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Effects of China's Trade Policies on the U.S. Distiller's Dried Grains

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EFFECT OF CHINA'S TRADE POLICIES ON U.S. DISTILLER'S DRIED GRAINS

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Domestic and export demand for distillers' dried grains (DDG) has increased since the early 2000s. DDG have become an important component of livestock feed given its nutritional value and competitive price. Over the last decade, China has become one of the major export destinations for U.S. DDG. However, there have been recent changes in trade policies in China. In this thesis, we develop an inverse demand equation to analyze the impact of China's policies on U.S. DDG prices. The model contributes to the literature by incorporating domestic and international demand through which exogenous shocks, such as China's trade barriers, may affect U.S. DDG prices. Our results provide evidence that U.S. DDG prices are significantly lower during the time that anti-dumping and countervailing duties are in place.

I dedicate this thesis to my parents, Meire and Dimas. Thank you for believing that knowledge is the greatest inheritance and for having taught me the value of wisdom. Also, I'm very grateful to my sister, Leticia, and grandma, Lany, for all the encouragement. This is for you.

Table of Contents

List of Figures

List of Tables

List of Equations

Chapter 1: Introduction

Distillers' dried grains (DDG) is a coproduct produced by dry-mill ethanol plants (Hoffman and Baker 2011). Initially, DDG was considered a waste product (Stewart et al. 2017). However, DDG is now recognized as a rich source of energy and protein making it a good substitute for corn and soybean meal in livestock and poultry diets. Adding DDG into these diets may present nutritional and/or price constraints. The volume of DDG to be incorporated in the animal feed depends on the nutrient requirements of the livestock/poultry species and the cost of alternative diet ingredients (Hoffman and Baker 2011). The animal nutrition industry has developed a strong demand for U.S. DDG as production of DDG has expanded (Stewart et al. 2017).

Ethanol production, and consequently, DDG production has been increasing in the United States over the last decade. Ethanol production increased by 13.79 billion gallons between 2000 and 2016, with most of this increase after 2006 (U.S. Energy Information Administration 2018). The sharp increase in ethanol supply was mainly driven by high crude oil prices, large tax credits for ethanol blenders, vast net exports in 2010 and 2011 and the Renewable Fuel Standards (RFS) mandates (Irwin and Good 2012). This increase in ethanol production contributed to an increase of over 43.71 million tons of DDG production between 2000 and 2016 (U.S. Energy Information Administration 2018). In 2016, the United States produced approximately 44.31 million tons of DDG.[1] Of this total, 70% of DDG were consumed domestically while the remaining 30% was exported.[2] Exports of U.S. DDG have also been

[1] Data calculated from ethanol production based on USDA calculation (1 bu of corn yields 2.8 gal ethanol generating 17.75 lbs DDG per bushel of corn) (USDA AMS 2018).
[2] Percentages calculated from comparison between total exports (Source: USDA ERS 2018) and consumption (calculated from total production minus total exports).

increasing during this time period by 11.76 million tons (USDA ERS 2018). In 2016, the United States delivered DDG to 50 countries around the world compared to only 22 countries in 2000 (U.N. Comtrade 2018).

China has emerged as an important import market of U.S. DDG. Prior to 2008, China sporadically imported small amounts of DDG. It was not until 2009 when the amount of DDG shipped to China became prominent. In 2008, China imported 9.37 thousand tons of DDG, and by 2010 they were the number one importer of U.S. DDG, importing approximately 2.79 million tons from the United States. However, exports of U.S. DDG to China have fluctuated due to market instability (USDA ERS 2018). China's potential imports of U.S. DDG depend on the price of corn, Chinese policies, and the availability and prices of other substitute feed ingredients (Jewison and Gale 2012). There have been several policies implemented by the Chinese government that have affected the trade of DDG over the last several years. The objective of this thesis is to analyze the impact of domestic and export demand on DDG prices in the United States. In particular, the impact of China's government investigations and policies on U.S. DDG prices.

Previous literature has focused on the interrelations between corn, soybean meal and DDG prices (Anderson, Anderson and Sawyer 2008; Tejeda 2012; Irwin and Good 2013; Johnson et al. 2015; Etienne, Trujillo-Barrera and Hoffman 2017). These studies found correlation among the prices over varying time periods. Our study contributes to the literature by incorporating domestic and international demand through which exogenous shocks, such as China's trade barriers, may affect U.S. DDG prices. With an increasing importance of the U.S. DDG export markets, this exposure may allow for further fluctuations of U.S. DDG prices. Identifying factors that contribute to the fluctuations in prices is relevant to understanding the future of the DDG market.

This study is organized as follows. Section 2 contains background information on the DDG market and on China's policies that are related to DDG. Section 3 provides an overview of previous literature on the analysis of U.S. DDG prices and inverse demand models. Section 4 presents the modeling procedure used to derive an inverse demand equation of U.S. DDG prices. Section 5 presents data description and data manipulation. Sections 6 and 7 discuss the empirical specification and results, respectively, related to the U.S. DDG prices inverse demand equation. Section 8 provides a discussion on what to expect for the future of the U.S. DDG export market to China and concluding remarks. References are in section 9. Figures and tables are presented in section 10. Finally, section 11 is the appendix, containing the R code used to run our models.

Chapter 2: Background

This section is divided into two parts. First, we present data to characterize the DDG domestic and international market. Second, we chronologically describe the DDG trade pattern between the United States and China, identifying factors that may be correlated with the apparent fluctuations in U.S. DDG prices.

2.1 DDG Market

Production of DDG in the United States has continued to rise over the last several years due to increases in ethanol production (figure 1). While exports of DDG have increased overtime, the percent of total U.S. DDG production that is exported has decreased from around 30% in 2015 to nearly 24% in 2017 (USDA ERS 2018). Thus, the domestic market has been consuming more DDG over time. In 2015, U.S. DDG exports reached 14 million tons, the highest amount of DDG the United States has ever exported. While the United States was still the largest exporter of DDG in the world in 2016, exports declined to 12.65 million tons (figure 2) (U.N. Comtrade 2018).[3] Over the last several years, China and Mexico have been the top export markets for U.S. DDG.

In 2015, China imported a record annual amount of 7.12 million tons of DDG from the United States (figure 3) (USDA ERS 2018). However, from 2015 to 2016, the amount of U.S. DDG exports to China declined. China remained as the largest market for U.S. DDG exports in 2016, importing 2.58 million tons, but only representing 20.7% of the total U.S. DDG exports compared to 51% of the exports in 2015. Mexico was the second largest importer in 2016, importing 2.10 million tons representing 16.6% of total U.S. exports. Mexico has imported DDG from the United States since 1989, but the rate of Mexican imports has not followed the Chinese boom

[3] At the time of writing this paper, The U.N. Comtrade was not updated with the 2017 data.

in DDG imports (USDA ERS 2018). In 2017, China disappeared from the top U.S. DDG importers list, importing only 415.96 thousand tons (USDA ERS 2018). Mexico, Turkey and South Korea became the United States most important trade partners of DDG purchasing 2.30 million tons, 1.62 million tons and 1.04 million tons, respectively (USDA ERS 2018).

While China was not a major player in the DDG market prior to 2009, they have become an important export market for the U.S. DDG. China's rising agricultural imports reflect its growing demand for animal feed and the relative scarcity of its land resources (Gale, Hansen and Jewison 2015). As China's demand for animal proteins has increased, demand for livestock feed products has increased causing China to become a net importer of livestock feed products, including DDG (Fabiosa et al. 2009). Figure 4 depicts important aspects of the DDG trade between the United States and China.[4] The proximity between the curves of China's total imports of DDG and U.S. exports to China indicates that the United States is China's most important trade partner in the DDG market. From 2009 to 2017, the percentage of DDG exported from the United States to China ranged from a minimum of 11.6% to a maximum of 53.7%. There is evidence that the sudden drop in China's U.S. DDG imports over the last years is related to the Chinese government interventions in the DDG market.

2.2 China's Policies Related to DDG

China's domestic policies appear to have a large impact on U.S. DDG imports. Bans on shipments, anti-dumping and countervailing investigations and duties, quality requirements, and uneven regulations for inspection and quarantine are only some of

[4] China's total imports of "brewing or distilling dregs and waste" data for 2017 was not updated on U.N. Comtrade Database at the time this figure was made.

the factors that illustrate the uncertainty surrounding trade with China. However, China's policies have been more economically open to trade during some periods. For example, in the mid-1990s, China cut tariffs and eliminated the value-added tax on imports of soybean meal, DDG and other grain-milling by-products to address the deficit in raw feed materials. In 2001, China joined the World Trade Organization (WTO), and the country agreed to eliminate export subsidies, even though the Chinese government still applied tariff rate quotas (TRQ) on corn imports and other products (Rumbaugh and Blancher 2004). Because of this economic flexibility, the total commodity exports from the United States to China began to sharply increase (Hansen et al. 2017). China's large increase in the demand for meat caused expansion of livestock production which ultimately drove an increased demand for feedstuffs including DDG (Hansen et al. 2017). Based on data from the USDA ERS (2018), China's frequency and total quantity of DDG imports from the United States increased after 2009 (figure 5).

While trade between China and other countries was intensifying, new policies to promote food security and price stability, and to increase farmers' income were taking place. These policies have been causing distortions in the international market (Hansen et al. 2017). China was a net exporter of grains until the minimal price support policy was established in 2008 despite low international corn prices (Gale, Hansen and Jewison 2015). This environment was favorable for continued expansion of U.S. DDG exports to China. From 2008 to 2015, there was a reduction on the demand for foreign and domestic corn in China. The combination of the minimal price policy and TRQ on corn imports contributed to increase imports of alternatives to corn such as DDG, barley and sorghum and consequently, corn stocks from domestic production increased (Gale, Hansen and Jewison 2015). The government steadily increased the minimal price required to receive support for major grain crops, creating a gap between the national prices in China and international prices (Hejazi and Marchant 2017). Hence, the demand for international agricultural commodities increased and a large stockpile of agricultural commodities was accumulated, leading to the decision to end the minimal price support for corn in 2015 (Hejazi and Marchant 2017). Since 2015, China has been cutting down supports for national products, especially for cotton, soybean and corn (Zhong and Zhu 2017). Among the possible reasons for this decision, the Chinese government claims that many producers became dependent on high support prices to stay profitable (Hejazi and Marchant 2017). Consequently, corn prices in China are falling, and a portion of the stocks have lost their value as they have become too deteriorated to sell. These cheaper Chinese corn prices caused a reduction in the imports of corn and its substitutes, including DDG (Hejazi and Marchant 2017).

In December 2016, China’s administration of TRQs for rice, wheat and corn was questioned given issues related to application criteria, TRQ allocations and its announcements. Quota allocations are set upon private sector necessity and government interests (Michael, Anderson-Sprecher and Jiang 2014). Trade import opportunities were not clear, which reduced the market Accessed opportunities for worldwide producers (U.S. Trade Representative 2018). In 2017, TRQs were at 7.2 million tons of grains, unchanged from 2016 with non-state trade importers accounting for 40% of total quota allocations (Kim 2017). The TRQ rate has fluctuated significantly, however it usually has not exceeded a 50% rate (Anderson-Sprecher, Wei and Liwen 2015).

While minimal price supports and TRQ's were in place, several other Chinese policies impacted the monthly volatility of U.S. DDG exports to China, as shown in figure 5. China became the top importer of U.S. DDG in 2010 (USDA ERS 2018). In late 2010, China began an anti-dumping investigation into U.S. DDG imports with the investigation continuing until mid-2012, see figure 5 (MOCPRC 2012). The objectives of the investigation were, first, to analyze whether the U.S. DDG imported to China was dumped and the margin of dumping, and second, to evaluate the existence and intensity of damages the U.S. DDG imports could be causing the Chinese DDG industry (MOCPRC 2012). During this investigation, China's imports slowed down, especially in the first half of the period. In 2011, Mexico overtook China as the top U.S. DDG importer. However, in 2012 China regained the lead and continued as the top importer until 2016, when the sudden drop in Chinese imports led Mexico to the first position again in 2017 (USDA ERS 2018). This recent contraction of the Chinese DDG imports was primarily driven by Chinese government policies.

Chinese officials' concern over genetically modified (GM) traits in imported products have contributed to the adoption of import restraints over time that consequently affect the U.S. DDG market (U.S. Trade Representative 2018; Gale, Hansen and Jewison 2015), see figure 5. In July 2013, China started requiring a "GMO test report" for U.S. DDG plus an official U.S. government stamp to certify that DDG shipments did not contain GM material (U.S. Trade Representative 2018; Gale, Hansen and Jewison 2015). In November 2013, China imposed a zero-tolerance policy for unapproved GMOs after testing and detecting MIR 162 (an unapproved GM trait) in U.S. corn causing the rejection of U.S. corn shipments (Roberts and Bukovac 2015). Consequently, in December of 2013, China also began testing DDG and shipments were rejected when the GM trait was detected (MOCPRC 2013). Throughout 2014, there was large volatility in the trade of DDG between the two countries and between October and November 2014 the U.S. DDG exports to China dropped significantly (USDA ERS 2018). In December of 2014, China approved the MIR 162 trait and shipments of DDG products from the United States began again in 2015 (Roberts and Bukovac 2015), see figure 5. By May 2015, the monthly U.S. DDG exports to China reached the highest level of 1.06 million tons, an accumulation of 7.12 million tons for the year (USDA ERS 2018). Following the record high monthly exports in May, June and July of 2015, U.S. DDG exports to China began to fall. Between July 2015 and March 2016 monthly DDG exports fell 87% (USDA ERS 2018), see figure 5.

In January 2016, the Commerce Ministry of China started another anti-dumping and countervailing investigation on imports of DDG (MOFCOM 2016), see figure 5. Later in September 2016, the investigation supported China's decision to impose anti-dumping duties of 33.8% on U.S. DDG and countervailing duties ranging from 10% to 10.7% (MOCPRC 2017).[5] In January 2017, China announced that new anti-dumping duties would increase ranging from 42.2% to 53.7% while the countervailing duties were raised to a range of 11.2% to 12% (MOCPRC 2017). The duties negatively affected U.S. DDG producers by reducing the exports to China, leading the United States to follow new strategies of diversification to other markets (IFBF Research and Commodity Services 2016) such as Vietnam and South Korea (USDA ERS 2018). In 2017, the DDG exports to China sharply dropped as Chinese buyers switched to alternatives (e.g. soybean) as a strategy to avoid the exorbitant import costs. In 2018, exports to China have been shrinking even more. Additionally, the Chinese government has provided incentives to domestic ethanol production,

[5] Anti-dumping duties vary for different U.S. companies. They are set according to a criterion established by the Ministry of Commerce of the People's Republic of China.

which may increase the domestic DDG production in the country (Clever 2018). So far, the Chinese DDG production remains limited and quality of the corn stored may be of concern (Clever 2018).

Chapter 3: Literature Review

Previous research analyzing DDG prices has primarily focused on the relation between DDG prices and corn and soybean meal prices. Anderson et al. (2008), Tejeda (2012), Irwin and Good (2013; 2015), Johnson et al. (2015) and Etienne et al. (2017) are a few of the studies that have analyzed the dynamic relation among these prices, each focusing on different time periods. Their results support the hypothesis that changes in corn and soybean meal prices affect DDG prices. Consequently, we include corn and soybean meal prices in our model. For example, Anderson et al. (2008) compared the time period from 1982 to 1988 with the time period from 1989 to 2007. Their results suggest that the relationship between DDG and corn is the strongest price relationship among the three products investigated and that the relationship between corn and DDG prices varied among the different time periods due to the expansion of the DDG market. Tejeda (2012) examined weekly price changes of DDG, corn and soybean meal on the time periods pre and post the Energy Acts of 2005 and 2007. His study found a significantly positive dynamic correlation in the period between September 2004 and August 2011 of both corn and soybean meal prices with DDG prices.

Irwin and Good (2013) analyzed the time period from 2007 to 2013 and found that 92% of the variation in DDG prices can be explained by the combination of corn and soybean meal prices. They reported that during this time frame, for every $1 per ton change in the prices of corn or the prices of soybean meal, DDG prices changed $0.85 per ton and $0.11 per ton, respectively. Irwin and Good (2015) did a follow-up study finding that DDG prices were impacted more by soybean meal prices between 2011 and 2014, a period of high soybean meal prices. This latter study also reported seasonality differences in the prices of DDG. Further, a study by Johnson et al. (2015)

analyzed the price relation between DDG, corn, and soybean meal prices from 2007 to 2014 and found that corn prices were the largest contributor to DDG price variations.

Etienne et al. (2017) analyzed the relation between prices of corn, soybean meal and DDG from 2000 to 2016 by evaluating the volatility transmission and how those interrelations possibly changed over time. The authors found that DDG prices are positively linked to both corn and soybean meal prices, however, corn prices were found to impact DDG prices more than soybean meal prices; and that DDG prices have little impact on the other two markets. Even though the correlation between the DDG and corn prices strengthened between 2006 and 2012, it weakened after 2012, indicating the potential increasing importance of the DDG export market (Etienne et al. 2017).

In addition to the correlation between prices, it is also important to take into account factors potentially impacting import demand. Farinelli et al. (2009) analyzed the import demand for Brazilian ethanol using a multiple regression model to estimate the long-run import demand for six importing countries. The quantity imported by each country was used as a function of import prices of ethanol, world import crude oil prices, real GDP, real exchange rate, import tariff, linear time trend and lagged quantity of ethanol imported. From Farinelli et al. (2009), we have a starting point about factors influencing DDG trade.

The U.S. DDG market is influenced by international trade. As discussed in section 2.1, trade with China represents a large portion of the U.S. DDG export market. The similarities between the fluctuations of DDG prices and the quantities exported to China monthly from January of 2009 to December of 2017 are shown in figure 6. Correlation during this time was calculated at 0.61 between DDG prices and the quantity of DDG exported to China.[6] The pattern shown in figure 6 suggests the potential influence of China's policies on the U.S. DDG industry. Furthermore, Zhang (2017) studied U.S. and global impacts caused by Chinese sorghum imports. In Zhang's study, different scenarios simulated possible effects on the U.S. and global markets that could be caused by the end of the Chinese corn price support policy and corn temporary reserve program nationwide. The results show that the eventual decrease of China's sorghum imports leads to lower availability of sorghum and a decrease of sorghum prices in the global market.

Limited research has analyzed the DDG trade market and, particularly, the trade between the United States and China. A study conducted by Matteis et al. (2017) used a gravity model to identify factors impacting U.S. DDG exports. Their results indicate that U.S. DDG exports were affected by U.S. ethanol production, *ad valorem* tariff, technical barriers to trade (indicator built from notifications of new regulations that U.S. trading partners sent to the WTO) and demand for DDG in importing countries (e.g. stock of cattle, red meat production or consumption). The authors conclude that the import demand for DDG was the most important factor to the U.S. DDG exports. Based on these results we assume that changes in the import demand will impact the U.S DDG exports. Consequently, the U.S. DDG exports work as an instrument through which changes in import demand may affect the U.S. DDG prices. Thus, we are incorporating components of the DDG import demand in our inverse demand model.

Following Barten and Bettendorf (1989) and Dhoubhadel, Azzam and Stockton (2015), we develop an inverse demand model to analyze the impact of

[6] U.S. DDG exported to China (Source: USDA ERS Database). Nominal U.S. DDG prices (Source: LMIC- USDA AMS: Eastern Cornbelt Distillers Grains Report (GX_GR212), Chicago, IL (WKDDGPrices)). Real U.S. DDG prices calculated using PPI grains base in December 2018.

domestic and export demand on DDG prices in the United States. According to Barten and Bettendorf (1989), inverse and regular demands are usually statistically different, which may cause inconsistent analysis. The decision of which one should be used depends on the characteristics of the market analyzed. Barten and Bettendorf (1989) suggest to always keep variables that are exogenously determined in the right-hand side of the demand equation to prevent inaccuracy. Following Dhoubhadel, Azzam and Stockton (2015), we assume a fixed supply of DDG based upon the amount of ethanol produced in the United States. Therefore, DDG supply is inelastic.

Inverse demand models constitute an alternative analysis to the standard consumer demand analysis (Anderson 1980). Inverse demand models can be developed as a system of equations (inverse demand systems) or as a single inverse demand equation. Inverse demand systems have three main characteristics. First, price is a function of quantity. Second, the system equations of prices are endogenously determined and derived from budget shares. And finally, variables in the system of equations are expressed as differential logarithms (Barten and Bettendorf 1989; Moschini and Vissa 1992; Wong and McLaren 2005; Lee and Kennedy 2008; Huang 2015). Barten and Bettendorf (1989) point out that, even though inverse demand systems are very useful, they are not used more often given the difficulties in collecting the required data. The lack of available data prevents the current paper from using a full inverse demand system in our investigation of the DDG market. Furthermore, Huang (2015) argues that endogeneity is also frequently a challenge when estimating inverse demand systems, especially when quantities are linked with market prices. For the reasons mentioned above, we develop an inverse demand equation instead of a full inverse demand system in our analysis of the DDG market.

As an alternative to a full inverse demand system, Igami (2015) developed an inverse demand equation to analyze the impact of market power on international coffee bean prices. The author analyzed the impacts of market structure on coffee prices. The inverse demand equation consisted of the world price of coffee beans as a function of quantity demanded, a demand shifter (importing countries' GDP), price of tea (coffee's substitute) and an unobserved shock that represents variation in consumers' preferences over time due to local temperature. The author added weather as an instrument for export quantity to address potential simultaneity bias and measurement error.

Demand for a product can be modeled as separate markets within one equation. For example, (Meinken 1953) analyzed the demand for food by assuming a reduced-form equation derived from two simultaneously determined equations representing the demand for farm products in domestic and export outlets. Karp and Perloff (1993) investigated the level of competition and adjustment paths of the coffee export markets for Brazil and Colombia (the two largest coffee exporters in the world). The authors developed a basic inverse residual linear demand curve where the real price was a function of the total quantity exported from Brazil and Colombia combined, subtracted from a variable capturing the effects of exogenous variables such as exports of other countries, among others. We are interested in the effect of China's trade policy and demand on U.S. DDG prices, thus we separate demand for U.S. DDG into export demand to China and residual demand (comprised of domestic consumption and exports to other countries).

Chapter 4: Model

This section introduces the modeling procedure developed to investigate our objective. We develop an inverse demand equation that describes factors implicit in the domestic and export demands that may affect the U.S. DDG prices, focusing on the effect of changes in U.S. DDG prices due to Chinese policies.

To analyze the impact of Chinese policies on U.S. DDG prices, we derive a model from the DDG market equilibrium between demand and supply. According to Dhoubhadel, Azzam and Stockton (2015), the supply of DDG is fixed based on the amount of ethanol production. Therefore, the U.S. DDG prices become a function of factors affecting demand. For this reason, we develop an inverse demand equation for DDG based on previous literature and the characteristics of the U.S. and international market. The total quantity of DDG produced in the United States ($Quantity\ produced$) can be expressed as the sum of the quantity exported to China ($Quantity\ China$) plus the residual demand ($Quantity\ residual$). The residual demand represents the quantity consumed domestically in the United States and the quantity exported (excluding China):

$$Quantity\ produced = Quantity\ residual + Quantity\ China \qquad (1)$$

Goldstein and Khan (1985) argue that a country's ability to influence the world price of a specific good depends on three factors: the country's share of world consumption expressed by import level, world production and the value of its own price elasticities of demand and supply for the good. Thus, we can argue that China's demand may be affecting the U.S. DDG prices. Based on discussion from previous sections we have the following three conclusions: China, overall, has represented a large share of the world consumption of DDG and the United States is predominantly the largest producer of DDG in the world.

According to the U.S. Grains Council (2012), some of the main elements that can potentially impact the U.S. DDG prices are domestic demand, corn and soybean meal prices, availability of supply for export, and import tariffs. As discussed in the literature review, previous research has found a relation between corn, soybean meal and DDG prices. Therefore, the U.S. DDG production ($Quantity\ produced$), is a function of U.S. DDG prices ($Price\ DDG$), corn prices ($Price\ Corn$)and soybean meal prices ($Price\ Soybean\ Meal$):

$$Quantity\ produced = f(Price\ DDG, Price\ Corn, Price\ Soybean\ Meal) \quad (2)$$

This step of the model focuses on China's import demand for U.S. DDG. As mentioned in the literature section, Farinelli et al. (2009) investigate Brazil's import demand of ethanol. Their study suggests that tariffs and import country's GDP are two of the factors directly impacting the Brazilian import demand for ethanol. Following Farinelli et al. (2009), this piece of our model defines the Chinese import demand ($Quantity\ China$) as a function of China's anti-dumping (AD) and countervailing (CV) duties, GMO requirement (GMO), anti-dumping investigations ($Investigation$) and Chinese real GDP ($GDP\ China$):

$$Quantity\ China = g(AD, CV, GMO, Investigation, GDP\ China) \quad (3)$$

To derive the inverse demand equation for DDG we first combine equations (1) and (3) resulting in equation (4). By substituting equation (2) into equation (4) we obtain equation (5). Finally, after rearranging equation (5) to solve for U.S. DDG prices we obtain the inverse demand for DDG in equation (6):

$$g(AD, CV, GMO, Investigation, GDP\ China) = Quantity\ produced - Quantity\ residual \quad (4)$$

$$g(AD, CV, GMO, Investigation, GDP\ China) = f(Price\ DDG, Price\ Corn, Price\ Soybean\ Meal) - Quantity\ residual \quad (5)$$

$$Price\ DDG = h^{-}(\text{Quantity residual}, Price\ Corn, Price\ Soybean\ Meal, AD, CV, GMO, Investigation, GDP\ China) \quad (6)$$

Chapter 5: Data

Our study uses monthly data from January 1996 to December 2017, for a total of 264 observations. Summary statistics of the data are presented in table 1. Weekly DDG nominal prices were collected from the Eastern Corn belt Distillers Grains Report and calculated by LMIC (2018). The DDG prices used represent the dried product. Monthly U.S. production of DDG is calculated based on the formula for fixed proportion of production of DDG and ethanol suggested by USDA AMS (2018) where one bushel of corn yields 2.8 gallons of ethanol and 17.75 pounds of DDG. Monthly ethanol production reported by the Energy Information Administration (U.S. Energy Information Administration 2018) is used to calculate the total DDG production. The residual demand for DDG was calculated as the difference between U.S. domestic production and exports to China. Monthly U.S. exports to China was reported by USDA ERS (2018). The USDA ERS database uses the term “Brewing or distilling dregs and waste” assigned to the code 23033000 of the Harmonized System classification, which for the United States is a suitable measure of DDG (RFA 2017). However, for other countries this code may also represent data for alternative products, which is a minimal amount relatively compared to the U.S data.

Nominal prices of corn and soybean meal are collected from USDA AMS (2018). Corn prices are based on the reported prices for Chicago (IL) and soybean meal prices are based on the reported prices for 48% (Rail) Central Illinois. The collected nominal prices of DDG, soybean meal and corn are converted into real prices using Producer Price Index (PPI) for grains collected from the Federal Reserve Bank (2018a). The index base is adjusted to December 2017 = 100.

Anti-dumping and countervailing duties are also included in the model. In September 2016, the anti-dumping duty was implemented at a 33.8% rate and the countervailing duty at a range of 10 to 10.7%. In January 2017, the anti-dumping increased to a range of 42.2% to 53.7% rate and the countervailing duty increased to a range of 11.2 to 12%. The increased rate of both duties lasts until the most recent observation in December 2017. In our data, the observations of this variable consist of a dummy variable indicating zero for the period before the duties were imposed and one for the period when the duties are imposed. The information about the duties was collected from MOCPRC (2016) and MOCPRC (2017).

A dummy variable was added to capture the GMO test requirement from July 2013 to October 2014, where one indicates the policy was imposed and zero otherwise. Finally, China’s two anti-dumping investigations, from November 2010 to June 2012 and from January 2016 to August of 2016 are represented as one variable with one during the period of the investigations and zero otherwise.

The current price GDP in China is collected from the Federal Reserve Bank (2018b) as quarterly data in billions of Chinese yuan, seasonally adjusted. The quarterly data is deflated using the annual GDP implicit price deflator collected from OECD (2018) and the index base is adjusted to January 2018 = 100. From the quarterly deflated data, monthly data was estimated through cubic spline interpolation. The monthly data is then converted in U.S. dollars using real monthly average exchange rates from the USDA ERS (2018).

Chapter 6: Empirical Specification

The objective of this paper is to estimate the impact of domestic and export demand on U.S. DDG prices. Thus, we estimate the inverse demand specified in equation (6) and apply tests to check stationarity, multicollinearity, structural break, autocorrelation, homoskedasticity and normality. Based on these tests, we are running four models. We will first discuss the tests followed by the final models. First, we apply an augmented Dickey–Fuller test (ADF). ADF is used to test the null hypothesis that a unit root is present in the time series data. The presence of unit roots (i.e. series is not stationary) may cause problems in statistical inference. The ADF test indicates that U.S. DDG prices, residual demand, corn prices and soybean meal prices are non-stationary. After applying log transformation in all price variables and residual demand, all the variables became stationary (at the 10% significance level). In addition, the benefits of the log transformation extend to the possibility of analyzing the elasticity of our explanatory variables with respect to the U.S. DDG prices, so we are applying log transformation on the variables. Knowing that all our series are stationary, we do not need to test for cointegration.

Continuing with the regression analysis, because *AD* and *CV* are dummy variables occurring at the same time, collinearity issues exist. Therefore, we decide to add one dummy variable to capture the joint impact caused by both duties. We also hypothesize that past values of corn and soybean meal prices could be affecting the U.S. DDG prices. However, after applying the variance inflation factor (VIF) test to check for correlation among explanatory variables (multicollinearity), we find high multicollinearity among current and past corn and soybean meal prices. The VIF test shows how much the variance of the estimated coefficients are inflated in comparison with a case where the explanatory variables are not linearly related. Usually, VIF values exceeding 10 indicate multicollinearity (O'Brien 2007). Thus, we decide to run two different models. Model 1 has the impact of past corn and soybean meal prices, and model 2 does not contain them. The log of corn prices in model 2 has a VIF of 13.97, which is much lower than its VIF in model 1 (54.32). Even with a VIF higher than 10, we decide to keep this variable in the models based on the theory discussed in previous sections of the importance of corn prices on DDG prices. By allowing a certain level of multicollinearity we are accepting standard errors potentially overestimated and, consequently, the significant test may be biased.

The null hypothesis of no autocorrelation (i.e. the residuals are independent of one another) is tested using the Durbin-Watson (DW) test. We find evidence of autocorrelation in all four models (e.g. model 1 shows t-stat = 0.419 and p-value < 0.001), therefore the null hypothesis is rejected. Autocorrelation is corrected in all models by including four lags of the dependent variable in the model; the number of lags is tested via hypothesis test. Also, the performance of the model suggested in equation 6 is tested though both AIC and BIC tests; both tests suggest that our models will be best performed if containing four lags. To check if the problem is fixed, the Durbin Watson test is performed again. No evidence of autocorrelation is found, failing to reject the null hypothesis (e.g. model 1 shows t-stat = 1.942 and p-value = 0.166).

A Chow test indicates a structural change beginning in September 2014. However, after adding the structural break, we test for multicollinearity again and find that it is highly correlated with the GDP variable (table 2 presents the correlation matrix of all variables). The VIF for GDP is indicated as 22.12. Without the structural break, the VIF for GDP is 9.19 (e.g. model 1). Given that both variables are important for our model, we decide to keep both in separate models. Thereby, we keep the GDP variable in model 1 and 2 without the structural break. We add two new models (models 3 and 4) that do not include the GDP variable but the structural break. Model 3 contains corn and soybean meal lags and model 4 does not. We re-apply the Chow test in models 3 and 4, finding that there is now a structural break in September 2010 when GDP is not included. Thus, we add this structural change as a dummy variable indicating zero before September 2010 and one after. As we can hypothesize from the background section, the period after September 2010 is characterized by China becoming a major player in the DDG market.

We also test the null hypothesis of homoskedasticity using the Breusch Pagan test. We find evidence of heteroskedasticity in all four models (e.g. model 1 shows t-stat = 38.701, p-value < 0.001). To avoid biased inference, heteroskedasticity is fixed using Eicker–Huber–White standard errors.

Finally, we test the normality of the residuals. We apply the Shapiro–Wilk normality test, because it has the highest power among all tests for normality. At 1% we fail to reject the hypothesis that the sample comes from a population which has a normal distribution (e.g. model 1: W = 0.99155, p-value = 0.141).

As a result of the tests described above, after adding log transformations and significant time lags equation (6) becomes equation (7) for model 1, equation (8) for model 2, equation (9) for model 3 and equation (10) for model 4, which are the following estimated equations:

$$logPriceDDG_t = \alpha_0 + \alpha_1 log\ Quantity\ residual_t + \alpha_2 log\ Price\ Corn_t + \alpha_3 log\ Price\ Corn_{t-1} + \alpha_4 log\ Price\ Corn_{t-2} + \alpha_5 log\ Price\ Soybean\ Meal_t + \alpha_6 log\ Price\ Soybean\ Meal_{t-1} + \alpha_7 (AD\&CV)_t + \alpha_8 GMO_t + \alpha_9 Investigation_t + \alpha_{10} GDP\ China + \alpha_{11} log\ Price\ DDG_{t-1} +$$

$$\alpha_{12} log\ Price\ DDG_{t-2} + \ \ \alpha_{13} log\ Price\ DDG_{t-3} +$$

$$\alpha_{14} logPriceDDG_{t-4} + \varepsilon_{1_t} \qquad (7)$$

$$logPriceDDG_t = \beta_0 + \beta_1 logQuantityresidual_t + \beta_2 logPriceCorn_t +$$

$$\beta_3 logPriceSoybeanMeal_t + \beta_4 (AD\&CV)_t + \beta_5 GMO_t +$$

$$\beta_6 Investigation_t + \beta_7 GDPChina + \beta_8 logPriceDDG_{t-1} +$$

$$\beta_9 logPriceDDG_{t-2} + \beta_{10} logPriceDDG_{t-3} +$$

$$\beta_{11} logPriceDDG_{t-4} + \varepsilon_{2_t} \qquad (8)$$

$$logPriceDDG_t = \gamma_0 + \gamma_1 log\ Quantity\ residual_t + \gamma_2 log\ Price\ Corn_t +$$

$$\gamma_3 log\ Price\ Corn_{t-1} + \gamma_4 log\ Price\ Corn_{t-2} +$$

$$\gamma_5 log\ Price\ Soybean\ Meal_t + \gamma_6 log\ Price\ Soybean\ Meal_{t-1} +$$

$$\gamma_7 (AD\&CV)_t + \gamma_8 GMO_t + \gamma_9 Investigation_t +$$

$$\gamma_{10} Structural\ Change + \gamma_{11} log\ Price\ DDG_{t-1} +$$

$$\gamma_{12} log\ Price\ DDG_{t-2} + \gamma_{13} log\ Price\ DDG_{t-3} +$$

$$\gamma_{14} logPriceDDG_{t-4} + \varepsilon_{3_t} \qquad (9)$$

$$logPriceDDG_t = \delta_0 + \delta_1 log\ Quantity\ residual_t + \delta_2 log\ Price\ Corn_t +$$

$$\delta_3 log\ Price\ Soybean\ Meal_t + \delta_4 (AD\&CV)_t + \delta_5 GMO_t +$$

$$\delta_6 Investigation_t + \delta_7 Structual\ Change +$$

$$\delta_8 log\ Price\ DDG_{t-1} + \delta_9 log\ Price\ DDG_{t-2} +$$

$$\delta_{10} logPriceDDG_{t-3} + \delta_{11} logPriceDDG_{t-4} + \varepsilon_{4_t} \qquad (10)$$

where $(AD\&CV)$ represents the dummy variable capturing the joint effect caused by the anti-dumping and countervailing rate imposed since September 2016.

Chapter 7: Results

We want to identify the impact of China's policies on U.S. DDG prices. Thus, equations (7) to (10) are estimated using Ordinary Least Squares (OLS) regression in R. Coefficients and robust standard errors for the four models are presented in table 3. The residual quantity has a significant negative impact on U.S. DDG prices.[7] As previously discussed, because the U.S. DDG production is being considered inelastic, this variable captures the residual demand, predominantly U.S. DDG domestic consumption, as well as, the export demand to countries other than China. Over the entire period we are analyzing, the quantity of U.S. DDG domestically consumed has increased. From the exports perspective, exports to countries other than China has represented a larger share in recent years. For a 1% increase in residual demand U.S. DDG prices decrease by 0.045% to 0.077%, depending on the model.

Our results suggest that current corn prices do not have a significant impact on current U.S. DDG prices in any of the four models. By adding corn price lags in models 1 and 3, the past values of corn prices capture some of the corn prices effect on current U.S. DDG prices. The first lag's effects are negative, and the second lag's effects are positive. For current soybean meal prices, all models show positive significant effects. A 1% increase in current soybean meal prices causes an increase in current U.S. DDG prices ranging from a 0.072% increase (model 4) to a 0.224% increase (model 1). Thus, low current soybean meal prices affect the DDG market by lowering the current U.S. DDG prices. The soybean meal price lag is shown to be negative in both model 1 and 3; indicating that the previous month price affects the current DDG's monthly price negatively.

[7] Results are considered significant at 10%.

Our objective is to determine the effect of China's policies on U.S. DDG prices. All four models present a negative impact of anti-dumping and countervailing duties on U.S. DDG prices. We find that during the time the duties are being enforced there is a decrease in U.S. DDG prices ranging from 5.8% (model 1) to 7.4% (model 4). This result indicates that government interventions in China are affecting the U.S. DDG market by decreasing U.S. DDG prices. Reductions in DDG prices can potentially affect the U.S. ethanol industry profitability. As described in the background section, these duties make U.S. DDG too expensive for Chinese buyers. Consequently, Chinese demand for U.S. DDG decreases. The Chinese demand represents an important share of the total demand for U.S. DDG, so we expect U.S. DDG prices to decrease as exports to China decrease. To compensate for the potential loss in revenue caused by low DDG exports to China, the United States has been looking for alternative export markets. Since 2015, new markets have emerged in the U.S. DDG export portfolio (e.g. Vietnam, South Korea) and in 2017 Mexico became the number one market for U.S. DDG. However, the exports to new markets have not been able to compensate the loss in U.S. DDG exports to China. The U.S. exports to China declined by 94.2% from the highest amount in 2015 to the lowest in 2017. Total exports of DDG declines from 2016 to 2017 by 3.5%. Due to shocks caused by the Chinese policies, the Chinese buyers may potentially be importing DDG from other countries by re-trade or also importing more substitutes of DDG.

The variables indicating the time frame when China required GMO testing on DDG as well as the period in which the anti-dumping investigation was ongoing are found not significant. Current discussion in this paper leads us to hypothesize that these variables had a direct impact on the Chinese DDG import market, however, results indicate that there is no evidence supporting that U.S. DDG prices were affected by them. While some shipments were rejected during the time period when the Chinese government was requiring GMO tests on U.S. DDG, a test requirement does not necessarily cause a permanent drop in the level of U.S. DDG consumption. The shipments were sporadically rejected over the time analyzed. Thus, these rejections may not be strong enough to significantly impact the U.S. DDG prices, as our results suggest. Our results also suggest that the anti-dumping investigations do not directly affect U.S. DDG prices. However, the investigations could affect the DDG market by generating uncertainty regarding the future trade conditions. Our results indicate that the potential uncertainty created by the investigations was not strong enough to significantly affect the U.S. DDG prices.

The GDP variable is shown to affect U.S. DDG prices positively. Results suggest that a one unit increase (millions of dollars) in China's GDP, increases the U.S. DDG prices by 5.7% and 6.4% in models 1 and 2, respectively. The income elasticity at the mean value indicates that a 1% increase in China's GDP increases U.S. DDG prices by 0.084% and 0.095%. As China's GDP increases, Chinese buyers can purchase more, therefore Chinese demand for DDG may increases. A relatively higher demand for DDG implies higher U.S. DDG prices.

The log linear regression model is estimated under the assumption that parameters are constant over time. However, a deep understanding of market operations may signal the existence of shifts in the pattern of the data in the time period analyzed. These potential shifts reflect lack of stability of the coefficients, which may lead to poor estimated coefficients. For this reason, the existence of structural changes is important to be checked. In our model, structural changes were suspected to exist because of the dynamic nature of economic systems. The period after September 2010 characterizes the moment when China became a major player in the DDG market. The result of the regression analysis reveals that U.S. DDG prices increased 9.6% and 8.9% in models 3 and 4, respectively, since China boosted its U.S. DDG imports (starting in September 2010). This result shows how important the Chinese consumption is for the U.S. DDG market, as previously discussed in the literature review.

Our model is also a dynamic model, since we are adding lagged variables to incorporate the effect of past values of U.S. DDG prices on the current one. The results suggest that the four lags are significantly affecting the current U.S. DDG price. Thus, we have evidence that the state of the time series up to four months back still has influence on current U.S. DDG prices.

Chapter 8: Conclusion

Since 2010, China has become an important trade partner for the United States regarding the DDG market. In 2015, China imported their largest amount of U.S. DDG representing 51% of total U.S. DDG exports. It is expected that variations on that Chinese market due to changing Chinese policies will consequently affect the U.S. DDG market. China's anti-dumping and countervailing duties impact imports of U.S. DDG. We find that the decrease in U.S. DDG prices ranges from 5.8% to 7.4% compared to when the duties were not in place.

The future of these exports depends on China's trade policies and on the availability and prices of alternative products. Understanding the effect of China's policies and keeping track of future negotiations are important to predict and adapt to changes in the market of DDG and related products.

The residual demand significantly affects U.S. DDG prices (calculated by subtracting U.S. DDG exports to China from U.S. DDG production). The residual demand captures U.S. domestic demand and rest of world (demand other than China). Even though the exports to the rest of the world have increased, the increase is not enough to compensate for the decrease in exports to China. The gap between U.S. production and total exports has increased. Thus, we can conclude that the domestic consumption of DDG has grown, and it may be driving the impact of residual demand on U.S. DDG prices.

A future perspective for the DDG market indicates challenges and opportunities. After the most recent challenges in trading with China, the United States has been trying to compensate the total exports of their DDG by increasing exports to other countries. Additionally, with Chinese corn stocks potentially decreasing and the approval of Syngenta GM corn, we could potentially expect a recovery of the DDG trade with China in 2018. However, the progress of the U.S. DDG exports to China will continue to depend on the U.S. and Chinese governmental policies. On one hand, China has announced an additional 30% tariff on U.S. DDG as a retaliation against the United States 25% tariff on Chinese imports. On the other hand, China is considering removing the value-added tax on imports of U.S. DDG. Both changes are expected to happen in 2018, creating an atmosphere of uncertainty for the short and long run.

During the years that China has not been the number one export market of U.S. DDG, Mexico has taken the lead. However, Mexico has only increased slightly its imports of U.S. DDG. One of the factors contributing to the increase in exports to Mexico is the competitive DDG prices over soybean meal prices. Moreover, in July of 2017, the North America Free Trade Agreement (NAFTA) negotiation objectives were released. One of the objectives is to reassure the U.S. ethanol and DDG exports to Canada and Mexico. Hence, this objective suggests a desire in keeping reciprocal duty-free market Accessed for agricultural goods among the three countries. However, the uncertainty about the future of NAFTA remains. Since 2015, Vietnam has also become a potentially important market for the U.S. DDG. In 2015, the country imported 717.64 thousand tons of U.S. DDG. Vietnam decided to temporarily withhold U.S. DDG imports in December of 2016 after discovering U.S. DDG shipments contaminated with warehouse beetle. In September of 2017, the Vietnamese government announced that it would discontinue the suspension of DDG imports and better accommodate fumigation requirements for U.S. corn and wheat imports. Following this announcement, U.S. DDG shipments arrived in Vietnam in the end of 2017. Hence, for 2018, we can expect an increase in the Vietnam participation of U.S. DDG total exports.

References

Anderson-Sprecher, A., J. Wei, and C. Liwen. 2015. “China - Peoples Republic of Grain and Feed Annual 2015.” USDA Foreign Agricultural Service. Available at: https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Grain%20and%20Feed%20Annual_Beijing_China%20-%20Peoples%20Republic%20of_5-11-2015.pdf. Accessed on May 2017.

Anderson, D., J.D. Anderson, and J. Sawyer. 2008. “Impact of the Ethanol Boom on Livestock and Dairy Industries: What Are They Going to Eat?” *Journal of Agricultural and Applied Economics* 40(2):573–579.

Anderson, R.W. 1980. “Some Theory of Inverse Demand for Applied Demand Analysis.” *European Economic Review* 14(3):281–290.

Barten, A.P., and L.J. Bettendorf. 1989. “Price Formation of Fish. An Application of an Inverse Demand System.” *European Economic Review* 33(8):1509–1525.

Clever, J. 2018. “China’s Robust Demand Expected to Drive Soybean Imports to 100 Million Metric Tons in MY18/19.” GAIN Report Number: CH18012. Available at: https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Oilseeds%20and%20Products%20Annual_Beijing_China%20-%20Peoples%20Republic%20of_3-13-2018.pdf. Accessed on May 2018.

Dhoubhadel, S.P., A.M. Azzam, and M.C. Stockton. 2015. “The Impact of Biofuels Policy and Drought on the U.S. Grain and Livestock Markets.” *Journal of Agricultural and Applied Economics* 47(1):77–103.

Etienne, X.L., A. Trujillo-Barrera, and L.A. Hoffman. 2017. “Volatility Spillover and Time-Varying Conditional Correlation Between DDGS, Corn, and Soybean Meal Markets.” *Agricultural and Resource Economics Review* 46(3):529–554.

Fabiosa, J.F., J. Hansen, H. Matthey, S. Pan, and F. Tuan. 2009. “Assessing China’ s Potential Import Demand for Distillers Dried Grain: Implications for Grain Trade.” Working paper, CARD Staff Reports, Iowa State University. Available at: https://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=1005&context=card_staffreports. Accessed on March 2017.

Farinelli, B., C.A. Carter, C.Y. Cynthia Lin, and D.A. Sumner. 2009. “Import Demand for Brazilian Ethanol: A Cross-Country Analysis.” *Journal of Cleaner Production* 17(November): S9-S17.

Federal Reserve Bank. 2018a. “Producer Price Index by Commodity for Farm Products: Grains.” Available at: https://fred.stlouisfed.org/series/WPU012. Accessed on May 2018.

Federal Reserve Bank. 2018b. “Current Price Gross Domestic Product in China.” Available at: https://fred.stlouisfed.org/series/CHNGDPNQDSMEI. Accessed on May 2018.

Gale, F., J. Hansen, and M. Jewison. 2015. “China’s Growing Demand for Agricultural Imports.” USDA-ERS Economic Information Bulletin Number 136. Available at: http://ageconsearch.umn.edu/record/198800/files/eib136.pdf. Accessed on March 2017.

Goldstein, M., and M. S. Khan. 1985. "Income and Price Effects in Foreign Trade." Handbook of International Economics, edition 1, volume 2, chapter 20, pages 1041-1105 Elsevier.

Hansen, J., M.A. Marchant, F. Tuan, and A. Somwaru. 2017. "U. S. Agricultural Exports to China Increased Rapidly Making China the Number One Market." *Choices Magazine* 32(2):1–6.

Hejazi, M., and M.A. Marchant. 2017. "China's Evolving Agricultural Support Policies." *Choices Magazine* 32(2):1–7.

Hoffman, L.A., and A. Baker. 2011. "Estimating the Substitution of Distillers' Grains for Corn and Soybean meal in the U.S. Feed Complex." US Department of Agriculture Economic Research Service FDS-11-1-01. Available at: https://www.biofuelscoproducts.umn.edu/sites/biodieselfeeds.cfans.umn.edu/files/cfans_asset_417548.pdf. Accessed on November 2017.

Huang, P. 2015. "An Inverse Demand System for the Differentiated Blue Crab Market in Chesapeake Bay." *Marine Resource Economics* 30(2):139–156.

Igami, M. 2015. "Market Power in International Commodity Trade: The Case of Coffee." *Journal of Industrial Economics* 63(2):225–248.

Irwin, S., and D. Good. 2015. "Ethanol Production Profits: The Risk from Lower Prices of Distillers Grains." *farmdoc daily* (5):46, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, March 24, 2015.

Irwin, S., and D. Good. 2012. "Is the Long Ethanol Boom Coming to a Close?" *farmdoc daily* (2):99, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, May 24, 2012.

Irwin, S., and D. Good. 2013. "Understanding the Pricing of Distillers' Grain Solubles." *farmdoc daily* (3):133, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, July 12, 2013.

IFBF Research and Commodity Services. 2016. "U.S. DDGS Exports (09/29/2016)". Available at: https://www.iowafarmbureau.com/Article/US-DDGS-Exports-09292016. Accessed on January 2017.

Jewison, M., and F. Gale. 2012. *China's Market for Distiller's Dried Grains and the Key Influences on Its Longer Run Potential*. United States Department of Agriculture Economic Research Service. Available at: https://www.researchgate.net/profile/Fred_Gale2/publication/287306629_China%27s_market_for_distillers_dried_grains_and_the_key_influences_on_its_longer_run_potential/links/57fcddd008aeb857afa09435/Chinas-market-for-distillers-dried-grains-and-the-key-influences-on-its-longer-run-potential.pdf?origin=publication_detail. Accessed on June 2017.

Johnson, M., T.E. Yu, A.P. Griffith, K.L. Jensen, and S.-H. Cho. 2015. "Regional Dynamic Price Relationships between Distillers Dried Grains and Feed Grains." Selected paper presented at the 2015 Southern Agricultural Economics Association Annual Meeting, Atlanta, GA. Available at: https://ageconsearch.umn.edu/bitstream/196900/2/Matthew%20Johnson%20SAEA%20Manuscript.pdf. Accessed on July 2017.

Karp, L.S., and J.M. Perloff. 1993. “A Dynamic Model of Oligopoly in the Coffee Export Market.” *American Journal of Agricultural Economics* 75(2):448–457.

Kim, G. 2017. “People’s Republic of China Grain and Feed Update China Unloads Corn.” GAIN Report Number: CH 17001. Available at: https://gain.fas.usda.gov/Recent GAIN Publications/Grain and Feed Update_Beijing_China - Peoples Republic of_1-19-2017.pdf. Accessed on January 2018.

Lee, Y., and P.L. Kennedy. 2008. “An Examination of Inverse Demand Models: An Application to the U. S. Crawfish Industry.” *Agricultural and Resource Economics Review* 37(2): 243–256.

LMIC. 2018. Eastern Cornbelt Distillers Grains Report (GX_GR212), Chicago, IL (WKDDGPrices). *Livestock Marketing Information Center.* Accessed on May 2018.

Matteis, M.C. De, T.E. Yu, C. Boyer, and K. Lewis. 2017. “Analyzing Determinants of U.S. Distillers Dried Grains with Solubles Exports.” *Selected paper presented at the Southern Agricultural Economics Association Meeting, Mobile, Alabama, February 4-7, 2017*. Available at: http://ageconsearch.umn.edu/record/252668 /files/DDGS_SAEA_PAPER.pdf. Accessed on June 2017.

Meinken, K.W. 1953. “The Demand and Price Structure for Oats, Barley, and Sorghum Grains.” USDA Technical Bulletin No. 1080. Available at: https://ageconsearch.umn.edu/bitstream/156645/1/tb1080.pdf. Accessed on June 2017.

Michael, R., A. Anderson-Sprecher, and J. Jiang. 2014. “China Grain and Feed Annual Report.” GAIN Report Number: 14016. Available at: http://gain.fas.usda.gov/Recent GAIN Publications/Grain and Feed Annual_Beijing_China - Peoples Republic of_4-2-2014.pdf. Accessed on January 2017.

Moschini, G., and A. Vissa. 1992. “A Linear Inverse Demand System.” *Journal of Agricultural and Resource Economics* 17(2):294–302.

MOCPRC. 2012. “Announcement No. 86 of 2011 of the Ministry of Commerce of the People’s Republic of China on Extending the Anti-dumping Investigation Period of Imported Distiller’s Dried Grains Originated from the U.S.” *Ministry of Commerce People’s Republic of China*. Available at: http://english.mofcom.gov.cn/article/policyrelease/domesticpolicy/201201/20120107917089.shtml. Accessed on May 2017.

MOCPRC. 2013. “China Rejects U.S. GM Corn Byproduct.” *Ministry of Commerce People’s Republic of China*. Available at: http://english.mofcom.gov.cn/article/newsrelease/counselorsoffice/westernasiaandafricareport/201312/20131200442804.shtml. Accessed on May 2017.

MOCPRC. 2016. “MOFCOM Announcement No.48 of 2016 on Preliminary Ruling of Countervailing Investigation on Dried Distiller's Grains with or without Solubles Originated in the USA.” *Ministry of Commerce People’s Republic of China*. Available at: http://english.mofcom.gov.cn/article/policyrelease /announcement/201610/20161001495628.shtml. Accessed on May 2017.

MOCPRC. 2017. “MOFCOM Announcement No.80 of 2016 on Final Ruling on Anti-dumping and Countervailing Investigation against Distiller Grain Imported from the US.” *Ministry of Commerce People’s Republic of China*. Available at: http://english.mofcom.gov.cn/article/newsrelease/significantnews/201701/20170102500829.shtml. Accessed on May 2017.

Organization for Economic Co-operation and Development (OECD). 2018. “GDP Implicit Price Deflator”. Available at: https://stats.oecd.org/index.aspx?queryid=206#. Accessed on May 2018.

O’Brien, R.M., 2007. “A Caution Regarding Rules of Thumb for Variance Inflation Factors”. *Quality & quantity* 41(5): 673-690.

RFA. 2017. “2016 U.S. Ethanol Co-Product Exports and Imports. Statistical Summary.” *Renewable Fuels Association*. Available at: http://www.ethanolrfa.org/wp-content/uploads/2017/02/2016-US-Distillers-Grains-Trade-Statistics-Summary.pdf. Accessed on July 2017.

Roberts, S., and D. Bukovac. 2015. “Disruptions of Corn Trade with China, the Impact on Grain and DDGS Prices and Related Lawsuits Against Syngenta.” *Sikich Agribusiness Update*. Available at: https://www.stinson.com/Resources/Articles/2015_Articles/Disruptions_of_Corn_Trade_with_China,_the_Impact_on_Grain_and_DDGS_Prices_and_Related_Lawsuits_Against_Syngenta.aspx. Accessed on June 2017.

Rumbaugh, T., and N. Blancher. 2004. “China: International Trade and WTO”. IMF Working paper WP/04/36. Available at: https://www.imf.org/en/Publications/WP/Issues/2016/12/30/China-International-Trade-and-WTO-Accession-17189. Accessed on April 2017.

Stewart, L., J.R. Segers, K. Hammond, T. Cheely, B. Ward, and B. Allen. 2017. “Using Cotton Byproducts in Beef Cattle Diets.” Cooperative Extension, The University of Georgia Bulletin 1311. Available at: https://athenaeum.libs.uga.edu/bitstream/handle/10724/12026/B1311.pdf?sequence=1. Accessed on May 2018.

Tejeda, H.A. 2012. “Time-Varying Price Interactions and Risk Management in Livestock Feed Markets – Determining the Ethanol Surge Effect.” Selected Paper prepared for presentation at the Agricultural & Applied Economics Association 2012 AAEA Annual Meeting, Seattle, Washington, August 12-14. Available at: https://ageconsearch.umn.edu/bitstream/124956/2/Tejeda2.pdf. Accessed on May 2017.

U.S. Energy Information Administration. 2018. “Fuel Ethanol Overview.” Available at: https://www.eia.gov/totalenergy/data/monthly/. Accessed on May 2018.

U.S. Grains Council. 2012. “Distiller’s Dried Grains with Solubles (DDGS).” *U.S. Grains Council*. A guide to Distiller’s Dried Grains with Solubles. Available at: http://msue.anr.msu.edu/uploads/236/58572/cfans_asset_417244.pdf. Accessed on May 2018.

U.S. Trade Representative. 2018. “2017 Report to Congress on China’s WTO Compliance.” Available at: https://ustr.gov/sites/default/files/files/Press/Reports/China 2017 WTO Report.pdf. Available at: https://ustr.gov/sites/

default/files/files/ Press/Reports/China%202017%20WTO%20Report.pdf. Accessed on March 2018.

U.N. Comtrade. 2018. “HS 230330 Brewing or Distilling Dregs and Waste, Whether or Not in the Form of Pellets.” Available at: https://comtrade.un.org/data/. Accessed on May 2018.

USDA ERS. 2018. “Feed Grains Database”. *Economic Research Service*. Available at: https://data.ers.usda.gov/FEED-GRAINS-custom-query.aspx. Accessed on May 2018.

USDA AMS. 2018. “Eastern Corn Belt Ethanol Corn and Co-Products Processing Values.” *Agricultural Marketing Service*. Available at: https://www.ams.usda.gov/mnreports/gx_gr212.txt. Accessed on May 2018.

Wong, K.K.G., and K.R. McLaren. 2005. “Specification and Estimation of Regular Inverse Demand Systems: A distance Function Approach.” *American Journal of Agricultural Economics* 87(4):823–834.

Zhang, W. 2017. “Simulation of Chinese Sorghum Imports from a New Perspective: U.S. and Global Impacts.” MS thesis, Virginia Polytechnic Institute and State University. Available at: https://vtechworks.lib.vt.edu/bitstream/handle/10919/78211/Zhang_W_T_2017.pdf?sequence=1&isAllowed=y. Accessed on January 2018.

Zhong, F., and J. Zhu. 2017. “Food Security in China from a Global Perspective.” *Choices Magazine* 32(2):1–5.

Figures

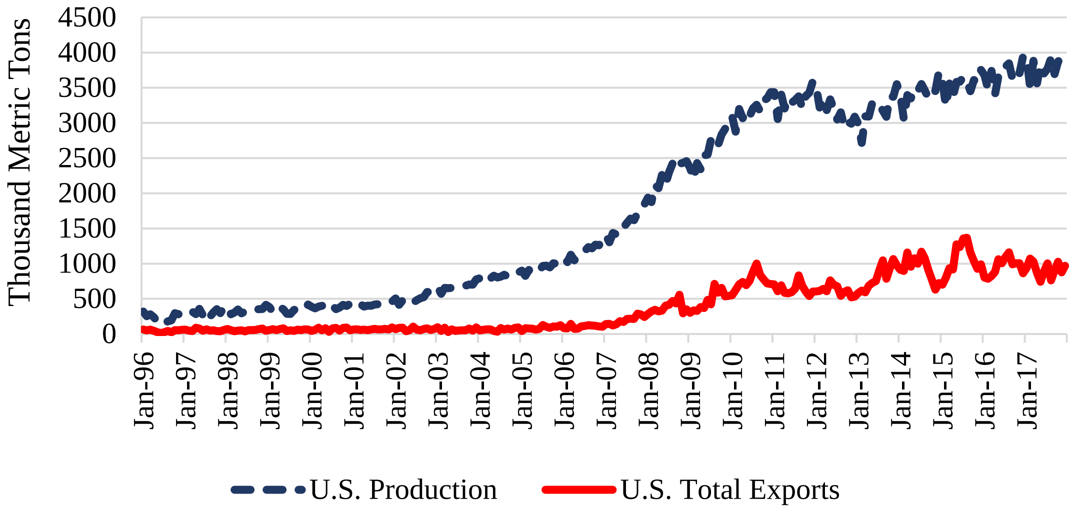

Figure 1: U.S. Production and Total Exports of Distiller's Grains
Note: Production was calculated from USDA AMS: 2.8 bushels of corn=1gallon of ethanol and 17.75 pounds of DDG.
U.S. Total Exports: ERS Feed Grains (2017) Database.

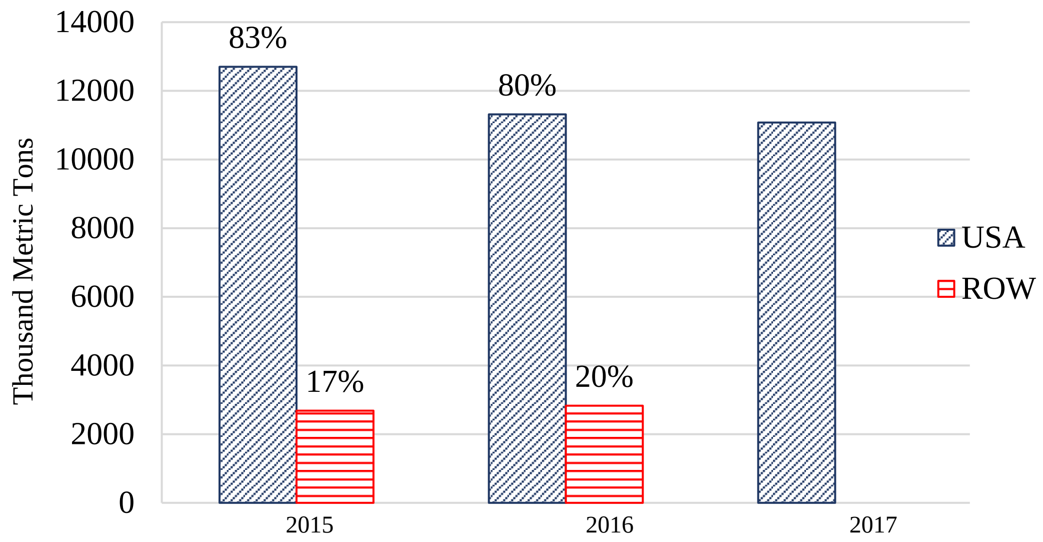

Figure 2: Total “Brewing or distilling dregs and waste” Exports from the United States and Rest of the World (ROW)

Note: Rest of the world (ROW) represents the total “brewing or distilling dregs and waste” exports less the exports from the United States. The 2017 data were not available in the U.N. Comtrade by the time this graph was made.

Source: USDA ERS, 2018.

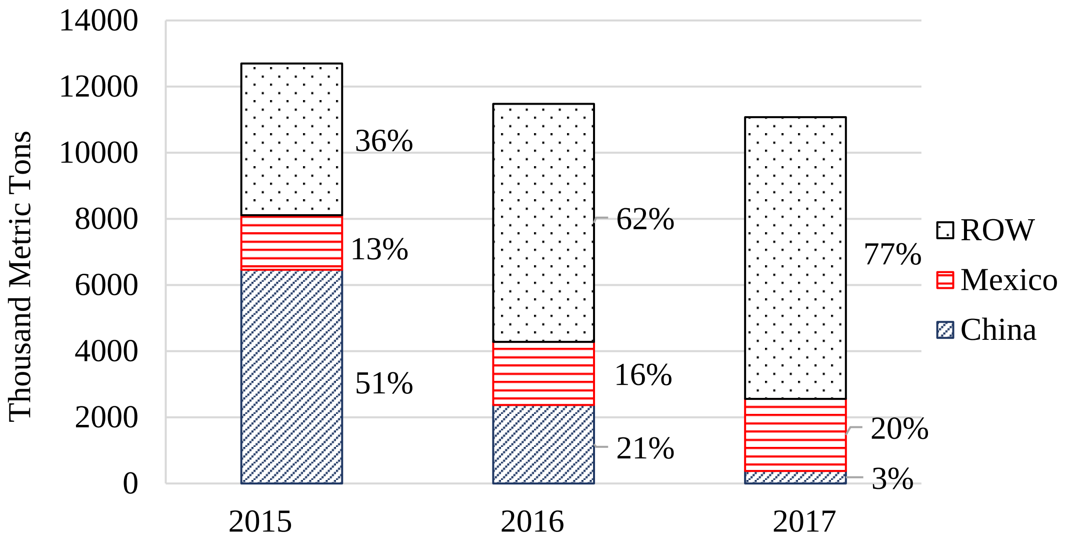

Figure 3: Total "Brewing or distilling dregs and waste" Exports from the United States to China, Mexico and Rest of the World (ROW)
Source: USDA ERS Database, 2017.

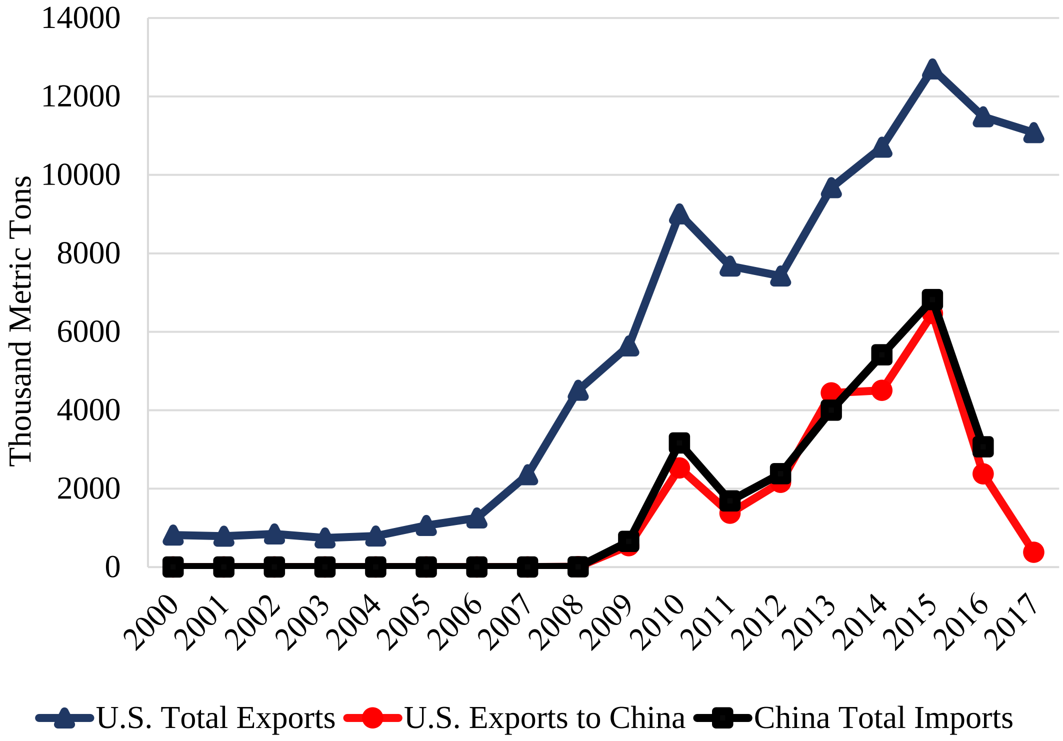

Figure 4: Yearly Trade Patterns for "Brewing or distilling dregs and waste" in China and the United States, 2000-2017
Source: U.N. Comtrade, 2018. China Total Imports of "brewing or distilling dregs and waste" data for 2017 were not available by the time this figure was made.

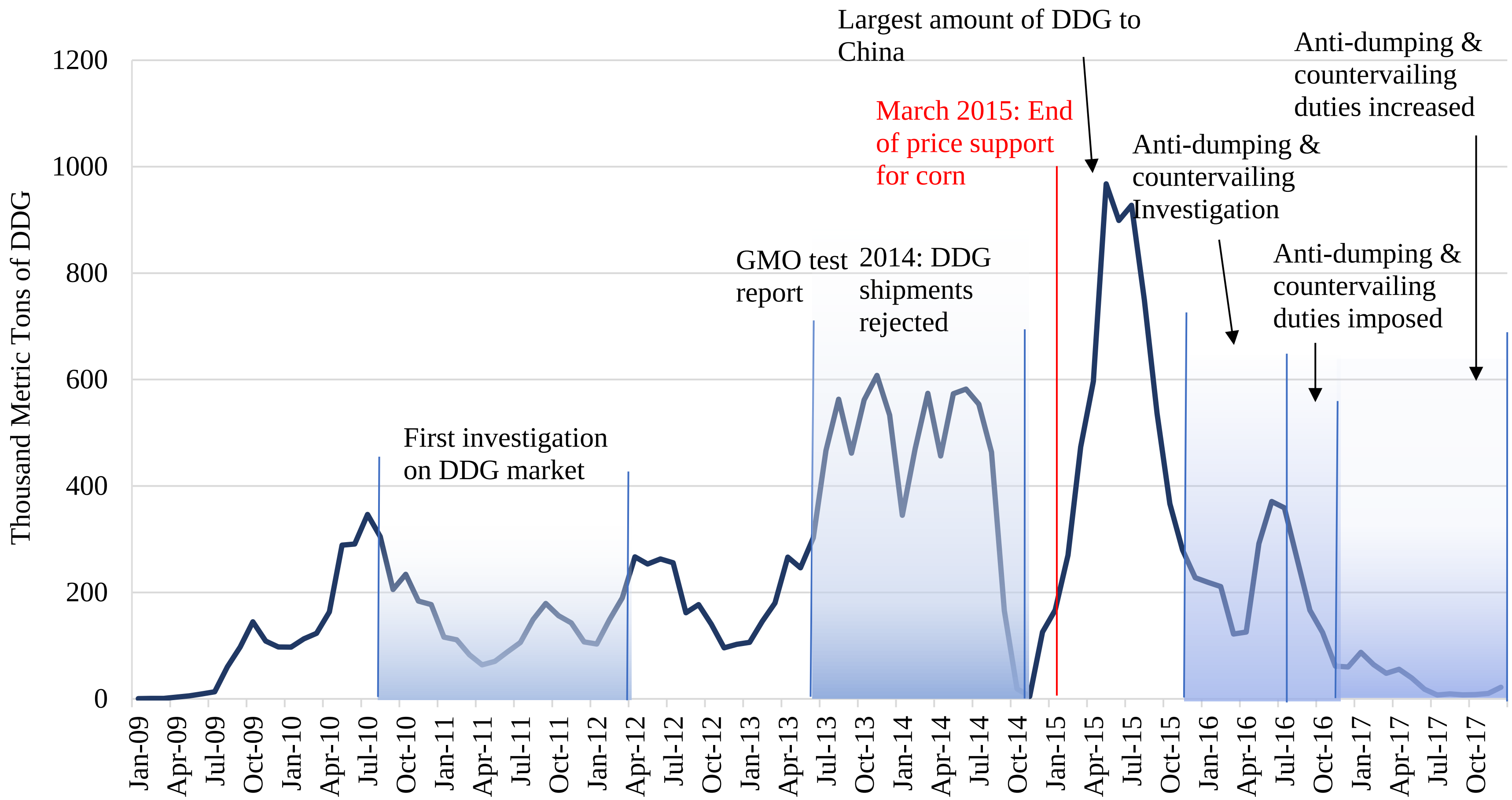

Figure 5: Monthly U.S. "Brewing or distilling dregs and waste" Exports to China January 2009-December 2017
Source: USDA ERS, 2017

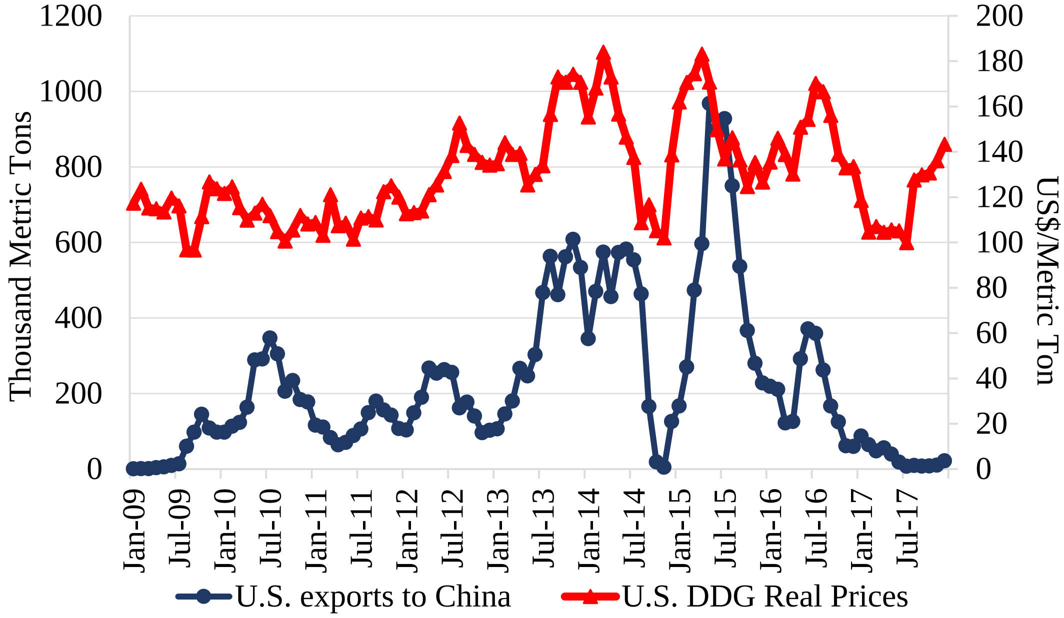

Figure 6: U.S. Exports to China and U.S. Distiller's Grains Real Prices from January 2009 to December 2017
Source: U.S. Exports to China: USDA ERS, 2018
U.S. DDG prices: USDA AMS, 2018 (Eastern Cornbelt Distillers Grains Report (GX_GR212), Chicago, IL).

Tables

Table 1: Summary Statistics of Monthly Data from January 1996 to Dec 2017, n = 264

Variable	Description	Mean	Std.dev	Min	Max
Price DDG	$/ton	124.64	21.44	86.88	182.66
Quantity residual	Million tons	1743.03	1254.05	133.09	3940.60
Price Corn	$/ton	126.39	44.58	52.27	220.72
Price Soybean Meal	$/ton	293.95	121.70	74.07	608.90
AD&CV	1 for AD and CV duties starting in Sep. 2016; 0 otherwise	0.06	0.24	0	1
GMO	1 for GMO test requirement from July 2013 to Oct. 2014; 0 otherwise	0.06	0.24	0	1
Investigation	1 for investigations from Nov. 2010 to June 2012 and from Jan. 2016 to Aug. 2016; 0 otherwise	0.11	0.31	0	1
GDP China	Millions of dollars	1.48	0.98	0.36	3.78
Structural Change	1 starting in Sep. 2010; 0 otherwise	0.34	0.47	0	1

Table 2: Correlation Matrix of Variables

	Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	*log Quantity residual*	-														
2	*log Corn Price*	-0.71	-													
3	*log Corn Price$_{t-1}$*	-0.70	0.97	-												
4	*log Corn Price$_{t-2}$*	-0.70	0.96	0.97	-											
5	*log Soybean Meal*	-0.53	0.90	0.88	0.85	-										
6	*log Soybean Meal$_{t-1}$*	-0.52	0.89	0.90	0.88	0.97	-									
7	*AD&CV*	0.31	0.00	0.00	0.00	0.08	0.09	-								
8	*GMO*	0.24	-0.26	-0.28	-0.30	-0.03	-0.06	-0.07	-							
9	*Investigation*	0.36	-0.40	-0.40	-0.39	-0.47	-0.48	-0.09	-0.09	-						
10	*GDP China*	0.88	-0.63	-0.63	-0.64	-0.41	-0.41	0.46	0.34	0.32	-					
11	*Structural Change*	0.47	-0.09	-0.10	-0.11	0.07	0.08	0.60	-0.02	0.13	0.71	-				
12	*log Price DDG$_{t-1}$*	-0.48	0.41	0.41	0.37	0.47	0.47	-0.14	0.17	-0.23	-0.23	-0.04	-			
13	*log Price DDG$_{t-2}$*	-0.49	0.42	0.41	0.41	0.48	0.47	-0.12	0.18	-0.26	-0.25	-0.04	0.89	-		
14	*log Price DDG$_{t-3}$*	-0.49	0.43	0.42	0.41	0.48	0.47	-0.10	0.20	-0.29	-0.26	-0.03	0.75	0.89	-	
15	*log Price DDG$_{t-4}$*	-0.49	0.44	0.42	0.41	0.49	0.48	-0.09	0.20	-0.30	-0.27	-0.02	0.64	0.75	0.89	-
16	*Structural Change 1*	0.73	-0.64	-0.64	-0.64	-0.48	-0.48	0.36	0.36	0.49	0.90	0.60	-0.11	-0.12	-0.13	-0.14

Note: Structural Change 1 refers to the structural change starting in September 2014 tested by Chow test and not added in the final model.

Table 3: Effects on log Price DDG

Variable	Model 1	Model 2	Model 3	Model 4
Constant	2.130***	2.450***	1.932***	2.197***
	(0.410)	(0.400)	(0.346)	(0.356)
log Quantity	-0.067 ***	-0.077***	-0.045***	-0.051***
residual	(0.016)	(0.016)	(0.010)	(0.011)
log Price Corn	-0.078	-0.053	0.071	-0.075
	(0.090)	(0.047)	(0.089)	(0.047)
$log\ Price\ Corn_{t-1}$	-0.425***		-0.430***	
	(0.108)		(0.106)	
$log\ Price\ Corn_{t-2}$	0.294***		0.286***	
	(0.058)		(0.057)	
log Price Soybean	0.199***	0.072***	0.224***	0.101***
Meal	(0.073)	(0.033)	(0.073)	(0.034)
log Price Soybean	-0.132**		-0.132**	
$Meal_{t-1}$	(0.077)		(0.079)	
AD&CV	-0.066***	-0.074***	-0.058***	-0.063***
	(0.024)	(0.026)	(0.023)	(0.026)
GMO	-0.019	-0.007	-0.031	-0.019
	(0.030)	(0.031)	(0.030)	(0.031)
Investigation	0.007	0.017	-0.020	-0.012
	(0.014)	(0.018)	(0.016)	(0.020)
GDP China	0.057***	0.064***		
	(0.015)	(0.015)		
Structural Change			0.089***	0.096***
			(0.021)	(0.022)
$log\ Price\ DDG_{t-1}$	1.163 ***	0.989***	1.166***	0.998***
	(0.066)	(0.063)	(0.064)	(0.063)
$log\ Price\ DDG_{t-2}$	-0.541***	-0.362***	-0.544***	-0.371***
	(0.088)	(0.094)	(0.087)	(0.096)
$log\ Price\ DDG_{t-3}$	0.261**	0.210***	0.256***	0.205***
	(0.075)	(0.093)	(0.077)	(0.096)
$log\ Price\ DDG_{t-4}$	-0.173***	0.172***	-0.188***	-0.188***
	(0.052)	(0.062)	(0.055)	(0.065)

Note: (***), (**), (*) denote significance at the 1%, 5% and 10% levels, respectively. Robust Standard Errors in ().

Model 1: Residual standard error: 0.0613. Multiple R-squared: 0.878, Adjusted R-squared: 0.871 F-statistic: 126 on 14 and 245 DF, p-value: < 0.000.

Model 2: Residual standard error: 0.0706. Multiple R-squared: 0.8363, Adjusted R-squared: 0.829 F-statistic: 115.2 on 11 and 248 DF, p-value: < 0.000.

Model 3: Residual standard error: 0.0612. Multiple R-squared: 0.8783, Adjusted R-squared: 0.8713 F-statistic: 126.3 on 14 and 245 DF, p-value: < 0.000.

Model 4: Residual standard error: 0.0707. Multiple R-squared: 0.8355, Adjusted R-squared: 0.8282 F-statistic: 114.5 on 11 and 248 DF, p-value: < 0.000.

Appendix: R Code

```{r ADF test }
#DDG prices
adf.test(ddgs_dt_s1$lrprice_d_US)
#Residual demand
adf.test(ddgs_dt_s1$res_d_US)
#Corn price
adf.test(ddgs_dt_s1$rprice_c_US)
#Soybean meal price
adf.test(ddgs_dt_s1$rprice_sm_US)
#Investigations
adf.test(ddgs_dt_s1$inv1_inv2)
#DUMP
adf.test(ddgs_dt_s1$dump01)
#GMO
adf.test(ddgs_dt_s1$gmo)
#Structural change
adf.test(ddgs_dt_s1$st_1)
#rGDP_ch
adf.test(ddgs_dt_s1$GDP_ch)
```

``` {r initial eq}
#Initial equation
reg<- lm(lrprice_d_US~ lres_d_US+ lrprice_c_US+ lrprice_sm_US+ inv1_inv2+
dump01+ gmo+ GDP_ch, data=ddgs_dt_s1)
#Multicollinearity
vif(reg)

#CorrelationMatrix
data1 <- ddgs_dt_s1[, c("lres_d_US","lrprice_c_US", "lrprice_c_1",
"lrprice_c_2","lrprice_sm_US","lrprice_sm_1","dump01","gmo","inv1_inv2","GDP_
ch", "st_2","lrprice1","lrprice2", "lrprice3", "lrprice4", "st_1" )]
cor <- cor(data1)
```

#Model 1
```{r Model1 gdp}
reg1 <-
lm(lrprice_d_US~lrprice1+lrprice2+lrprice3+lrprice4+lres_d_US+lrprice_c_US+lrpri
ce_c_1+lrprice_c_2+lrprice_sm_US+lrprice_sm_1+inv1_inv2+dump01+gmo+GDP_
ch,data=ddgs_dt_s1)
```
###Normality
res1 is the residual Im extracting to use later in the Wu Hausman test
```{r Normality1}
res1=residuals(reg1,type="response")
shapiro.test(res1)
```

````
```
###Multicollinearity
```{r Model1 VIF}
vif(reg1)
```
###Homocedasticity
```{r Model1 Heterosk}
bptest(reg1) #Heter
```
###Autocorrelation
```{r Model1 Autocorrelation}
dwtest(reg1) # No Auto
```
###Final Model- Robust SE
```{r Model1 gdp RobustSE}
reg1_1 <- coeftest(reg1, vcov = vcovHC(reg1, type="HC1"))
```
#Model 2
```{r Model2 gdp}
reg2 <-
lm(lrprice_d_US~lrprice1+lrprice2+lrprice3+lrprice4+lres_d_US+lrprice_c_US+lrpri
ce_sm_US+inv1_inv2+dump01+gmo+GDP_ch,data=ddgs_dt_s1)
```
###Normality
res2 is the residual Im extracting to use in the Wu Hausman test
```{r Normality2}
res2=residuals(reg2,type="response")
shapiro.test(res2)
```
#Multicollinearity
```{r Model2 VIF}
vif(reg2)
```
###Hemoscedasticity

```{r Model2 Heterosk}
bptest(reg2) #Heter
```
###Autocorrelation
```{r Model2 Autocorrelation}
dwtest(reg2) # No Auto
```
###Final Model- Robust SE
```{r Model2 gdp RobustSE}
reg2_1 <- coeftest(reg2, vcov = vcovHC(reg2, type="HC1"))
```
#Model 3
```{r Model3}
reg3 <-
lm(lrprice_d_US~lrprice1+lrprice2+lrprice3+lrprice4+lres_d_US+lrprice_c_US+lrpri
````

````
ce_c_1+lrprice_c_2+lrprice_sm_US+lrprice_sm_1+inv1_inv2+dump01+gmo+st_1,d
ata=ddgs_dt_s1)
```
###Normality
res3 is the residual Im extracting to use in the Wu Hausman test
```{r Normality3}
res3=residuals(reg3,type="response")
shapiro.test(res3)
```
###Multicollinearity
```{r Model3 VIF}
vif(reg3)
```
###Homoscedasticity
```{r Model3 Heterosk}
bptest(reg3) #Heter
```
###Autocorrelation
```{r Model3 Autocorrelation}
dwtest(reg3) # No Auto
```
###Final Model- Robust SE
```{r Model3 RobustSE}
reg3_1 <- coeftest(reg3, vcov = vcovHC(reg3, type="HC1"))
```
#Model 4
```{r Model4}
reg4 <-
lm(lrprice_d_US~lrprice1+lrprice2+lrprice3+lrprice4+lres_d_US+lrprice_c_US+lrpri
ce_sm_US+inv1_inv2+dump01+gmo+st_1,data=ddgs_dt_s1)
```
###Normality
res4 is the residual Im extracting to use in the Wu Hausman test
```{r Normality}
res4=residuals(reg4,type="response")
shapiro.test(res4)
```
###Multicollinearity

```{r Model4 VIF}
vif(reg4)
```
###Homoscedasticity
```{r Model4 Heterosk}
bptest(reg4) #Heter
```
###Autocorrelation
```{r Model4 Autocorrelation}
dwtest(reg4) # No Auto
```
````
````

````
###Final Model- Robust SE
```{r Model4 RobustSE}
reg4_1 <- coeftest(reg4, vcov = vcovHC(reg4, type="HC1"))
```
````