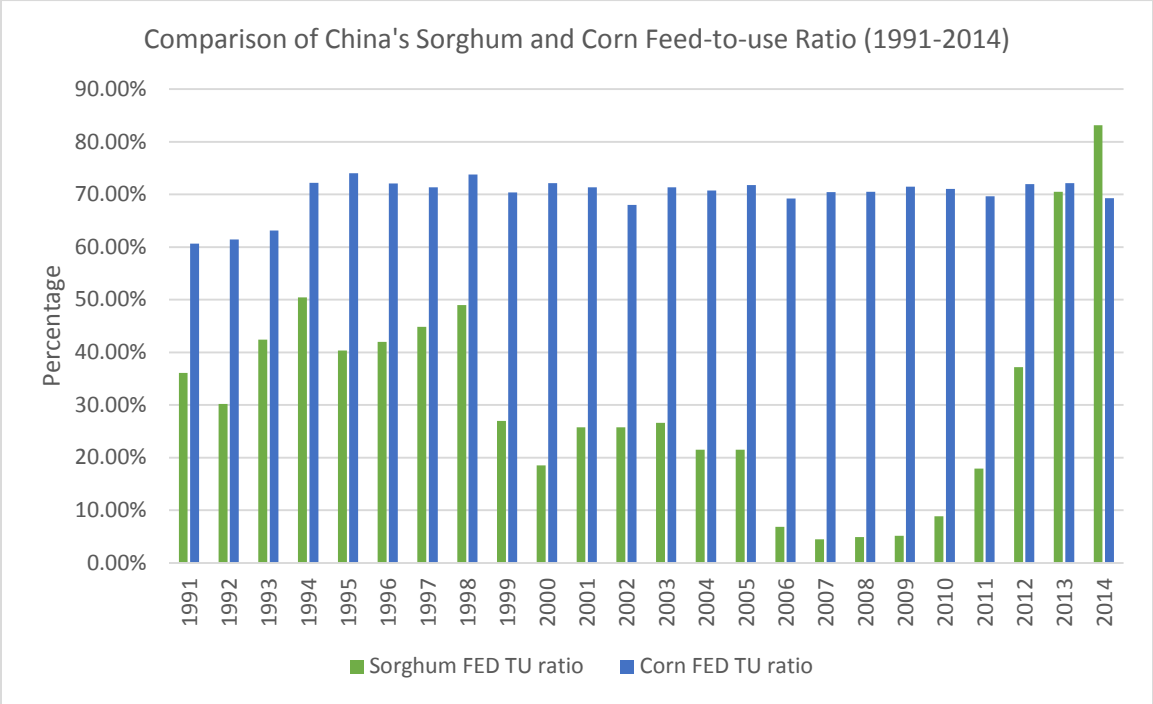

Figure 3. Comparison of FAPRI Projections 2012 Baseline and Actual Data for Chinese Corn Ending Stock, Feed Consumption, and Domestic Total Use

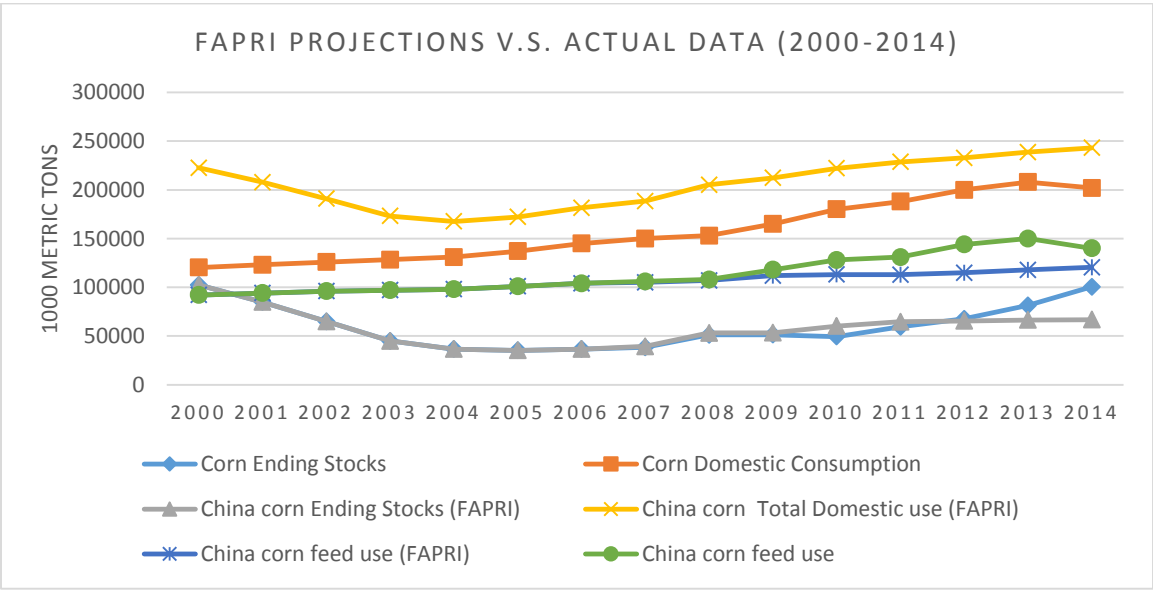

Figure 4. Observed vs. Predicted and Baseline Projected Values of China Corn and Sorghum Wholesale Prices

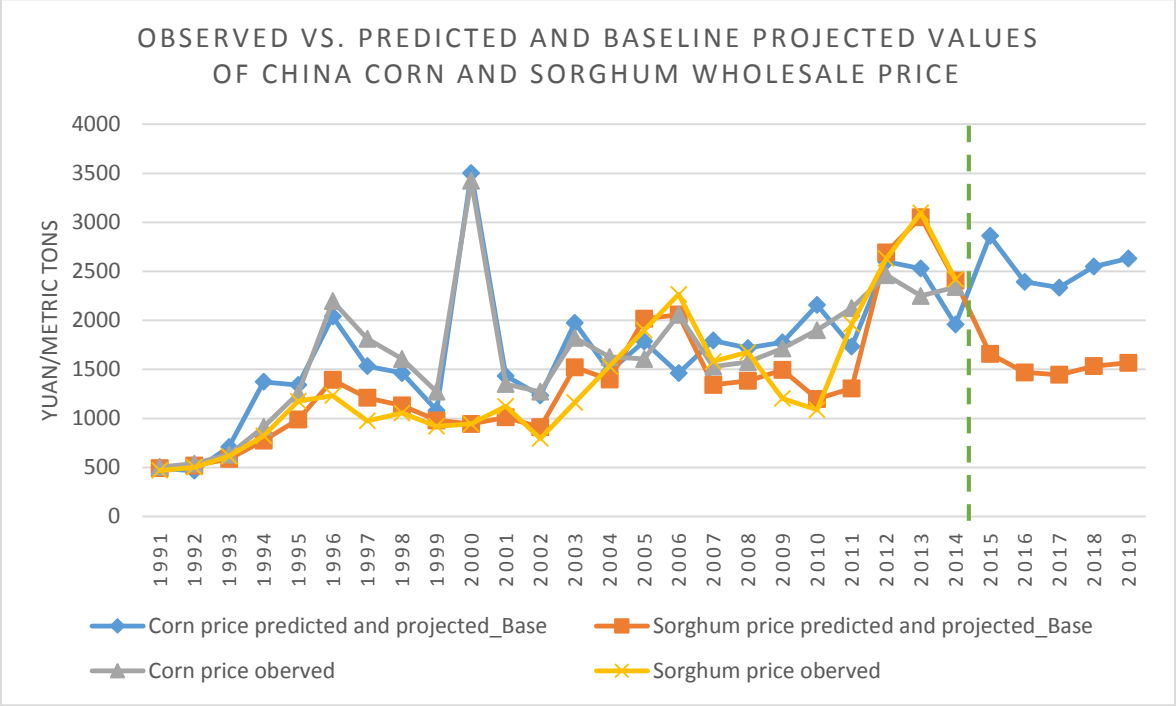

Figure5. Observed vs. Predicted and Scenario One Forecasts Values of China Corn and Sorghum Wholesale Prices

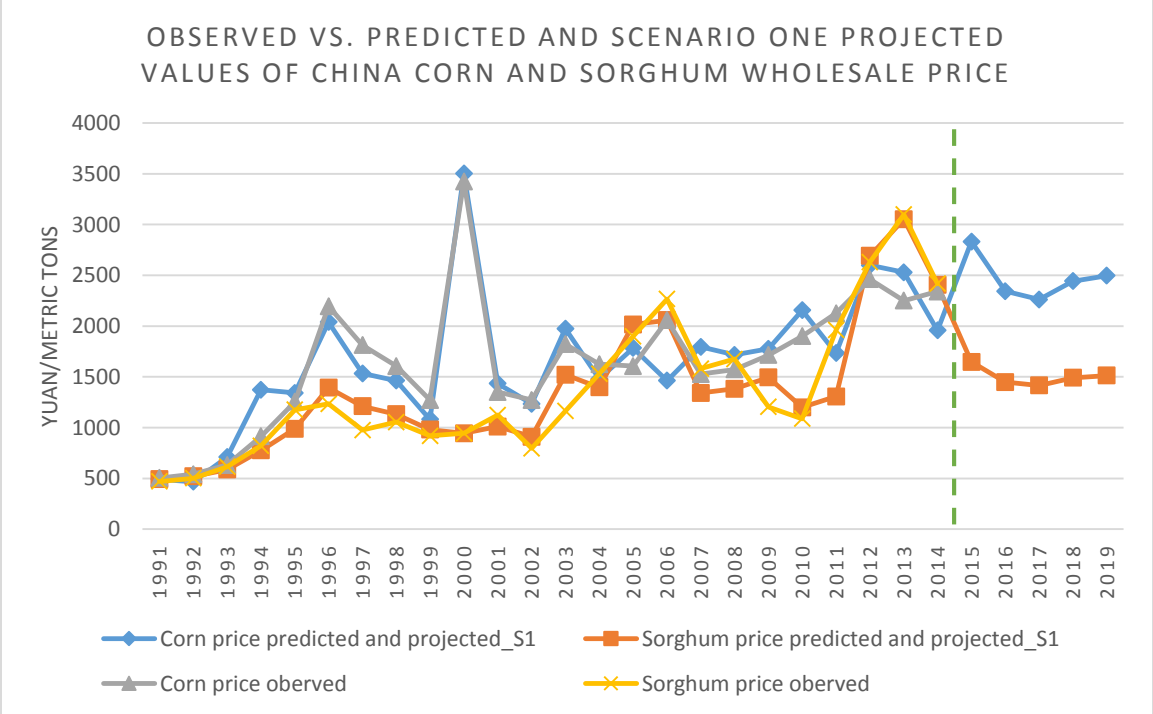

Figure6. Observed vs. Predicted and Scenario Two Forecasts Values of China Corn and Sorghum Wholesale Prices

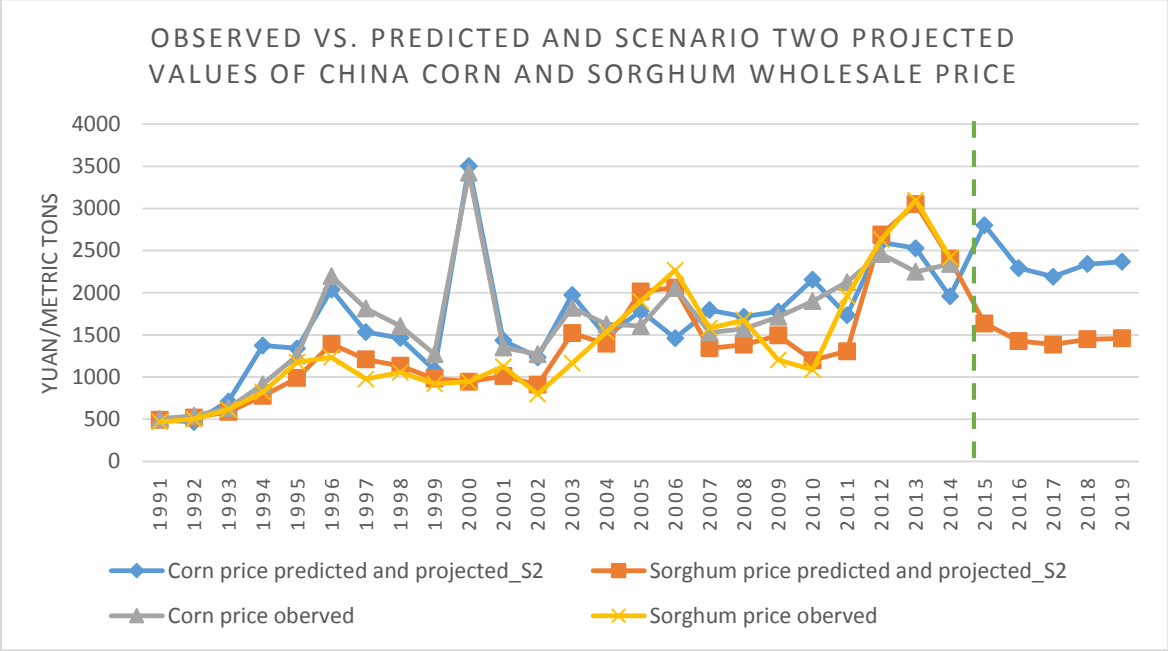

Figure7. Observed vs. Predicted and Scenario Three Forecasts Values of China Corn and Sorghum Wholesale Prices