RICE VARIETY CHOICE AND SUBSIDY EFFECTS ON MARKET SHARE

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MASTER OF SCIENCE

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ABSTRACT

The United States has been losing market share because the unintended consequences of policy decisions have influenced what rice to grow, rather than taking the signal directly from buyers. U.S. share of Mexican rice imports has fallen from 100% in 2002 to 67% in 2021 as better perceived-quality product is purchased from other international origins. During this same time, hybrid rice acres have gone from 0% to over 70%. This research develops a theoretical model to evaluate subsidy effects on market-share performance when support for quality rice improvements is considered. Empirical analysis using Granger Causality suggests that planting hybrid rice is the primary factor causing the loss of market share, which significantly reduces competitiveness and decreases industry returns for the overall U.S. rice industry. The implications for farm policy are vast, with the potential suboptimal behavior occurring. A discount for poor quality and subsidy targeting improvements for quality are encouraged.

ACKNOWLEDGMENTS

First and foremost, this thesis would not be possible without God. His wisdom and love have carried me through many days, which led to this day. My family must also be thanked for the time that I took to complete this study and to finish my graduate program. Specifically, I want to thank my parents, James and Sharon Zwinger, for their support through my formative years and for teaching me the value of agriculture.

I could not have completed this document without my committee. Dr. William Nganje deserves great praise for his patience and prolonged support. Dr. David Bullock was extremely helpful with the empirical model and encouragement throughout the overall process. I would also like to thank Dr. Rajani Ganesh Pillai for being on my thesis committee. Additionally, Dr. Bill Wilson mentored me for many years and was kind enough to give direction on a variety of topics. I must also thank Ed Schafer who has helped me and given me excellent life advice for many years. His direct wisdom is something that I will always appreciate and respect. The many others who supported me and have given thoughts are also well deserving of thanks.

DEDICATION

This manuscript is dedicated to my family and God. I would not be here without you. You will forever be remembered in my heart, mind, and soul. Time is short and may we all learn the lessons of the day, while enjoying the beauty of the moment in time.

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1. INTRODUCTION

The availability of food domestically and for international trade is a key component for stability in terms of national and global security. Related to key strategic concerns and showing the vast influence that this topic has on the global community, in 2018, it was predicted that, by the year 2030, global food demand would rise by 50% (Allaoui et al., 2018). Therefore, one must look at how the world helps direct an efficient system through policy, production, and technological advancement, along with the consumer's ever-changing and advancing demands.

Food production is critical to meet a nation's nutritional needs. The USA is one of the largest global food producers and is a key contributor to the global grain trade. The strength for agricultural output can be attributed to the influence of government policies in the sector along with the actions that are driven by these policies. Maintaining the United States' competitiveness with international trade and the efficient utilization of agricultural resources are key goals of governmental and private-sector policies. Enhancing farmers' profitability while keeping food prices low is a critical aspect to maintain domestic and international food security.

It is important to note that global rice, and specifically the U.S. rice industry, is a critical piece in the overall food security complex. While rice-consumption rates in the United States do not rival Asia or Latin America, rice remains the largest consumed food commodity, by volume, in the global community. As shown over time, using subsidies is highly effective but can also have unintended consequences. Overall, it is important to recognize that rice is the largest consumed food commodity in the world. Most of this consumption occurs in very close proximity to where the rice is grown worldwide. This situation greatly distorts the picture because statistical trade data do not clearly show the immense importance of this commodity. Rice remains one of (if not the top) the most politically driven crops in the global community. It is important for the United States to increase quality production and to improve market share in order to remain competitive.

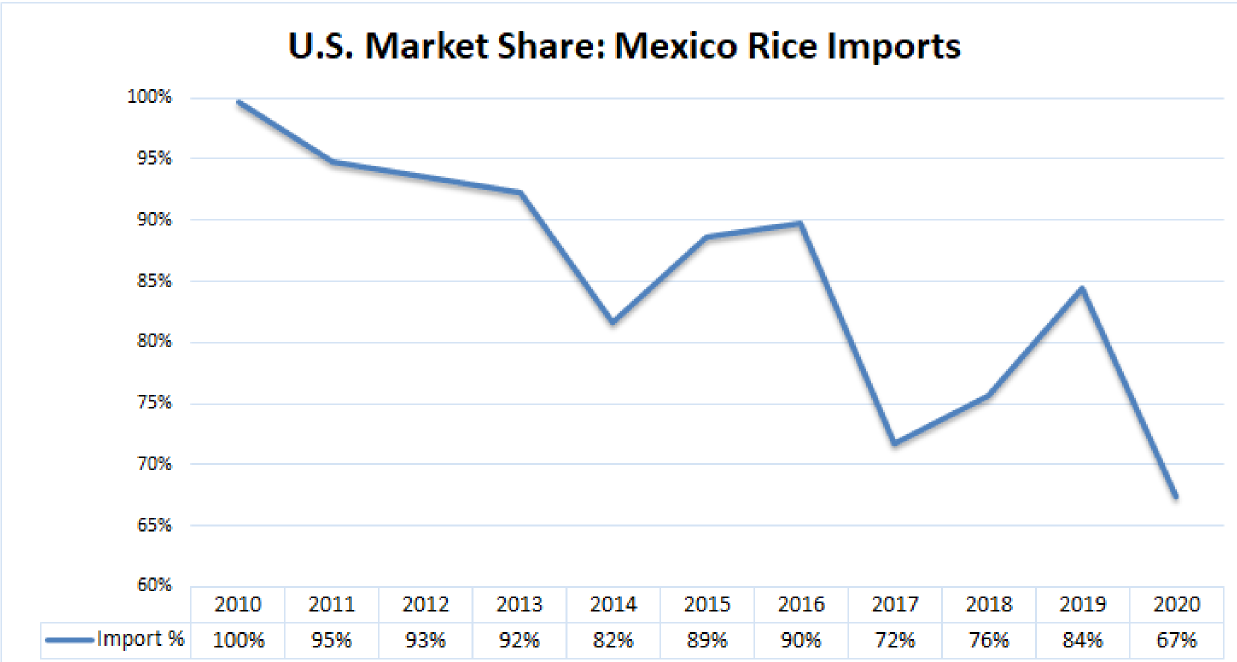


Figure 1. U.S. Export Market Share to Mexico: 2010-2020 (The Rice Trader, 2021)

As Figure 1 shows, the United States has been losing significant market share with regards to its key customers because policy decisions have influenced the type of rice grown, rather than taking the signal directly from the consumer. The U.S. share of Mexican rice imports has fallen from nearly 100% to approximately 67% in the most recent year (Figure 1; The Rice Trader, 2021). In addition, there are concerns that Mexico is obtaining higher-quality rice from competing countries because the U.S. quality has recently declined from its position as the global quality leader, partially due to the introduction of higher-yield but lower-quality hybrid rice varieties. The introduction of hybrid rice is seen in Figure 2, which illustrates that hybrid rice acres have gone from 0% in 2000 to over 70% in 2021. Because Mexico is the largest U.S. market, this change is critical and dramatically affects the U.S rice industry's trade flows. While a grower can switch to other higher-returning crops, businesses that own rice-specific assets, such as rice mills and rice driers, are put at great risk with this system. The overall strategic strength of the United States' agricultural economy is also affected by the loss of market share and the subsequent weakening of the rice industry. Policy is an important and key component of growers' decisions, and there are often delays in the marketing-system reaction on both sides; therefore, policy planning is critical due to the long-term effect on U.S. global competitiveness.

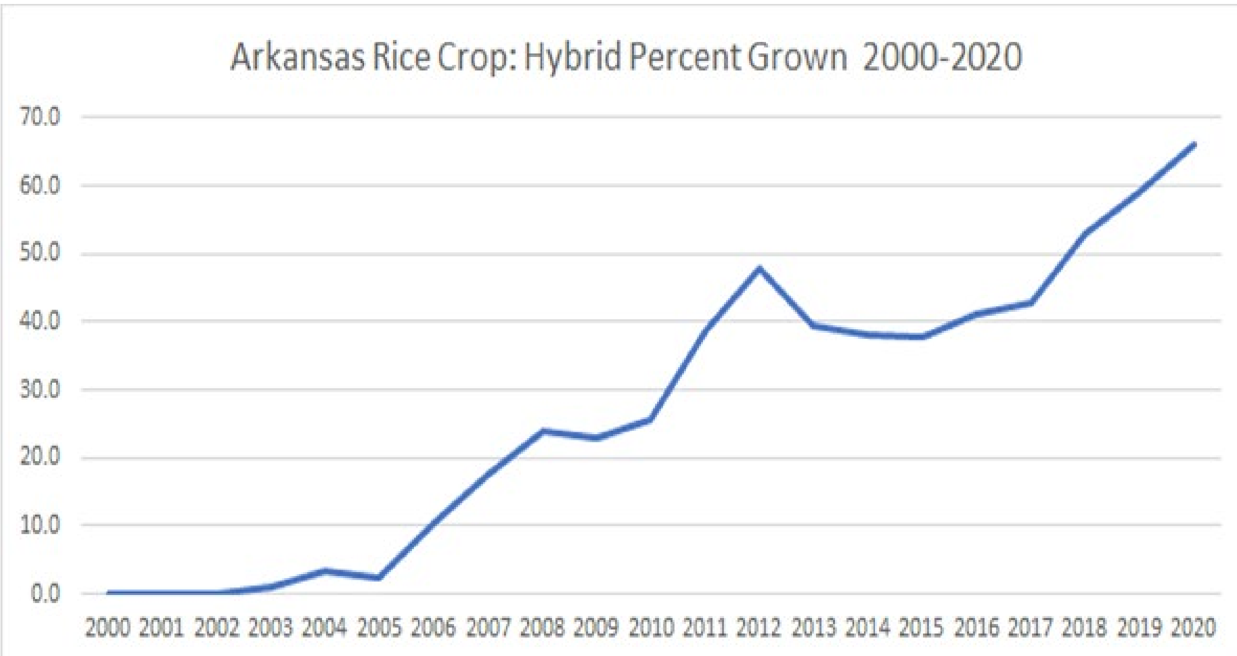


Figure 2. Percentage of Hybrid Rice Production in Arkansas, 2000-2020 (Rice Technical Working Group Proceedings, 2020)

Specifically, the intention of this study is to outline and to examine the effects of the growers' actions and profitability based on the U.S. rice subsidy, where planting lower-quality but higher-yielding varieties often leads to a decreased market share. The overall U.S. rice subsidy, then, has a balancing effect on growers' revenues, which is an important piece in the domestic and global markets where demand is greatly strained by a lack of market signals directing the production decisions. When simply looking at the last few decades, the choice was for higher yield with less concern for quality because neither the market nor the government subsidy program had presented effective quality incentives to U.S. rice growers.

The complex nature of the U.S. rice industry has increasingly focused on short-term revenue generation, with much less focus on quality, making the creation of a subsidy even more important because, at times, what an industry lobbies for may have longer-term, unintended consequences. It is, therefore, hypothesized that utilizing quality requirements would benefit the U.S. market and would improve market share. The rice market is rather complex, with much lower price transparency and decreased trade; most rice is consumed close to the region where it is planted. It is important to note that the situation for rice is not completely unique because the U.S. wheat industry went through similar issues in the 1990s when subsidies based on quantity were established. The formation of wheat subsidies led to lower wheat quality in the market and harmed U.S. wheat competitiveness for a time. Subsequently, the wheat-quality issues led the industry to work diligently in order to initiate quality programs and services to educate buyers regarding the average annual quality of the U.S. wheat crop.

1.1. Relevance and Motivation

The U.S. rice industry is facing a loss of market share for exports to its key market, which is Mexico, the largest foreign buyer of U.S.-grown rice. This study's goal is to explain the factors causing this observed phenomenon. Related to the quality issue, McClung et al. (2019) showed that hybrid varieties are rated as the lowest in quality for all the observed varieties, which is in contrast to hybrids becoming dominant in terms of acreage planted. Well over 50% of the overall long-grain rice industry acres have hybrid rice planted and are highly centralized around the lower part of the Mississippi River system. The continued growth of hybrid rice could influence competitiveness, leading to shifts in market structure. The objective is to evaluate what has, along with what is, caused this change over the last few decades and what can be done to mitigate it from happening again with rice or other major food commodities. It is hypothesized that more subsidies pushed growers to take on more business risk (Collins, 1985), which led producers to grow higher-yielding, but inferior, varieties because the U.S. rice subsidy rewards quantity over quality. The gains with being subsidized could also have led growers to continue pushing for additional subsidies because the lack of competitiveness increased the need to reduce financial risk and to enhance profitability.

The comingling of varieties (Wilson, 2007) and the lack of discounts for quality in the market contributed to market shifts as well, with the major cooperatives and other players treating all rice the same even though there is a clear customer distinction (McClung et al., 2019). Hybrid rice creates more chalky rice kernels that are more susceptible to breaking up during transit. Hybrid rice is the lowest-rated variety while also being the highest-grown variety with these recent studies about the key long-grain growing region.

The current market-share loss appears to be attributed to the increased adoption of these hybrid rice varieties as well as trade agreements that give overseas customers more options when purchasing rice. How the level of hybrid rice adoption has affected the level of subsidies will be also explored because one would expect that subsidies would be utilized to make up for a loss of market value. The implication of these findings could be important to evaluate the current subsidy programs and to provide an understanding about the effects that subsidies can have on market share. With the 2023 Fam Bill being written, this topic is very timely regarding the subsidy policy. The competitiveness of the U.S. rice industry is at stake, and rice is a key strategic piece in the overall commodity equation.

With the above in mind, we hypothesized the following:

1. Subsidies increase the growth of low-quality varieties
2. Low quality varieties causes decline in market share

3. Subsidy targeting quality improvements will increase market performance / market share

1.2. Specific Objectives

The specific objectives of this study are as follows:

1. Show trends for the U.S. rice subsidy and U.S. rice's market shares.
2. Develop a risk-balancing, hypothetical model to evaluate the theoretical effects of a subsidy on market-share performance with an emphasis on quality improvements.
3. Use Granger Causality analysis to determine the relationships among subsidies, hybrid rice production, and U.S. rice's market share.
4. Evaluate policy implications for the current and potential subsidy designs.

1.3. Outline

This study is organized into five sections. Chapter 1 gives the Introduction to the rice market along with the key issues that affect these markets. Chapter 2 contains a review of the relevant literature with regards to the effects of farm policy, quality uncertainty, and rice market characteristics and trends. Chapter 3 provides a discussion about the data used and the methodology employed for the analysis. Chapter 4 presents the empirical results from the models used in the analysis along with a discussion of the policy implications. Chapter 5 contains a summary of the conclusions derived from the analysis and the policy effects along with suggestions for further study. Additionally, the appendix provides an overview for the overall global rice industry, including key figures and graphs.

2. REVIEW OF THE LITERATURE AND TRENDS IN U.S. RICE

2.1. Trends in U.S. Rice Subsidies and the U.S Market Share

This section addresses objective 1; the global rice industry, the U.S rice industry, changes in U.S. rice's market share, and the trends for the U.S. rice subsidy are clearly shown. The rice industry is complex because it is more locally traded than most major commodities while rice is the most-eaten food commodity in the world.

2.1.1. International Trade Agreements, Competition, and Subsidies

There was a vast change in the overall subsidy level with a massive increase towards the start of 2000, leading growers to be more focused on quantity than quality. Figure 3 has a summary of the U.S. farm payments to rice growers since 1995.

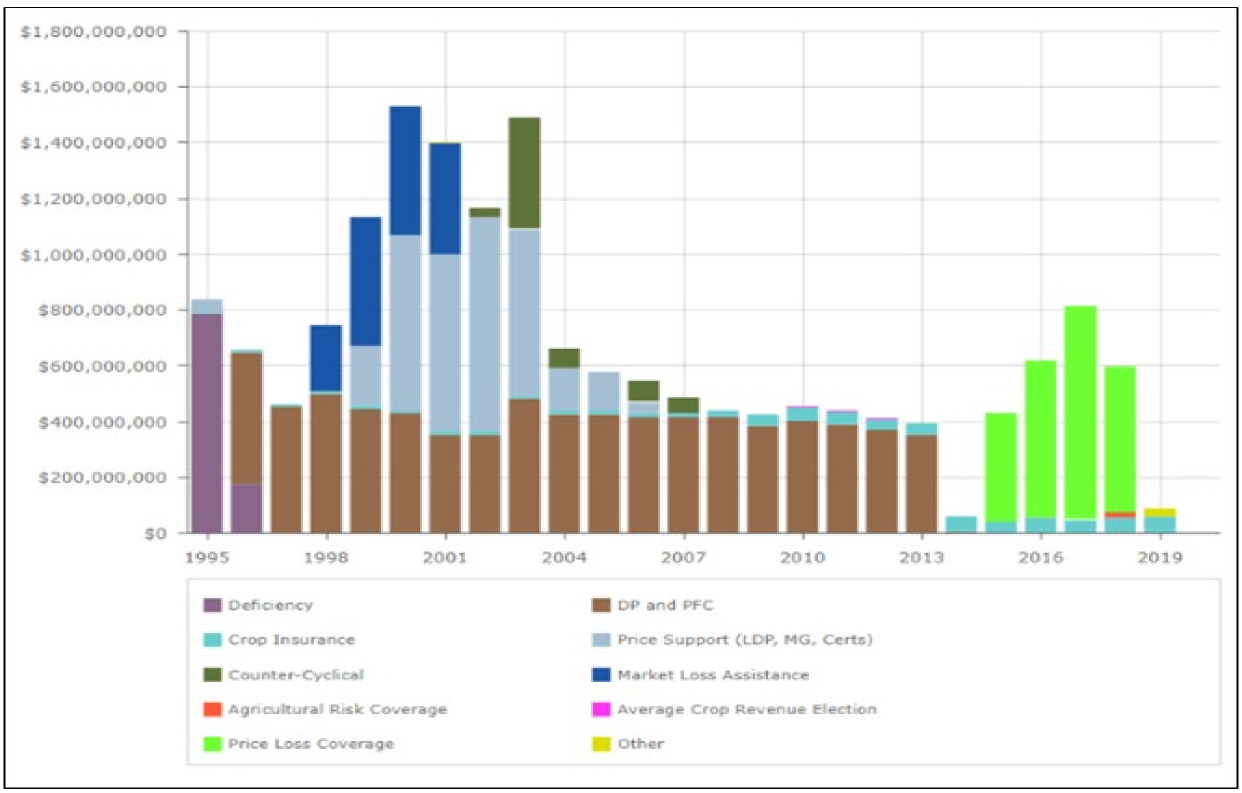
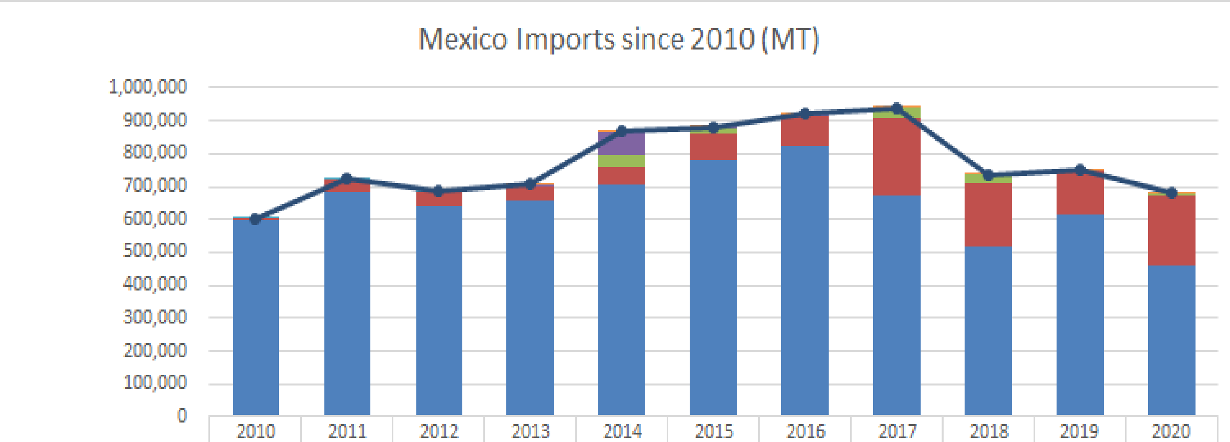


Figure 3. Review of Rice Subsidies: 1995 to 2019 (Environmental Working Group, n.d.)

It is critical to understand how farm subsidies as well as a grower's decisions and his/her profitability (presented in Figure 2) are correlated. Growing poor-quality rice could influence trade flows and competition.

With the World Trade Organization (WTO), multi-lateral trade agreements, and other country-to-country trading mechanisms increasing, the importance of global competitiveness is exceptionally critical on a daily basis. For rice alone, the North American Free Trade Agreement (NAFTA) opened the U.S. market to paddy trade with Mexico in 1994, which fundamentally shifted the U.S. rice industry from mill-rice sales to paddy-rice shipments for southern U.S. long-grain rice. Paddy rice has been the predominate type of rice shipped to Mexico, showing how policies, subsidies, and trade negotiations can dramatically affect the flow of food commodities (Foreign Agricultural Service, 2021b).



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
India	0	0	65	5,665	1,598	1,325	336	487	696	1,712	1,696
Pakistan	18	62	1,589	0	0	0	0	0	0	0	0
Vietnam	0	0	0	2,643	66,663	2,237	3,000	0	175	179	720
Thailand	71	83	70	187	40,300	19,071	2,461	28,899	26,382	1,665	4,174
South America	1,569	37,666	43,151	46,728	50,040	76,865	88,533	235,547	189,716	133,486	215,807
U.S.	600,423	683,865	642,374	654,975	707,451	781,574	825,397	674,352	519,212	615,373	458,892
Total Imports	602,181	721,813	687,382	710,374	866,244	881,340	919,963	939,631	736,408	752,415	681,289

Figure 4. Mexico's Rice Imports, by Country, 2010 to 2020 (The Rice Trader, 2021)

In recent times, Mexico's increasing number of country trade deals has complicated the U.S. market share, as have the serious quality concerns which have come forth in the last several decades. As shown in Figure 4, the predominant players that are taking market share from the United States are Uruguay, with tightly controlled varieties that are held to high quality standards, and Vietnam, with increased quality but a much cheaper price. Milled rice has been about 30% cheaper from sources outside the United States. As the other countries' quality has increased, the U.S. quality has decreased, in relative measure, which could be a reason for shifts in buying habits for higher-quality rice. The interesting point is that Uruguay's rice has been trading at a premium compared to the U.S. price with no effect on the market share or overall demand. From a trader's and destination buyers' perspective, this change is just for trade patterns and logistic flows; growers do not have this level of freedom after they make their planting decisions.

The reality remains that growers are price takers with near perfect competition and little ability to store rice and other commodities for long periods of time. Farmers are often in situations where they must sell for capital; many growers sell at harvest which is, by far, the worst time, on average, to market crops. The reason for a trade agreement is to allow the quick transfer of goods to other locations that are supply deficient and to do so at a negotiated price. Balié et al. (2019) revisited this long-standing issue regarding the value of trade policy and bilateral agreements. Global trade is critical for countries' success, yet there is a natural tendency for governments to be overly involved with affecting this key area; this mechanism could result in unintended consequences with trade flows.

2.1.2. Global and U.S. Rice Industry Overview

To obtain a more complete understanding about the complexities of the rice market and the changes in trade flows, it is critical to have a keen understanding about the overall U.S. and global rice industries. While it is the largest consumed food commodity in the world, rice is not well understood and is certainly less publicly transparent compared to other major grains (Foreign Agricultural Service, 2021a). Furthermore, the publicly traded rice futures markets currently exhibit low trading volumes and do not represent the commodity's true price due to the lack of price transparency. It is important to recognize that most rice is consumed in very close proximity to where it is grown worldwide, which greatly distorts the picture because trade data do not clearly show this commodity's immense importance. Rice is one of the most politically driven and influenced crops in the global community. The political nature of rice has a great effect on farm policy, which dictates production and the trade flows for rice.

To add to this discussion, global trade is largely based on cash or unreported spot trading, which are privately reported in most instances and where the trade largely relies on independent, non-governmental sources for clarity. The terminology is, often, poorly defined, with multiple names used for the same type of rice, which can differ significantly from what is grown.

For example, the global market largely uses the term "Indica rice" while the U.S. market uses the term "long-grain rice" to define the same crop, the key area of discussion in this study (The Rice Trader, 2021). The last one-third from the United States is the medium-/short-grain rice that is largely grown in California, which internationally would be called "Japonica." With much of Latin America consuming rice as a main dietary component, the crop is also a key export from the U.S. Gulf area, even if in smaller quantity than the major grains. About two-thirds of the U.S. production is within an area encompassing 75 miles on either side of the lower 500 miles of the Mississippi River, and that crop is predominately long-grain rice. Table A1 (Appendix) shows the rice area planted on an annual basis starting from the year 2000. There is a significant increase in acres in 2020, which follows the normal 2-year field rotation of lower soybean acres with 2021 showing those fields going back to soybeans.

Table A2 (Appendix) shows the estimated acres planted in 2021 according to the U.S. Department of Agriculture's (USDA) annual "Prospective Plantings" report (National Agricultural Statistics Service, 2021). Trends for U.S. production are further shown in the USDA's summary (World Agricultural Outlook Board, 2021) for long- and medium-grain rice which is illustrated in Tables A3 and A4 (Appendix).

To continue the topic of terminology, paddy rice could be looked at like wheat because it is the product that is directly taken from the grower and what is harvested in the fields. In the United States, rice is often sold in paddy form, largely to Mexico and obviously to the local U.S. mills, while the paddy quality in the global community is not as consistent with mud balls and other issues forcing an additional processing step before milling. Therefore, only in recent years, and with great technological advancements at certain origins, have new countries entered the paddy-trading game. Brown rice is a milled rice that has its hull taken off while the bran layer remains, which is about 88% of the paddy rice, by volume, in the U.S. markets. White rice is milled rice with the bran layer removed. On the storage receipts, which are given to the USDA Farm Service Agency (FSA) for the USDA loan program, a test for the head and total is shown on the paddy rice for quality. The head rice is the entire kernel, and the broken rice is non-whole kernels. The rice's valuation is heavily tied to the number of whole kernels, with prices being vastly different depending on the number of broken kernels.

The price disparity based on the amount broken kernels is illustrated in Table A5 (Appendix), which shows a weekly breakdown of global prices for the major exporting areas and shows the price by type. The table is especially effective for illustrating the price spread by country and by rice type, both of which are worthy of greater study with different data. Individuals who have experience with and an understanding about the wheat market could make the correlation between protein content in wheat and the percentage of broken rice kernels with a great amount of confidence. Of interest, broken kernels are often used by brewers to make beer, and there are times when broken rice can even be sold at a premium to milled rice that is nearly all full kernels. As a result, Anheuser Busch is the largest buyer of rice in the United States. It is important to note that there is the odd time where broken kernels, or so-called “brewers rice” using different terminology, receive a premium compared to full-kernel rice, which affects the value equation.

It is important to note that brown rice still has the bran layer on the rice kernel. The bran layer degrades much quicker and takes longer to cook, which makes brown rice less appealing in many markets. Organic rice, which can be found for any of the previously mentioned rice varieties, is also a subset of the rice type. Organic rice has increased in popularity at the consumer level.

A topic that is worthy of additional discussion is California Calrose, a type of medium-grain rice (called Japonica in global circles), which is very different in nature and almost another product in many ways (The Rice Trader, 2021). There is a long history of growers self-funding variety development through the creation of an extremely good, professional grain-warehousing system with about 95% in certified professional storage, good shipping, etc. In contrast to the advances for production and quality, there is an exotic model of marketing that utilizes “rice pools,” which is basically like having a privatized co-op system where companies promise to maximize the shareholder’s return. The grower loses marketing control and has to wait 18 months to be fully paid for the goods, receiving partial payments throughout the marketing year. This system is unique, and the positive variety factors have far outweighed the marketing mechanisms. With nearly all of the rice irrigated due to extremely hot, dry weather in the producing regions, the rice quality is exceptionally high and consistent, which is a huge value that also goes well beyond the other factors. It is worth noting that there is a major difference with how varieties are developed and then released for the long-grain (Indica) versus the medium-grain (Japonica) markets in the United States.

Most of this study deals with long-grain rice and its export to the Mexican market, which is the largest buyer of U.S. rice, but one should be aware of this specialty market because there could be much correlation with durum wheat. In fact, one could make a comparison to wheat classes and contrast that information with U.S. rice because there are great similarities with long-grain, short-grain, and southern medium-grain rice; California Calrose; and other specialties, such as Akita rice. There are also other specialty rice varieties, such as parboiled rice, which is partially cooked before shipment, and glutinous rice, which has rather opaque grains along with very low amylose content and is especially sticky when cooked. Other specialty varieties include fragrant, or Ho Mali rice, which has a longer kernel but gives a nice fragrance when cooking, as well as Basmati rice, which also has a fragrance and very long kernels.

2.1.3. Introduction of Hybrid Rice in the United States

The introduction and increased dominance of hybrid rice varieties are worth noting. The introduction of the Clearfield hybrid varieties in the early 2000s began a trend that led to most growers raising this variety today. The growth of hybrid rice is shown in Figure A2 (Appendix), where the Arkansas acres went from 0% grown in 2000 to over 70% of the rice acres in 2021. Looking at Louisiana as a reference point shows that the Clearfield rice varieties make up more than 50% of the state's rice acres. The total acreage in 2020 was 475,927 acres, and the total for the conventional Clearfield varieties plus the hybrid models totaled 233,306 acres (53%). The varieties covered by designations CLJ01, CL111, CL151, CL153, CL163, CL172, CLL15, CLM04, and CL153 were the most grown with 83,124 of the total 151,402 acres. The hybrid varieties covered by designations CLXL745, Gemini214 CL, RT7321 FP, RT7521 FP, and CLXL745 were 55,426 of the total 103,904 hybrid acres. A recent article (McClung and Chen, 2019) explains that the quality is, in fact, the lowest for these varieties while the field yields are 7 to 10 cwt (hundred weight) per acre higher. The long-term domestic and foreign acceptance of the quality for these varieties is a key question as well as the price point at which buyers will continue to purchase for quality.

2.1.4. U.S. and Global Rice Overview

Focusing on the southern long-grain industry, market signals (or the lack thereof) and subsidies have paved the way for hybrid rice to come to the market and to take over as much as 80% of the production while dramatically decreasing the quality of the U.S. rice crop as noted by McGung and Chen (2019). This issue is most easily seen by the drop in market share for U.S. rice exports to Mexico, which have gone from close to a 100% share to just 67% in recent years, as illustrated in Figure A1 (Appendix). Figure A4 (Appendix) also shows the origin breakdown of Mexican rice exports and the subsequent changes in market share for the U.S. and other competitors.

The overall quality issue has been long standing and has even been a complaint from major regional import and trade associations. Often, hybrid rice has higher yield with a lower-rated quality portfolio. Hybrid rice also has a known factor of breakage during transit, which makes hybrid rice less appealing because the origin grades often differ greatly from the destination grades. Even with these concerns, certain countries still grow this rice due to its higher yield capacity, especially when the question is more caloric intake versus food quality. The Central America Rice Federation, which often goes by the acronym FECARROZ, has privately and publicly pushed for a change to get higher-quality rice by signaling that its members would consider changing origins. Some market players believe that this is more for price negotiations with trade while others have made the point that studies show decreased quality; the buyers' change for purchases based on perceived needs to be taken very seriously. It is important to note that, for this and all study objectives, the debate about this topic remains active. At the same time, the use of hybrid rice is increasing, and blending becomes more difficult to impossible.

Similarly, Iraq has looked to buy rice from other sources, such as Uruguay and Thailand, even at a premium to U.S. rice on these tenders. The quality issue is serious for the overall complex, with rice's global ending stocks currently at relatively high levels. To take a step back and forward, the U.S. players have historically had an issue because rice varieties were bred to not have taste; the rice is utilized as an accompaniment for stronger-tasting dishes, such as jumbo. This mentality has started to shift but currently affects U.S. consumption because most customers have not been appropriately exposed to high-taste, quality rice and, therefore, assume that the U.S. long-grain variant is all there is for rice. The reality is that this rice was bred for quantity and for a neutral taste pallet, rather than what today's consumer would choose as having the highest value. Therefore, the history of variety development is a critical factor and shows the need for field studies to take all factors into account when making variety selections.

In the last 15 years, the overall U.S. rice industry production has ebbed and flowed most years. As seen in Figure A6 (Appendix), U.S. production went from 243 million cwt in 2010 to a low of 178 million cwt in 2013. Production was 185 million cwt in 2019 and was followed by 224 million cwt in 2020. In some southern states, rice farmers will plant a lot of rice one year, and then in the next year, they will rotate to another crop, such as soybeans. Arkansas and some geographically related states have a two-year rice/soybean rotation; adding soybeans into the rotation is good for the soil because of the nitrogen added to the soil.

As observed in Figure A6 (Appendix), U.S. rice exports do not have a clear pattern like production does, with price and other competitive factors coming into play. Some years, you will see exports over 100 million cwt while, at other times, you will see as low as 87 million cwt. Since 2005/2006, the average annual exports have been equal to 100.82 million cwt compared to an average production level of 204.64 million cwt. To state a market truism, some years are better than others for production while some years have more global market competition, which makes no two years of rice trading the same. The last few years follow the latter trend, where South America is outcompeting the United States for some Central and Latin American market share. A rather extensive list of key trade flows is shown in Table A7 (Appendix), which illustrates the trade fluctuations over time, from country to country and from even region to region.

The overall domestic market has been a little bit more consistent than the export market, which must deal with many factors. In the last few years, domestic consumption has been higher than it was 15 years ago because of population growth, dietary changes, etc. The average since 2005/2006 is 128.92 million cwt, and recent years have those numbers anywhere between 133.2 and 144.4 million cwt. Observations show that, in 2020/2021, domestic consumption is estimated to be 160 million cwt, but this number is something that the market has never seen before and should be closely monitored. Ending stocks are more consistent and more on par with how the domestic market looks. The average since 2005/2006 is 38.62 million cwt, with a range from 28.7 to 48.5 million cwt (happened twice). As seen in Figures A2 and A5

(Appendix), yields have continued an upward trend as the use of hybrid rice has climbed, and this result shows in the production per acre.

Much like the overall market, long-grain production is not the same every year, and some of this variation is due to the 2-year rice-and-soybean cycle discussed earlier. A lot of the fluctuation happens in Arkansas, and other states, such as Texas, are more reliant on the weather. This cycle has been more apparent since the 2015/2016 marketing year. The average since the 2005/2006 marketing year puts production at 146.29 million cwt, with a range from 125.6 to 183.3 million cwt.

Domestic consumption has been relatively stable compared to the other categories. The average since 2005/2006 is 96.53 million cwt, with a range from 87.4 to 109 million cwt. There is an outlier of 125 million cwt, which seems like an unlikely early year prognosis, that is supposed to occur in 2020/2021.

Looking at U.S. price fluctuations over time, there is significant price movement from year to year, as shown in Figure A7 (Appendix). The paddy price for rice started to increase between 2005 and 2008; the price was between $16.18 and $16.92 per cwt in 2008 (the highest in the last 15 years). Then, the price hovered in the range of $11.85 to $16.28 per cwt from 2009 to 2014. (Remember that yields rose in 2012/2013, with the 2nd highest price in 2013). Then, prices stayed in the range of $10.75 to $12.08 per cwt from 2015 to 2019, showing that the market was a bit more stable in the south. In 2020 and 2021, there were much higher paddy prices, and this change could largely be due to the pandemic and the level of rice stocks. For 2019/2020, stocks were 16.9 million cwt, which is the lowest stock number in the last 15 marketing years and a key reason that prices were so high.

Reviewing the global rice situation is necessary because it is key to the study's objective. Because the terminology will be switching from the cwt used in the U.S. to metric tons (MT), which are more quoted globally, it is important to note that there are 22.04622 cwts to every 1 metric ton of rice. Global rice production has outperformed consumption since 2006, as illustrated in Figure A8 (Appendix), taking global ending stocks to nearly 180 million metric tons (MMT) as seen in Figure 9. It is important to look at the overall rice, wheat, and corn stocks, which have increased to over 800 MMT as shown in Figure A10 (Appendix). The trends for global food illustrate the immensity of food stocks when looking at the aggregate number (The Rice Trader, 2021).

When looking internationally and comparing to the United States as a standard, there is better price and quality competition coming from countries such as Vietnam or India, and even more so from the major South American exporters, led by Uruguay, with Argentina, Brazil, and Paraguay also playing major roles. Imports to Mexico, as shown in Figure A4 (Appendix), remain a key example of the shift and potential for the rice trade to shift away from the United States to competing export nations. While, right now, the United States has its 5% broken rice price at $600 PMT (per metric ton), countries in South America are at roughly the same price but have better perceived quality than the United States. Asian players, as shown in Table A5 (Appendix), sell their rice for almost $200 PMT less than the United States, and the Asian rice is arguably better-to-similar quality when compared to U.S. production.

Moving more broadly, it is important to observe the current top exporter in the world, which is India. As shown in Figure A11 (Appendix), the last few years have seen India go from the 3rd largest exporter to the largest by many magnitudes; in 2021, there is an amazing 15-20 MMT level of exports, even in the midst of the COVID challenges. The development of varieties and irrigation is a success story, but it is important to note that India has had roughly 40 years of statistically improbable good monsoon weather, which is sure to change at some point in the future. Indian rice has 70% to 80% of the market and is heavily subsidized by the government, which is a point of major contention because a push for level trading is occurring. The United States has said that India's rice subsidies total US$26.43 billion a year and heavily violate the WTO rules that only allow 10%; in an effort to end this imbalance, the United States submitted a complaint to the WTO. At the end of November 2020, India bought 20 MMT of paddy rice from domestic growers (16.89 MMT the year before), and 14.28 MMT came from the Punjab region.

The reason that the Indian government uses this action is to keep paddy prices above the minimum support price. Higher government buying is effective because it keeps paddy rice prices above the floor price as it limits the supplies available for private players. Export demand is good for Indian rice. The amount of rice has been increasing since 2009/2010 (95 MMT), and now, 2020/2021 has 121 MMT. The government help has certainly contributed to the amount of rice that is grown every year. The low price in India (Table 5) is causing a depression for the global price of rice at a time when the major grains have run to exceptionally high levels. These examples show how internal agriculture subsidy policies can affect the amount of a crop that is grown and the price set for international trade.

As shown in Figure A12 (Appendix), Thailand once dominated the global rice market but has fallen behind India in the last few years. Thailand's greatest strength was from 2009-2014 when the country's farmers were consistently producing over 20 MMT a year. Exports during this time fluctuated and could be over 10 MMT one year, going down as far as 6.7 MMT. Thailand's last great year was 2017/2018 when the country produced 20.6 MMT and exported

11.6 MMT of rice. During this time, China's aggressive exports of rice began coming to the market and started to affect the big 5 exporting countries; Thailand did not get its old steam back. The biggest issue was a lower yield and, in many ways, a lack of variety development, which was known but not fully addressed. This lack of variety and irrigation development greatly affected Thailand's ability to stay competitive.

Thailand does have a share of rice subsides, which changed over time depending on the governmental leadership. One recent round of government subsidies caused Thailand to lose more than $27 billion in funds and led to great change on many levels. The Rice Farmer Assistance Program started in 2011 and stopped in 2014. It paid growers $450 PMT for their rice, and that price was well above the market value; then, stocks began to rise, and as a result, the government had to sell the rice on the export market for $380 PMT to $390 PMT, which was significantly lower. Robert Cummings, Chief Operating Officer of the USA Rice Federation, noted (Laws, 2015):

> They (Thailand) had a very high price support program for paddy rice that led to huge stocks of around 15 million metric tons. Exports dried up, and it was a very expensive program for a country that is not all that rich. Clearly, we believe they exceeded their WTO commitment, and it left Thailand in a very bad economic situation.

As in any country, the subsidies come and go, depending on the form of government and the market situation. Rice remains and always will be a political crop for Asia and many other regions.

As shown in Figure A13 (Appendix), China is very interesting in the rice equation because it is the largest producer, consumer, and importer of rice and because it has even flirted with being one of the largest exporters in certain years. Figure A14 (Appendix) shows a key factor for the immense amount of grain imports that go to China. Rice is very small portion of the import balance, which is in comparison to the fact that rice is the most-eaten food in China. Each year, China has specific import quotas, with about 5.66 MMT allowed yearly and split equally between the Indica and Japonica rice classes. Trade is dominated by state trading enterprises, of which China Oil and Foodstuffs Corporation (COFCO) is the key leader and the dominant player for the domestic rice trade in China.

As expected, China is another country that subsidizes its rice industry (as well as its corn and wheat industries). This aid has a profound effect on production, and as of late, China has, at times, been dramatically affecting the market with its incredibly low rice prices. Before the pandemic, China had the lowest prices in the world and was heavily pressing India; Thailand; Vietnam; and even some U.S. markets, such as Puerto Rico. The USA Rice Federation has expressed great concern about China's subsidy actions being anti-competitive practices. In 2015, USA Rice filed a complaint with the WTO to say that China was spending US$100 billion more than allowed on subsidies for the rice, corn, and wheat industries. Finally, in 2019, the WTO made a ruling, agreeing with the United States, that China was over-subsidizing the industries. USA Rice Chief Operating Officer Robert Cummings said (USA Rice, 2019):

> The WTO ruling vindicates the USA Rice stance that China has for years been undertaking excessive and illegal support programs, and it will set a precedent for the future. Many other countries are believed to be subsidizing their agricultural producers in excess of their WTO commitments, and we believe this ruling is a compelling reason for them to curb these practices.

The U.S. Rice Federation recently cited a Texas A&M study (Outlaw et al., 2016) which showed that, if China wasn't subsidizing its rice industry, production would drop 4%, putting

China's production around 142 MMT instead of the current level of 148 MMT. That study also described how China's rice imports would have to increase because its domestic prices would be more in line with the rest of the world.

Shifting to the buying side of the equation, looking at a major importing region is key to understand trade flow, which is often hard to track because most rice stays very close in proximity to where it is grown; therefore, statistics do not show the reality of the full situation. Rice is the most consumed commodity in the world, but this fact does not show in the trade data because the actual consumption versus trade is rather imbalanced. Some regions are becoming more imbalanced when rice is considered and are worthy of great investment. As an example, Africa has struggled with how to effectively induce domestic production of rice, and imports have continued to climb to approximately 15 MMT, as shown in Figure A15 (Appendix). Production has flattened at about 22 MMT while consumption continues to grow and is estimated to be over 38 MMT in 2021. The ending stocks for rice in Africa have plummeted in recent years, which is a point of great concern.

Due to the various governments which are disconnected, the lack of a universal strategy, developing-nation issues, etc., one could make the case that Africa is facing the opposite issue from the rest of the world with a lack of support and investment. Because food supplies have been high globally, this issue has been smaller, but a change could dramatically influence import-dependent regions. The issue in Africa is a clear area of needed research about how the global community can help to increase production, which has flattened, in a time when consumption continues to grow. With much of Africa estimated to have a huge population increase over the next 30 years, this area needs development on many levels, and future study is necessary.

2.1.5. Value of U.S. Rice

The value of U.S. rice, along with the subsidy rates shown in Figure A16 (Appendix), has fluctuated for the last 15 marketing years. In order to make the equation relatively simple, value is defined as the production amount multiplied against the grower's average selling price. A more complex variant of exports versus domestic prices could be used. The average long-grain price for the last 15 years is $11.22/cwt, and the average of 147.25 million cwt for production results in an average rice value of $1,642.51 million per year. During this time, the average amount of subsidies given to the rice industry is $452.21 million, with a range of $57.14 million (2014/2015) to $811.62 million (2017/2018).

The biggest year for rice was 2010/2011 when the long-grain rice industry was worth $2,346.24 million; the total subsidy was $453.94 million for the entire U.S. rice industry. In 2017/2018, the long-grain rice industry was valued at $1,496.43 mil, and the subsidies were the highest that they have been in the last 15 years and double the amount for 2010/2011.

2.1.6. U.S. Government Farm-Support Policy and the Implication for Rice

Over time, rice subsidies have had many different names and have filled various functions. The amounts are summarized in Table A8 (Appendix) as well as in Figure A3 (Appendix), which we discuss in depth in the following sections. It is important to note that the Environmental Working Group (n.d.) has been gathering data and showing summaries of all the possible monetary totals for rice subsidies through extensive Freedom of Information Act (FOIA) requests. We use these data and the description of farm programs in addition to the USDA's extensive descriptions. In 1995, farmers were paid almost $800 mil dollars from the Deficiency Program, crop-insurance subsidies, and price support payments. Then, 1996 brought a new program, Production Flexibility Contracts, which ran from 1996 until 2002 and totaled

$2.9 billion in farmer payments. This program subsequently changed its name to Direct Payments from 2003 until 2008 (which totaled $4.5 billion).

Crop-insurance subsidies ran from 1995 until 2013 when they were stopped. From 1998 until 2002, there was a program called Market Loss Assistance (which totaled more than $1.5 billion). From 2002 to 2007, another program was created and called Counter-Cyclical Payments (which totaled $596 million). Then, there was a small rice-subsidy program from 2010 to 2012 that was titled Average Crop Revenue Election ($2.4 million). In 2014, there was a subsidy of crop-insurance payments which didn't total very much ($57 million). From 2015 through 2018, there was a new program called Price Loss Coverage (total of $2.2 billion). Since 1995, Arkansas has received $7.3 billion, California has received $2.8 billion, Louisiana has received $2.1 billion, Mississippi has received $1.3 billion, and Missouri has received $753 million in total rice government payments and subsidies. In a way, the amount of payments by state makes sense because there is similarity to the rankings of harvested acres by state.

Looking at 2020 numbers, Arkansas was first with 1.4 million acres; California was second with 0.5 million acres; Louisiana was third with 0.43 million acres; Missouri was fourth with 0.219 million acres; Texas was fifth with 0.184 million acres; and finally, Mississippi was sixth with 0.15 million acres. The reality is that the data considered several farm bills from the last 2 decades, with many policy changes which put more price and market risk on the growers. This increased risk was offset by production programs, which were largely focused on the quantity that one could deliver to the market, rather the need for the crop to be marketed.

A closer look at these programs starts with Production Flexibility Contracts/Direct Payments. In 1996, Congress passed the Freedom to Farm Act as an attempt to move away from a subsidized farming system and go to a freer market system. The goal was to make sure that, over time, growers would rely less on the government. However, this program went longer than initially expected and, instead, became a federal entitlement program that costs more than $5 billion a year. This program drove up land prices and made it much harder for small farmers and new farmers to break into the business, thereby adding a barrier to entry for new participants.

The next program is Counter-Cyclical Payments (CCPs). This program was intended to compensate farmers for market drops. Congress was going to set a price, and if the price ever dropped below that target, growers would receive a direct government payment. The program was like direct payments and was tied to historic production, not current production, and many people close to this program said that it did not make true economic sense.

Congress realized this problem and, with the 2014 Farm Bill, decided to get rid of the program, replacing it with Price Loss Coverage (PLC). The problem with this government program was that it basically continued the CCP but set a higher price target than the CCP did. Analysts said that this new program magnified the CCP's problems. The 2018 Farm Bill changed some things, hoping to fix various problems. The 2018 Farm Act introduced an "effective reference price" that allowed the statutory reference price to increase up to 15% when the previous 5-year average of market prices is above the statutory price. The compensation amount is the payment rate multiplied by the historical acres for a covered commodity, up to 85% of the farm's base acres for that commodity, multiplied by the payment yield. The 2018 Farm Act permitted growers to update a farm's historical payment yield, but the downside was that this action could only be done once.

Marketing Loan Guarantees (MLG), the Loan Deficiency Program (LDP), and Certificates are the next program to discuss. This program is intended to be a loan, giving growers an opportunity to keep rice on hand while waiting until the market needs their rice. As an example, the current market is $7 per cwt for average-quality rice in California. The strategy and economics behind the program are that, if farmers didn't have this loan, then they would sell all their rice after harvest, creating a temporary product glut with low prices; then, there would be a negative price effect.

The Average Crop Revenue Election (ACRE) Program was created in 2008 and ended in 2014. It was designed to ensure that eligible growers received a minimum total revenue. ACRE was meant for growers who lost yields due to weather, pests, or something else. Individuals who enrolled would lose their right to the CCP payments as well as having a 20% reduction for direct payments and a 30% reduction for MLGs and LDPs.

Disaster Payments are the next program of interest. This assistance was meant to help farmers in the case of a disaster. These payments equaled a billion dollars a year for all crops (totaling $20.4 bil from 1995-2020). The disaster payments are a major piece of support for people affected by hurricanes or other natural calamities, which have devastating effects on certain growers when untimely events occur.

The last program to discuss is Agricultural Risk Coverage (ARC). It was also introduced with the 2014 Farm Bill and continued with the 2018 Farm Bill. The program gave income support payments to growers based on historical base acres. The commodities included rice, wheat, feed grains, peanuts, oilseeds, and pulses. The 2018 Farm Bill changed so that growers could participate based on individual farm revenue instead of county revenue. Payments were based on the individual benchmark instead of actual individuals' revenues. Compensation was limited to 60% of the farm's historical base acres.

2.2. Risk, Leverage, and Competitiveness of the U.S. Agricultural Sector

When looking at trade policy and the direction of commodities over longer periods, it becomes critical to understand what influences the risk decisions and the overall competitiveness for U.S producers in the agriculture sector. Collins (1985) studied the risk of unintended consequences as it relates to policy making. He concluded that policies aimed at reducing business risk led to increased financial risk because farmers have an overall equilibrium risk level, which is called the risk-balancing hypothesis. Further, Knight (1921) differentiated between events involving risk and uncertainty. Under risk, the probability of all outcomes is known with a high degree of certainty. For example, rolling a fair, single die has six possible outcomes, all of which have a certain probability of 1/6. With uncertainty, some (or all) of the outcomes have uncertain probabilities. The uncertainty is due either to nature (an unstable stochastic process) or can be attributed to a lack of information regarding the true probabilities. For example, if we had an unbalanced die, we may have to roll it many times in order to determine its limiting probability distribution, gaining information with each subsequent roll of the die.

A grower has many risks that he/she must manage, and in many ways, the variability of events that are thrown at the producer make managing these risks difficult. Key among these risks are production, trade, and financial risk. Patrick (1992) stated that the inherent random variability for a farmer's production process is production risk. Trade and price come into play when a grower decides how and when to market crops, along with how much should be left to be sold on the open cash market or how much should be hedged in the futures market. On that same note, markets without futures often have different paths to the same goal when a grower decides how much to precontract versus waiting for the marketing year to unfold.

The leverage position that is taken gives a variation for the return on equity, which is a multiple of business risk (variability for the return on investment) and the level of indebtedness (financial leverage) (Collins, 1985). Collins states that the chosen leverage position produces a variance for the return on equity that is some multiple of business risk. The magnitude of this leverage (equity multiplier) may be regarded as the overall financial risk. Managing all these risks becomes a key factor for business success, with the overall success probability being a function of managing the parts that are interconnected. The agricultural policy's effect on the risk decisions that growers make is not often well understood. In fact, policies that reduce the growers' business risk may cause them to increase their financial risk, which is often exhibited in their debt-equity structure.

Gabriel and Baker (1980) showed that the concepts of business and financial risks are linked in an equilibrium risk position for farmers. Gabriel and Baker's study was followed by Collins (1985) and Featherstone et al. (1988), where the theoretical effects of farm policies on optimal leverage and the probability of equity losses were examined. Just et al. (1999) showed that the demand for crop insurance may be affected by closely related incentives and that adverse selection can often occur. Companies that provide this insurance must effectively evaluate the true risk because they could have negative revenues while the grower may, in fact, face a situation where not getting insurance is the preferred choice.

Barry et al. (2000) showed that growers adjust to long-run financial targets for equity, debt, and leasing, but that additional financing needs to follow a pecking order that is stronger for farms with greater asymmetric information problems. On average, greater access to financing led to higher profitability. The obvious indication was that growers shift their business structure based on their revenues, of which subsidies are part of the revenue's overall balance.

Escalante and Barry (2003) examined a correlation relationship to measure the strength of trade-offs between business and financial risks as a representative of the strategic-capital adjustment process. Interestingly, the 1980s were a time of liquidity constraints with an emphasis on risk-balance plans, a push towards specialization, and market revenue-enhancing strategies. The 1990s were a period with more risk-reducing crops and insurance protection plans.

Sherrick et al. (2004) looked at many factors that influence farmers' crop-insurance decisions and how subsidy levels were part of this equation as the overall value of the insurance mechanism. Additionally, Escalante et al. (2009) showed the difficult nature of sustaining growth in the farm sector with variable risk and the competition for land and financial assets. The study illustrated that farms' tendencies to attain balanced growth seem to be more influenced by asset productivity and leverage decisions, which are given different emphasis by grain and livestock farms due to differing operational structures and constraints.

Kropp and Whitaker (2011) estimated the effect of decoupled direct payments from the 2002 Farm Bill on the farm operators' credit terms, specifically the interest rate for short-term operating loans. If farm operators obtained more favorable credit terms and reduced their operating cost, there was an additional mechanism through which decoupled payments could distort current production. Glauber (2013) described the growth of using federal crop insurance from 1990 to 2011, with insurance as a risk-managing tool. There was also a key point made because insurance moved from being based strictly on yield reduction to more based on revenue reduction and index price products.

Adding to Glauber's (2013) study, Ifft et al. (2015) examined the question of whether a federal crop-insurance support policy led to higher farm debt, which pointed to the fact that, the more subsidy given, the higher the amount of financial risk which a grower is willing to take.

Xouridas (2015) took the question of risk further by looking at agricultural-finance risks that result from extreme events. While most equations assume a normal distribution, this study addressed the question about what occurs when improbable, high-impact risk events occur. How the risk management effects each aspect of the industry is different but well connected. Cole et al. (2017) showed that risk management heavily affects production decisions. Part of this risk management was growers working towards higher subsidies as a key piece of their revenues. The effective result was that growers push for higher payments and change based on the payments' overall profitability. The insurance's effect on trade and U.S. competitiveness is yet to be deeply studied, especially when considering the U.S. rice industry.

2.3. The Value of Policy and Grower Options

Ashok et al. (2012) found that profit levels are rather diverse for growers. The key factors affecting profitability are operator education; farm size and typology; specialization; and, critically, the level of government payments. For this example, the DuPont model was used to functionally show these statistical relationships. What was also interesting is the grower's balancing game of being more profitable as subsidies increase and how growers' profits are affected.

As is always the case, growers are just pushing on areas and policies that gain the highest return which, at times, may not be the best long-term strategy for the industry or the competitiveness of U.S. agriculture. There are also examples of change and risk management for global and more diverse growers. Nganje et al. (2015) took an interesting shift for insurance and applied it towards growers' health subsidies. Because producers have much more risk of harm than the normal population, this component is key to the risk equation. A portion of the farm switch subsidy was preferred by growers with higher healthcare spending, people with older farms, and farmers who had experienced health issues in the past. Cai et al. (2020), in their study of rice producers in China, showed the importance of a subsidy to affect producers' actions. Furthermore, there are many implications for a game-theory model of continued iterations because the growers learn from their experience; therefore, the subsidy is as much a tool to create positive change as it is a tool to support learning among the growers' community. In addition, the speed of adoption for new varieties is affected by the grower's current skill level. The gain from this subsidy, in the form of education, was modeled and shown to be significant, and the payoff functions were clearly positive.

2.4. Varied Use of Risk-Management Tools and the Importance of Quality with Trade

Marketing and using risk-reducing hedge mechanisms are long-debated topics. Turve and Baker (1989) observed optimal hedging with alternative capital structures and risk aversion. Turve and Baker (1990) conducted a farm-level financial analysis of farmers' use of futures and options with alternative farm programs.

Wilson et al. (2007) showed the value of quality and how uncertainty greatly affects the value proposition of wheat varieties grown and then utilized by end users. The effects on the buyers' interest to purchase a product and how this value is made are greatly influenced by the quality and the consistency where the buying occurs. As technology advances, the ability to buy more regionally specific items will increase. Wilson and Dahl (2008) examined how actual strategies, by region, improved the quality's consistency. The observations shifted the question about quality improvement to the forefront of the research.

Katchova (2010) looked at agricultural contracts and alternative marketing options. She showed that growers will make decisions to obtain the optimal return, with more educated growers moving to the optimal solution faster. With higher subsidies being a key factor for this decision, growers will plant the quality that makes the most sense for their farm income. In the rice industry, where subsidy payments are not tied to quality, quantity versus quality is pushed.

Skadberg et al. (2015) added to this discussion by looking at competition, risk, and arbitrage for soybeans. Overall, the decision about when and where to trade is different, yet similar, between the buyer and seller. Bullock and Wilson (2019) further enhanced the study when examining the key factors that affected soybean basis levels. The yearly supply, demand, transportation, seasonal timing, average prices by marketing year, and other market variables were shown to be key factors that influenced the basis.

The unanswered question is if the trend for subsidies and/or variety choice affects the loss of market share or has a correlation with other key factors. The trends will be tested in the theoretical and empirical analysis section.

3. THEORY AND CONCEPTUAL FRAMEWORK

This chapter addresses the second objective. The premise of this framework is that the amount of risk which a producer is willing to take is vastly affected by U.S. agricultural policy. The policy and subsidy level influence the producer's overall decisions, therefore leading to the need to closely monitor the subsidy's effects on grower decisions and the agricultural sector's overall performance. Grower decisions may not be consistent with the optimal competitiveness of U.S. agricultural trade. In recent years, much of the focus for farm-bill policy has been on making sure that the choice of optimal quantity prevails over quality. One must also be cognizant of the critical point that growers can choose suboptimal decisions, which lead to an increased need and effort to receive subsidies. The overall influence on revenues may increase as a result of subsidy effects for the market, yet trade could be negative if quality improvements are overlooked.

The U.S. rice market has seen a declining market share with more low-quality rice production. A higher market share usually means greater sales, less effort to sell more, and a strong barrier to entry for other competitors. A higher market share also means that, as the market expands, the leader gains more than the others. By the same token, a market leader–as defined by its market share–also has to expand the market for its own growth. On the other hand, a subsidy is the amount of incentive provided to facilitate production. A subsidy could reduce the financial burden or increase revenues for growers.

The gross sales to equity ratio (also referred to as the GSE ratio), a measure that compares the relationship between a firm's sales and its financial leverage, can be used to analyze the subsidy's effect. The ratio can also be used to measure a firm's competitive strength and performance, which indicates how well the firm is meeting its sale target. A higher GSE ratio shows that a firm can create sales without external support (e.g., debt financing or a subsidy). The GSE ratio is also utilized to measure the state of a nation's market share globally because the measure gauges competitiveness and performance, thus making it important for this study.

3.1. Conceptual Framework

Governments have developed a vast menu of subsidy policies in order to create sustainable agriculture and to help push the optimal strategy for production and trade. Thus, many studies focus on subsidy policies in the context of agriculture, especially how agricultural subsidy policies influence production. As an example, Xu and Pu (2014) built a risk insurance model to determine the effect of crop-insurance subsidies on agricultural output, and they concluded that premium subsidies can continuously lead to increased agricultural production. However, limited research has been done to study the influence that a subsidy has on trade, especially how the subsidy affects the overall value of agricultural exports or how quality factors may come into play with this process.

According to Collins (1985), an increased subsidy decreases financial risk, which could lead to more business risk being taken. However, his study does not consider the possibility of quality inclusion for subsidized farmers. No study has fully captured the relationship between quality improvement and a subsidy. Studying the effects of a subsidy and variety choice on market share motivates the interest for this study; there is a need to develop a framework in order to test the effects of a subsidy provided by the government on U.S. rice's market share and to determine the implications for U.S. rice's overall competitiveness. This study's framework also includes the subsidy's effect on quality improvement, which can be clearly seen in Figure A17 (Appendix).

3.2. Theoretical Method

The general expected utility model is used to develop the theoretical model for the analysis. The general expected utility model is given as follows:

$$\underset{w}{\text{Max}}\,\text{EU}[w] = \text{E}[w] - \frac{\lambda}{2} \cdot \text{Var}[w]\ , \tag{1}$$

where E[w] represents the mean of wealth, λ is the risk-aversion parameter, and Var[w] is the variance of wealth. The expanded return on equity formula (DuPont Analysis) is utilized to approximate the utility function. We use these derivatives to determine the effect that a subsidy and quality improvement have on the market share. This study is an extension of Robert A. Collins' (1985) article titled "Expected Utility, Debt-Equity Structure, and Risk Balancing." Here, we are extending the DuPont formula to include quality improvement with respect to market share and subsidies. We assume that the profit margin in the DuPont formula is a constant, thus we focus on the total asset turnover and the equity multiplier. The DuPont formula is given as follows:

$$\text{Re} = \text{PM} * \text{TAT} * \text{EM}, \tag{2}$$

where Re represents the return on investment, PM is the profit margin (we assume to be constant), TAT is the total sales-to-asset ratio, and EM is the equity multiplier.

We assume that the total sales are a proxy for market share and that additional equity in the EM is the subsidy, thus we have the following equation:

$$\text{Re} = \frac{Market\ Share}{Subsidy}. \tag{3}$$

This ratio is referred to as the gross sales-to-equity ratio (GSE). Therefore, equation (2) becomes

$$\text{Re} = \text{GSE}. \tag{4}$$

In this study, we decompose the GSE into two components in order to capture the effects of quality improvements on the market share. Therefore, introducing a quality function in equation (4), using weights for both components, yields

$$\text{Re} = W_1 GSE + W_2 Q_i \;, \tag{5}$$

where W_1 represents the weight for the GSE (subsidy without quality improvement specification), Q_i represents the quality improvement, and W_2 is the weight attached to the quality-improvement component. It is assumed that both variables, or components, are stochastic in nature. This specification ensures that a portion of the subsidy is for quality improvement, hence the reason for the weights, W_1 and W_2.

Equation (5) has an expected value of

$$\text{Re\_} = W_1 \overline{GSE} + W_2 \overline{Q_1} \tag{6}$$

and a variance of

$$\sigma_{Re}^2 = \alpha W_1^2 - W_1^4 \overline{GSE}^2 + \beta W_2^2 - W_2^4 \bar{Q}_i^2 + 2W_1 W_2 Cov_{GSE\ Qi}. \tag{7}$$

Given the mean and variance in equations (6) and (7), respectively, the expected utility maximization of Re can be presented as follows:

$$\text{R(M)}=W_1 \overline{GSE} + W_2 \bar{Q}_i - \frac{\lambda}{2} * \left(\alpha W_1^2 - W_1^4 \overline{GSE}^2 + W_2^2 - W_2^4 \bar{Q}_i^2 + 2W_1 W_2 Cov_{GSE\ Qi}\right), \tag{8}$$

where R(M) is the certainty equivalent for the return on investment.

The first-order condition for maximizing the expected utility function with respect to the gross sales-to-equity ratio and quality improvement are presented in equations (9) and (10), respectively, as follows:

$$\frac{dR(M)}{d\overline{GSE}} = W_1 + \lambda W_1^4 \overline{GSE} = 0 \tag{9}$$

$$\frac{dR(M)}{d\bar{Q}_i} = W_2 + W_2^4 \bar{Q}_i = 0. \tag{10}$$

Equating equation (9) to equation (10) and solving for GSE produce the optimum gross sales-to-equity ratio, $\overline{GSE}^*$, as follows:

$$\overline{GSE}^* = \frac{\lambda W_2^4 \bar{Q}_i + W_2 - W_1}{\lambda W_1^4} . \tag{11}$$

Merely by looking at the optimum gross sales-to-equity ratio, it can be deduced that the introduction of quality has a positive effect on the $\overline{GSE}^*$. The effects can be illustrated by differentiating equation (11) with respect to Q_i in order to obtain

$$\frac{d\overline{GSE}^*}{d\bar{Q}_i} = \frac{W_2^4}{W_1^4} . \tag{12}$$

According to equation (12), the weight attached to the quality improvement has a direct relationship with the optimum gross sales-to-equity ratio. Higher subsidy targeting increases sales or exports, ultimately leading to an increase for the optimum GSE, or improved market or trade performance.

Differentiating equation (11) w.r.t W_1 results in the following relationship:

$$\frac{\mathrm{d}\overline{GSE}^*}{\mathrm{d}W_1} = \frac{3W_1 - 4W_2 - 4W_2^4\overline{Q_i}}{\lambda W_1^5}. \tag{13}$$

Equation (13) yields a positive relationship between the optimum gross sales-to-equity ratio and the weight attached to it; that is, as the quality weight increases, it is expected that the GSE increases, hence the market share will increase.

Also, differentiating w.r.t W_2 yields equation (14):

$$\frac{\mathrm{d}\overline{GSE}^*}{\mathrm{d}W_2} = \frac{1 + 4\lambda W_2^3\overline{Q_i}}{\lambda W_1^4} . \tag{14}$$

The relationship shows that the weight assigned to the quality improvement also influences the market share; that is, more weight attached to quality improvement increases the desired gross sales-to-equity ratio, hence there is a rise in market share. It is important to improve quantity and quality simultaneously.

Finally, differentiating equation (11) w.r.t the risk-aversion parameter, λ, yields the following relationship:

$$\frac{\mathrm{d}\overline{GSE}^{*}}{\mathrm{d}\lambda} = \frac{W_1 - W_2}{\lambda^2 W_1^4}. \tag{15}$$

This relationship explains the risk-aversion parameter's effect on the optimum gross sales-to-equity ratio. The higher the risk-aversion parameter is, the lower the desired gross sales-to-equity ratio is, creating an inverse relationship to the overall expected equation.

In conclusion, according to the models developed in this study, the inclusion or addition of quality improvement alongside a subsidy to farmers is crucial to improve a nation's market share. The use of quality incentives results in a positive effect on the market share, hence increasing the country's competitive power on the global stage. Therefore, it is important for the government to develop policies that consider quality improvement as subsidies are provided to farmers.

3.3. Empirical Model and Data

We have built a time-series database to analyze the relationship between market-share loss and subsidies. We start by looking at Mexico, the largest market for U.S. rice and also the most representative for the U.S. long-grain industry as a whole. The Mexican rice market is also representative because it has trade flow from South America and Asia, which gives observations with the ability to best represent a market indicator for key changes. We then use a time-series set of monthly shipments to Mexico from the key rice-exporting regions of the United States, Asia, and South America in order to explain trade flow from the key global-trading entities, as shown in *The Rice Trader* (2021), which is based on USDA census data and private reports about shipping to overseas markets. We also have prices, by week, from these rice-export origins which were not used in the model because those prices were not significant for predicting market share. We use Arkansas' production data because that state is, by far, the dominant player for long-grain rice production in the United States.

The market share for Mexican trade can fluctuate marginally by crop year, but it is very representative of a shifting trend, especially in the last 10 years. We use milled-rice equivalent because this choice keeps the quantities of milled rice in direct comparison; Mexico is the largest buyer of paddy rice, and the quantities must be held in a like manner whether there are processed or soon-to-be processed materials. We then start looking at key variables which could affect this market share. We first look at monthly prices from the last 20 years for the 3 major regions: United States, South America, and Asia. As shown in Table A5 (Appendix), the price is for 5% broken rice from South America, with Uruguay being the representative price, and 5% broken, Thai white rice as the representative price factor for Asian rice. The U.S. export price is similar with its #2/4% grade rice and is generally considered to be equal to the quoted prices for the other markets that quote 5% rice. In general terms, this is a USDA #2 grade with 4% broken rice, which is the standard on the U.S rice futures contract. One would expect price to be the factor which affects market share, but our analysis did not find this o be the case; therefore, we did not use these critical data for this study.

For the next time-series dataset, we use the direct amount of the subsidy being given to the grower, taking out the Loan Deficiency Payment (LDP) in order to focus on direct payments that are tied to quantity produced. We utilize the amount of rice that was marketed in a given month and extrapolate a monthly subsidy for that quantity. Last, we look at the amount of rice which was planted to normal varieties and compare it, over 20 years, to the amount which was planted to hybrid rice. The breakdowns for the number of planted acres are from the Rice Technical Working Group Proceedings (2020) and are reported by each state. As we discussed earlier, hybrid rice is significantly inferior in quality but has a 7% to 10% increased yield in the U.S. growing region. We take these acres and extrapolate a value for the monthly marketed quantity based on monthly shipments by assuming that, due to the commingling of the varieties, the amount marketed will be equally drawn from traditional and hybrid varieties. With hybrid rice not being introduced until roughly 2000, the dataset consists of 20 years of monthly data from 2000 to 2019, the last year for which we have full data.

One limitation is that much of our data are weekly or monthly while the subsidy and the hybrid-rice planting are done on a yearly basis. While we do break things down to monthly data, we utilize yearly data. Even though this choice limits the size of our dataset, we feel that the result is more accurate and uniform based on all the data. Varieties are developed in this manner, and waiting longer to try to adjust variety usage would take this model from being applied economics to being theoretical, with less actual use to help formulate strategic decisions. Upon observation, we also note that planting hybrid rice during his period has an over 80% negative correlation coefficient with market share, which suggests a preliminary hypothesis about the relationship between a subsidy and hybrid rice.

3.4. Granger Causality

The dataset is arranged in a time-series format. To test our hypothesis that subsidies and/or an increased percentage of hybrid-rice acres have caused the loss of market share, we use a vector-autoregression (VAR) model to test Granger Causality (Granger, 1969). Normally, a regression analysis shows the variables' correlations when defining an outcome. For example, the following equation represents a standard regression: [$y = \beta x + \varepsilon$]. The significance of the coefficient (β) in the regression only tells the co-occurrence of x and y, but not necessarily that x causes y in the equation. The reality is that regression analyzes if there is some relationship between the variables, not necessarily the nature of the relationship or causality.

Granger Causality uses time-series data to test causality by utilizing current and lagged values of the current series along with current and lagged values of the other time-series variables. It is critical to note that this test does not fully prove causality from one variable, *X*, to another variable, *Y*; rather, it merely states that changes in variable *X* are generally followed by observed changes in variable *Y* that are consistent with regards to the change in *X*. Therefore, there is a strong predictive value in variable *X* as it applies to variable *Y*.

There are also several key assumptions for this test to be valid. First, changes in the causal variable *X* are assumed to precede the observed changes in the caused variable *Y*; in other words, causality is defined with regards to the time dimension only. Second, the causal variable, *X*, has unique information that is fully reflected in the subsequent values of the caused variable, *Y*. Third, the time-series frequency for both the causal (*X*) and caused (*Y*) variable must be the same. Fourth, both time series must exhibit stationary levels in both the mean and variance. Last, we must make sure that there is no feedback in the system where both variables are both causing each other, which is a key part of the equation to monitor.

Another assumption of Granger Causality is that the datasets are independent from each other. The null hypothesis is that lagged (x)-variable values do not explain the variation in (y). With our analysis, the result implies that market share is not affected by the subsidy or that the market share does not cause a subsidy. While many models just use a lag of 1, we conduct this test for many lag periods. If the lag periods are insignificant, then it means that there is no Granger Causality for these lag periods and beyond. To start, we say that the time series of Y is a function of the current and prior values of Y.

$$Y(t) = F [a0+a1*Y(t-p)] \quad (16)$$

The normal equation for Granger Causality is written as such, with X(t) being proven to predict the future values of Y(t). To predict Y, we take the values of X and Y for a particular lag in order to predict future values of Y. It should be clear that t-p is the lag over time. While many people assume a lag of 1 (t-1), it is critical to test for the optimal lag in order to obtain more exact predictability.

$$Y(t) = F [a0+a1*Y(t-p)+a2*X(t-p)] \quad \text{or simplified to } Y(t) = F [Y(t-p)-X(t-p)] \quad (17)$$

In our model, where Mshare is amount of market share and Msubsidy is the amount of subsidy, it is written as follows:

$$Log(Mshare) = logMshare(t-p) + logMsubsidy(t-p) + \varepsilon t$$

$$Log(Msubsidy) = logMsubsidy(t-p) + logMshare(t-p) + \varepsilon t$$

Ho: $a2 = 0$

H1: a2 is not zero

In our model specifically,

Ho1: M% does not cause Msubsidy

We will reject Ho if the p-value is less than 0.05 and then conclude that Mshare does not cause Msubsidy.

Ho1: Msubsidy does not cause M%

We will reject Ho if the p-value is less than 0.05 and then conclude that Msubsidy does not cause Mshare or that a subsidy does not affect the market share.

Lag (t-p) should be tested to find the most significant lag. One way to choose lags is to run a model-order test (i.e., use a model-order selection method). It might be easier to pick several values and then run the Granger test several times to see if the results are the same for different lag levels. The results should not be sensitive to lags.

We run a t test for individual coefficients.

We run an F test to test for joint coefficients.

Two equations can be used to find if $\beta_j = 0$ for all lags, *j*:

$$y(t) = \sum_{i=1}^{\infty} \propto_1 y(t-i) + c_1 + v_1(t) \tag{18}$$

$$y(t) = \sum_{i=1}^{\infty} \propto_1 y(t-i) + \sum_{j=1}^{\infty} \beta_j x(t-j) + c_2 + v_2(t)$$

Similarly, these equations test to see if y(t) Granger causes x(t):

$$x(t) = \sum_{i=1}^{\infty} \propto_1 x(t-i) + c_1 + u_1(t) \tag{19}$$

$$x(t) = \sum_{i=1}^{\infty} \propto_1 x(t-i) + \sum_{j=1}^{\infty} \beta_j y(t-j) + c_2 + u_2(t)$$

Calculate the f-statistic using the following equation:

$$\text{F} = \frac{(ESS_R - ESS_{UR})/q}{ESS_R - ESS_{UR})/(n-k)}. \tag{20}$$

As stated above, we reject the null hypothesis if the F statistic is greater than the f-value.

The theoretical model above leads to the key point of growers using subsidies for risk decisions and advancing when the risk is lower. This theory provides a clear indication that growers will continue to push for increased revenues, whether the revenues are from the market or from increased subsidies. As the subsidy increases, growers are willing to take on more risk, such as planting varieties for the sake of a higher yield, even if there are market implications.

4. GRANGER CASUALITY RESULTS FOR OBJECTIVE THREE

The results for objective three are given below as the market-share shifts for rice exports to Mexico by using the Granger Causality method. When looking at the rice industry's shifts in the last 20 years, Granger Causality is a valid tool to help understand what is causing the loss of market share and what can be done to reclaim the strategic advantage, which is discussed in this chapter.

4.1. Implications for the Market Structure and Data Organization

As noted in prior discussion, initially, the data were set up as monthly data points, but we were forced to move to yearly data because subsidies and the amount of a hybrid grown can only be accurately calculated on a yearly basis. The change to use yearly data did limit the data points, but 20 years of data are exceptional when deciding what varieties to grow. Therefore, we elected to use these data rather than converting to monthly data, which appeared to not accurately reflect the model. Ideally, more data would be helpful for statistical significance; however, hybrid rice production did not really start until 2000, and there is only one crop per year in the United States.

Conversations and interviews with key developers of rice-seed technology, including a 2021 interview with David Boehm (the current Technical Manager for the Northern Crops Institute in Fargo, ND; a former U.S. Research & Development Manager for SESVanderHave Sugarbeets; and a former key account lead for Syngenta and AgriPro Wheat), allowed us to see that the way we utilized the data was applicable to what normal plant research groups do when developing varieties. With normal yield trials, seed companies only have 4-5 years of field data before a variety is released. The reality is that, after breeding a line, 3 years of advanced yield trials occur before releasing a seed to the public. In the third year, variety developers are, in many cases, doing seed production, justifying the use of 20 years of data. Variety developers use multiple sites to obtain more data; the more advanced the line is, the more locations you use. Our data show the consistent lack of quality for hybrids, even with a higher yield. One could make the case that trade with multiple countries would be better, but in reality, trade with Mexico is rather representative of the U.S. rice trade because Mexico is the biggest yearly buyer.

Of additional importance, there is also an interesting observation when looking at the overall industry strategy. Industries such as sugarbeets and barley approve varieties while wheat and other major commodities go through a more open public release with fewer controls for what is planted and, more importantly, what is commingled into the overall supply system. The California rice market follows the sugarbeet and barely industries' model with the California Rice Certification Act Advisory Board that approves rice varieties to be publicly released as well as what can be transported to California under state mandate. The southern long-grain rice industry is more open regarding seed release. As a noteworthy observation, products which are closer to the actual consumer appear to have varieties that are closer to what the customer wants. The proximity of customers to a variety may be worthy of future study.

The wheat industry's history shows some correlation, where quality become an important issue in the 1980s, with major intervention by industry leadership after the United States lost significant market share. The resulting subsidy was based on the quantity and quality produced. There has always been a focus on the amount of protein and test weight for wheat, rather than the actual baking characteristics. The wheat quality tours and wheat quality report came to be during this time in order to address the overseas buyers' issues. The efforts to improve wheat quality were effective to regain strategic advantage and market share. This has not been the case for hybrid rice.

4.2. Correlation Analysis for the Market Share and Subsidies

To further illustrate the issue's importance, we started with a correlation analysis and saw that there was an over 80% negative correlation between the Mexican market share of rice imports from the United States and the production of hybrids in the United States. To add further weight to the analysis, we did a cross-autocorrelation (Figure 18) showing the U.S. hybrid percentage and Mexico's market share using the *Gretl* (Cottrell and Lucchetti, 2021) econometrics software package. The deeper negative values on the right-hand side of Figure 5 indicate that the correlation's direction is stronger for the percentage of hybrid rice grown for Mexico's market share and not vice versa, therefore creating the need for a deep analysis using Granger Causality. The cross-autocorrelation test shows a relationship between the variables but does not clearly show causation.

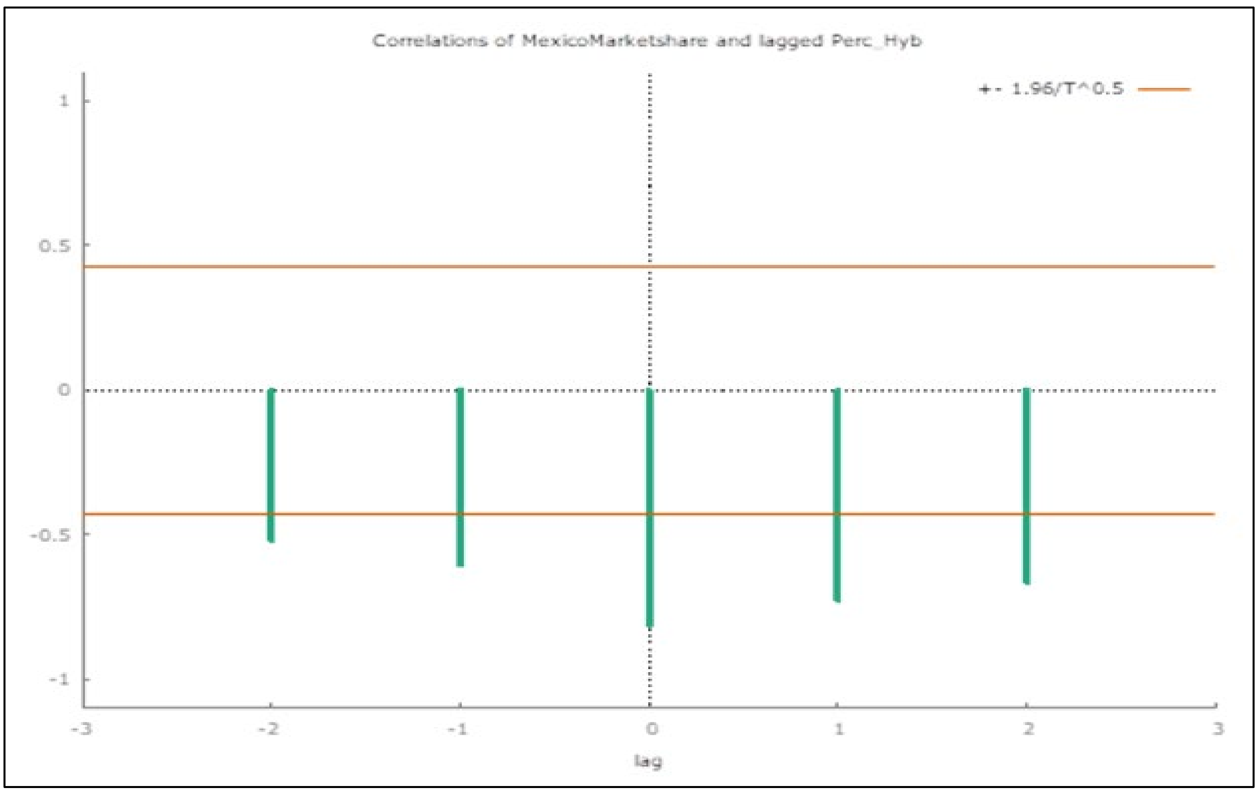


Figure 5. Cross-Autocorrelation for Hybrid Rice Production and Mexico's Market Share

4.3. Granger Causality for a Subsidy and Market Share

4.3.1. Results and Model Test

The time-series database of yearly data from 2000 to 2020 was utilized to analyze the market share's effects using the *Stata* (Statacorp, 2021) statistical analysis software package. Looking at the model and the results, we first tested the dataset for the appropriate number of degrees of freedom and the lag for the goodness of fit by running a lag-order selection criterion. The model measures for appropriateness, including the Akaike's information criterion (AIC) level of -188.905, Hannan and Quinn information criterion (HQIC) of -189.253, and Schwarz's Bayesian information criterion (SBIC) of -187.21, were the most negative for 7 lags. As the results in Table 1 show, 7 lags was the most significant and appropriate for the 3 multi-variable function.

Table 1. Stata Lag Tests for Market Share, Subsidy, and Hybrid Percentage

Lag-order Selection Criteria								
Sample: 2008 thru 2020 Number of obs = 13 * optimal lag								
Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	**-50.5369**				**0.758604**	**8.23644**	**8.20965**	**8.36682**
1	**-29.5403**	**41.993**	**9**	**0.000**	**0.127327**	**6.39082**	**6.28363**	**6.91231**
2	**-18.7636**	**21.554**	**9**	**0.010**	**0.133319**	**6.11747**	**5.92989**	**7.03008**
3	**11.6835**	**60.894**	**9**	**0.000**	**.014989***	**2.81793**	**2.54995**	**4.12166**
4	**1229.61**	**2435.8**	**9**	**0.000**	**.**	**-183.171**	**-183.519**	**-181.476**
5	**1248.77**	**38.325**	**9**	**0.000**	**.**	**-186.119**	**-186.467**	**-184.424**
6	**1262.36**	**27.18***	**9**	**0.001**	**.**	**-188.209**	**-188.558**	**-186.514**
7	**1266.88**	**9.038**	**9**	**0.434**	**.**	**-188.905***	**-189.253***	**-187.21***
8	**1264.67**	**-4.4251**	**9**	**.**	**.**	**-188.564**	**-188.913**	**-186.869**

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	**-87.9293**				**2.88107**	**9.5715**	**9.59674**	**9.72062**
1	**-57.78**	**60.298***	**9**	**0.000**	**.316893***	**7.34527***	**7.44622***	**7.94175***
2	**-49.5933**	**16.374**	**9**	**0.059**	**0.377676**	**7.43087**	**7.60753**	**8.47472**

Log likelihood	=	**-62.52532**	AIC	=	**7.452532**
FPE	=	**0.3517959**	HQIC	=	**7.569158**
Det(Sigma_ml)	=	**0.1042358**	SBIC	=	**8.049971**

Equation	Parms	RMSE	R-sq	F	P > F
Subsidy_Adjusted	**4**	**158.086**	**0.2682**	**1.954661**	**0.1615**
Perc_Hyb	**4**	**0.054201**	**0.9431**	**88.47987**	**0.0000**
MexicoMarketsh~e	**4**	**0.058031**	**0.7444**	**15.5319**	**0.0001**

With the degrees of freedom so large and the dataset relatively small compared to a weekly or monthly dataset analysis, it was logical and necessary to restrict the lag to a maximum of 2 as the most appropriate due to utilizing yearly data and having a smaller dataset. There could be some validity because time is required to change consumer behaviors, but the data size limited the ability to analyze with a larger lag. Looking at the slow reaction from the rice industry on the loss of market share, the 7-year lag could be a reality for what they perceive. There appears to be no urgency for change with passive actions more like the 7-year prior timeframe where the market share was 87% versus 67% today for Mexico; now, major intervention appears to be necessary.

Table 2. Vector Auto Regression for Market Share, Subsidy, and Hybrid Percentage: Stata

Vector Auto Regression: Stata						
	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
Subsidy_Adjusted						
Subsidy_Adjusted L1.	**0.2631847**	**0.2462167**	**1.07**	**0.301**	**-.2587714**	**0.7851408**
Perc_Hyb L1.	**328.6544**	**285.5643**	**1.15**	**0.267**	**-276.7149**	**934.0237**
MexicoMarketshare L1.	**64.87575**	**679.6532**	**0.10**	**0.925**	**-1375.925**	**1505.676**
_cons	**146.0692**	**723.1329**	**0.20**	**0.842**	**-1386.904**	**1679.043**
Perc_Hyb						
Subsidy_Adjusted L1.	**0.0000221**	**0.0000844**	**0.26**	**0.797**	**-.0001569**	**0.000201**
Perc_Hyb L1.	**0.9716826**	**0.0979078**	**9.92**	**0.000**	**0.7641275**	**1.179238**
MexicoMarketshare L1.	**-.1225843**	**0.2330239**	**-0.53**	**0.606**	**-.6165729**	**0.3714044**
_cons	**0.1471675**	**0.2479313**	**0.59**	**0.561**	**-.3784233**	**0.6727584**
MexicoMarketshare						
Subsidy_Adjusted L1.	**-.0001089**	**0.0000904**	**-1.20**	**0.246**	**-.0003005**	**0.0000827**
Perc_Hyb L1.	**-.2693624**	**0.1048268**	**-2.57**	**0.021**	**-.4915853**	**-.0471395**
MexicoMarketshare L1.	**0.3649824**	**0.2494915**	**1.46**	**0.163**	**-.163916**	**0.8938809**
_cons	**0.6846768**	**0.2654524**	**2.58**	**0.020**	**0.1219429**	**1.247411**

The reality remained that the degrees of freedom cannot be used up for the model to be significant. With results for AIC (7.34), HQIC (7.45), and SBIC (7.94), our lag-order selection criteria showed that 1 was the ideal lag, which was also what we found when we ran a simple 2-variable model, therefore adding to the results' validity. Consequently, a lag of 1 year was used as the most appropriate and ideal value for the time series in our model.

Following the selection of the appropriate lag, we ran a vector auto regression model that had a lag of 1, with the selection of a small dataset in the Stata program (Table 2). Looking at the results, we did not find a P value for the F test of significance when comparing our subsidy versus the hybrid percentage or the Mexican market share. There was some interaction between market share and the subsidy with a P value of .267, but it was not significant and was far from the needed threshold of .05. When examining the hybrid percentage, we did not find a significant relationship with the other variables and, therefore, could not consider other variables. Finally, when looking at Mexico's market share, we found that there was a P value of .021 for the F test, which clearly showed how the hybrid percentage has strong negative effect on the U.S. share of Mexican rice imports and falls into the 95% confidence ratio. The Mexican market share's relationship with the amount of hybrid rice had a -.2693 coefficient and a standard deviation of .1048.

4.4. Test of the Results' Robustness

Looking at the Granger Causality Wald test (Table 3), the summary shows a strong causal relationship between the percentage of hybrids affecting the U.S. share of Mexico's imports, with an F test of 0.0206. Because the F test is below .05, we must accept the results as statistically significant, which is, by far, more important than any other variable in terms of its effect on the market share. The F-tests have no significant causal links elsewhere, showing that no feedback loops are present, although there is an indication of some relationship between the amount of hybrid rice and the amount of the subsidy, even if the result, statistically, is not as applicable. Hybrid rice affecting the market share is the main statistically significant finding from our test's results and has vast implications for the current direction of the U.S. rice industry. Planting hybrid rice could lead to a lower market share for U.S. rice. The hybrid's effect on the market share appears to be so dominantly strong that it reduces the statistical expression of the subsidy's importance on the market share, indicating how important variety choice is.

Table 3. Stata: Granger Causality Wald Tests

Equation	Excluded	F	df	df_r	Prob > F
Subsidy_Adjusted	Perc_Hyb	**1.3246**	**1**	**16**	**0.2667**
Subsidy_Adjusted	MexicoMarketshare	**0.00911**	**1**	**16**	**0.9251**
Subsidy_Adjusted	ALL	**1.2161**	**2**	**16**	**0.3224**
Perc_Hyb	Subsidy_Adjusted	**0.06827**	**1**	**16**	**0.7972**
Perc_Hyb	MexicoMarketshare	**0.27674**	**1**	**16**	**0.6061**
Perc_Hyb	ALL	**0.24868**	**2**	**16**	**0.7828**
MexicoMarketshare	Subsidy_Adjusted	**1.4505**	**1**	**16**	**0.2460**
MexicoMarketshare	Perc_Hyb	**6.6028**	**1**	**16**	**0.0206**
MexicoMarketshare	ALL	**4.0506**	**2**	**16**	**0.0377**

In contrast to the Wald test which starts with the alternative and then observes movement to the null hypothesis, we use the Lagrange multiplier test that, inversely, starts with the null hypothesis and examines whether there would be an alternative movement which would better explain the results. This Lagrange-multiplier diagnostic test clearly shows no issues with autocorrelation in the equation residuals, with the probability at .7809 for 1 lag, which is a strong indication from zero. The results add to the validity of the model's variable and the confidence that the variables are independent.

Table 4. Stata: Lagrange-Multiplier Test

lag	chi2	df	Prob > chi2
1	**5.5823**	**9**	**0.78089**
2	**10.5353**	**9**	**0.30891**

To further test the model's robustness, we examine the Jarque-Bera diagnostic (Jarque-Bera) goodness of fit test, which looks to see if the sample data have skewness or kurtosis following a normal distribution. The results of the Jarque-Bera diagnostic test clearly show that there is no issue with non-normality in the residuals. The subsidy level is at .3515; the hybrid percentage is .3214; the U.S. rice share of the Mexican market is .3214; and the overall variables are at .5346. Being so far from zero, the results indicate that there is strong model fitness in this study.

Table 5. Stata: Jarque-Bera Diagnostic Test

Equation	chi2	df	Prob > chi2
Subsidy_Adjusted	**2.091**	**2**	**0.35152**
Perc_Hyb	**0.711**	**2**	**0.70068**
MexicoMarketshare	**2.270**	**2**	**0.32144**
ALL	**5.072**	**6**	**0.53458**

Overall, the most significant and clear finding is that the amount of hybrid rice grown has massive effects on the overall market share. The implications of these finding are highly significant and robust. The choice of variety, along with how the market players and government subsidy programs reward the variety selection, has the ability to greatly affect how the market share develops for many rice markets. We discuss our results, in more detail, in the final chapter's conclusion and applications.

5. IMPLICATIONS AND CONCLUSIONS

In this section, the study's fourth objective is addressed. We evaluate the policy implications for the current and potential subsidy designs while also looking at new areas of related study. The theoretical model's results showed that a subsidy is more beneficial to U.S. market performance when it targets quality improvements, which likely applies to the overall U.S. long-grain market. The clear finding from this study was that the larger the amount of hybrid rice that is grown, the lower the market share to Mexico. There were indications that the subsidy is affected by the amount of hybrid rice being grown, which would be applicable because a subsidy that does not encourage quality improvements reduced the ability to compete, with a subsequent reduction in market share. The issue here was that the empirical results were not statistically significant; therefore, this point could not be validated with the current data. The outcome could be studied further because there is a clear association between the subsidy level and the amount of hybrid rice grown.

It was also clear that subsidies which mostly target quantity will increase the grower's profitability, but it did not mean that what is grown can easily be sold on the market. The overall quality portfolio affected the market share for a given commodity, and trade flows shifted over time to follow the quality and quantity's value balance.

There are other factors, such as cheaper prices in the Asian origins and significantly better quality from South America, that enhanced this issue, but the reality was that the market has rewarded a higher yield at the cost of less quality. The U.S. rice industry's internal testing rated a hybrid as the lowest quality of all varieties tested, yet the fact that the hybrid is the most-grown variety was an indication that current subsidies, which may work in the short term, significantly decrease U.S. competition in the long run. The U.S. subsidies are quantity versus quality based, therefore likely enhancing the grower's return in the short run. As we illustrated, subsidies that only target quantity have played a part in the loss of market share by paying on this quantity basis and increasing the grower's interest to take risks. There is also the question of the longer-term effects of excessive stock and reduced-price potential for lower-quality rice.

What was not found is also interesting. Prices were not statistically significant for the analysis of market share, and this factor should be a foundational piece with the equation for any business. Critically, the varieties from Thailand and Uruguay, which were tested by the U.S. rice industry, were of higher quality than the U.S. hybrid and the traditionally bred programs. This attribute is worthy of future study. As we show in Table A14 (Appendix), global trade fluctuates from week to week, year to year, and country to country; there are different seasonal shifts that are worthy of additional study. The local crop size, the global supply and demand (S&D), hemisphere location, and major macroeconomic factors all affect trade to make the timing of trade flows variable.

Some of the results could be explained by the United States' logistical advantage and the general belief that Mexico is an extension of the U.S. market, especially when a large percentage of the trade with Mexico is paddy rice versus milled rice. The milled rice versus paddy rice export trade-flow equation is another piece worthy of study. Additionally, there was a great increase with imports into the U.S. from the higher-quality origins, which also influenced the overall balance. While there is research about the demand inelasticity for commodities, we found it interesting that areas with a high percentage of income being used for food would not be more price sensitive. Perhaps, some of the results are based on a delayed-reaction effect from the consumers in these areas. Customer preference is difficult to switch when the commodity is eaten directly by the consumer. This area needs more research.

The U.S. rice market would greatly benefit by reviewing its quality and pulling away from the hybrid varieties, as an overall short-term solution, until the overall value equation can be brought into line. Our data showed that, unless a major change occurs, one could expect a reduction in market share to continue and to spread to other countries. Various political interventions could delay the timing, but the inevitable result is a loss of market share unless a move to higher-quality rice is made. Increased quality from the competition and more market access as trade agreements are initiated make the occurrence of this process much quicker than in prior years; therefore, the need for change may be time based. We recommend industry changes regarding variety approval and rewards for varieties that yield higher while decreasing U.S. competitiveness.

The 2023 Farm Bill should have quality incentives in the subsidies instead of the current process that pays for the quantity grown. The lack of quality-based subsidies caused major quality issues for the wheat industry in the 1980s and is also affecting rice today. The current situation with rice seems to mirror what happened for wheat. At the very least, the effects that subsidies have on growing crops for quantity versus the overall value and market share need to be closely explored. It is important to note that several countries have rejected hybrid rice because the crop's quality has been lower than traditionally breed varieties; this situation is not an unknown issue. The effects of a grower's choice based on policy, especially when the markets are looking lower, are a critical piece that cannot be overlooked. There is clarity that the overall level of market price and subsidy level would change the situation. As prices go down and subsidies go up, you would likely shift the results to a subsidy having more causation; therefore, the results are not static but could also shift over a change in market prices, subsidy level, or structural change.

Similarly, one could also note that the head and total milling quality used for the Farm Service Agency's USDA loan system is not consistent with the high value that mills put on the total amount of head rice versus lower prices for broken kernels. In line with our other recommendations, we suggest a change here because there is a system imbalance that incorrectly rewards suboptimal behavior. The larger the disconnect between policy and the market is, the more inefficient the market mechanisms are. While quantity is very important, one must also look at the consumer and the value for which the customer is willing to pay. With water becoming a key resource and global competition coming into play, farming for value versus farming for quantity is a necessary market transition.

Therefore, we suggest that, with the coming subsidy programs, the industry would be better served by having quality incentives for payments rather than payments which are only linked to quantity. The loss of market share is both an effect of incorrect market signals with no discount for the lower-quality hybrid rice and having a subsidy which largely pays based on the quantity that is grown in the field; like the analogy of two engines on a plane, both the market and the subsidy will affect decisions to varying degrees. For the full effect on the market share, you need to have both the subsidy and the market signal so that there are equitable penalties for a lack of quality. As a result, the U.S. rice industry must choose to engage in this issue because subsidy modifications alone may not cause effective change. If one looks at the effects of the lack of action in the wheat market during the 1980s, urgency of change is also very critical. An adjustment to the correct market signals will not cause immediate change for the market share. Our data show a 7-year lag as a possible ideal reality, which would indicate that today's positive or negative have many years before they are fully observed. The market needs to get healthy, then stabilize, and then regain the lost market share, which will not immediately happen. There needs to be a mechanism that observes the cost of segregation because a change in variety cannot help influencing quality change if that rice is merely comingled with the other rice varieties. The issue is complicated because comingling occurs at the grower, truck, warehouse, barge, rail, rice mill, container, break bulk, and destination locations as well as other times where rice come together.

Related to our study, it is interesting to note that products in the food chain which are closer to the actual consumer appear to have varieties that are more similar to what the customer would like. This observation may be worthy of future study. The Calrose rice market is an example of this phenomenon because the varieties in California operate more like models that restrict production unless it meets the market specification for quality. A comparison study between the southern long-grain industry and the California market should be conducted. There has been a vastly different direction for warehouse management, variety development, marketing structure, and industry promotion. The unique nature of California's "pool" marketing system would also be of interest. The contrasting effects of WTO agreements on the long-grain market versus the Calrose market could be examined. It is also very important to realize that commodity subsidies reduce the overall cost of food; therefore, the consumers have great gains in ways that are not seen on a surface level.

Applying game theory to the growers and millers' choice would be of interest and could lead to some interesting results about what causes decision making on an individual basis. How the overseas players signal their needs on the market and how this indication is perceived by market players is also worthy of discussion. There is a complex situation where most governments want cheap food while companies desire to maximize profits. The consumer plays a factor in between because he/she wants to choose quality but is often price sensitive. These points deserve additional study and explanation.

The study would be better with more years of data; with yearly data, you can only go back a few decades if you desire a truly relevant examination. The development of plant varieties is on a 3- to 5-year time window, which implies limited data for a particular variety.

Finally, we review the study's objectives and summarize the findings. The first objective was to show trends for the U.S. rice subsidy and U.S. rice market shares. We did this step on many levels by describing the U.S. markets and showing the drop for the market share of U.S. hybrid rice. Chapter 2 provided a summary of the U.S. and global rice industries, which is an important piece to achieve a better understanding about this less-transparent market. There remains a key element of increased price, quality, and quantity competition from global players, which likely increases as more trade agreements are created. The correlation coefficient of over -.80 between the hybrid grown and Mexico's market share was an early indication about potential factors causing the market-share decline.

The second objective was to develop a risk-balancing, hypothetical model to evaluate the theoretical influences that a subsidy has on market-share performance; the model had an emphasis on quality improvements. Our model illustrated that a grower will use subsidy revenues to reduce financial risk, which affects planting decisions because he/she may decide to grow crops that increase yield rather than yield and quality. Subsidies that target quality improvements will enhance trade or overall market performance.

The third objective was to use Granger Causality analysis to determine the relationship among a subsidy, hybrid-rice production, and U.S. rice's market share. With statistical significance for the p value lower than the required .05, it was firmly concluded that the loss of market share for U.S. rice was most predominately directed by the amount of hybrid rice grown. This conclusion is the study's key finding, with current and future implications for the rice industry and, perhaps, for other major food commodities.

The fourth objective was to evaluate policy implications for the current and potential subsidy designs. We illustrated that future discussion about subsidies should have quality-based incentives which look at the overall industry's competitiveness, rather than merely focusing on farm-income improvements. This issue could be addressed in the 2023 Farm Bill.

This study considered many key points of interest for the U.S. hybrid rice industry, including how the variety's quality can greatly affect the overall market in the short and long run. The subsidy's effects on the grower's decision about risk remain a key issue. The results and analysis from our model clearly highlight that more hybrid rice led to less market share for U.S. rice in Mexico. The trend of lost market share will likely continue without a directional change. In the long run, the industry would benefit from quality-based incentives in the market and when subsidies are developed in the farm bill.

REFERENCES

Allaoui, H., Guo, Y., Choudhary, A., & Bloemhof, J. (2018). "Sustainable Agro-Food Supply Chain Design Using Two-Stage Hybrid Multi-Objective Decision-Making Approach." *Computers & Operations Research*, 89, 369-384.

Balié, J., Del Prete, D., Magrini, E., Montalbano, P., & Nenci, S. (2019). "Does Trade Policy Impact Food and Agriculture Global Value Chain Participation of Sub-Saharan African Countries?" *American Journal of Agricultural Economics*, 101(3), 773-789.

Barry, P.J., Bierlen, R.W., & Sotomayor, N.L. (2000). "Financial Structure of Farm Businesses Under Imperfect Capital Markets." *American Journal of Agricultural Economics,* 82(4), 920-933.

Briggeman, B.C., Towe, C.A., & Morehart, M.J. (2009). "Credit Constraints: Their Existence, Determinants, and Implications for US Farm and Nonfarm Sole Proprietorships." *American Journal of Agricultural Economics*, 91(1), 275-289.

Boehm, D. (2021). Technical Manager for Northern Crops Institute, Fargo, ND, interview.

Bullock, D.W. & Wilson, W.W. (2019). "Factors Influencing the Gulf and Pacific Northwest (PNW) Soybean Export Basis: An Exploratory Statistical Analysis." *NDSU Agribusiness and Applied Economics Report No. 788*, Fargo, ND.

Cai, J., Janvry, A.D., & Sadoulet, E. (2020). "Subsidy Policies and Insurance Demand." *American Economic Review*, 110(8), 2422-2253.

Cole, S., Giné, X., & Vickery, J. (2017). "How Does Risk Management Influence Production Decisions? Evidence from a Field Experiment." *The Review of Financial Studies*, 30(6), 1935-1970.

Collins, R.A. (1985). "Expected Utility, Debt-Equity Structure, and Risk Balancing." *American Journal of Agricultural Economics*, 67(3), 627-629.

Cottrell, A. and R. Lucchetti. 2021. *GNU Regression, Econometric and Time-series Library (GRETL)*. Retrieved from http://gretl.sourceforge.net/

Environmental Working Group. (n.d.). "Rice Subsidies: The United States." *Farm Subsidy Database*. Retrieved October 17, 2021, from https://farm.ewg.org/progdetail.php?fips=00000&progcode=rice

Escalante, C.L. & Barry, P.J. (2003). "Determinants of the Strength of Strategic Adjustments in Farm Capital Structure." *Journal of Agricultural and Applied Economics*, 35(1), 67-78.

Escalante, C.L., Turvey, C.G., & Barry, P.J. (2009). "Farm Business Decisions and the Sustainable Growth Challenge Paradigm." *Agricultural Finance Review*, 69(2), 228-247.

Farm Service Agency. (2021, January 12). "2020 Acreage Data as of January 5, 2021 (ZIP, 21 MB, January 12, 2021)." *U.S. Department of Agriculture*. Retrieved October 17, 2021, from https://www.fsa.usda.gov/news-room/efoia/electronic-reading-room/frequently-requested-information/crop-acreage-data/index

Featherstone, A.M., Moss, C.B., Baker, T.G., & Preckel, P.V. (1988). "The Theoretical Effects of Farm Policies on Optimal Leverage and the Probability of Equity Losses." *American Journal of Agricultural Economics*, 70(3), 572-579.

Foreign Agricultural Service. (2021a, October 12). "Grain: World Markets and Trade." *U.S. Department of Agriculture*. Retrieved October 17, 2021, from https://www.fas.usda.gov/data/grain-world-markets-and-trade

Foreign Agriculture Service. (2021b, October 21). "U.S. Export Sales." *U.S. Department of Agriculture*. Retrieved October 21, 2021, from https://apps.fas.usda.gov/export-sales/esrd1.html

Gabriel, S.C. & Baker, C.B. (1980). "Concepts of Business and Financial Risk." *American Journal of Agricultural Economics*, 62(3), 560-564.

Glauber, J.W. (2013). "The Growth of the Federal Crop Insurance Program, 1990-2011." *American Journal of Agricultural Economics*, 95(2), 482-488.

Granger, C.W.J. (1969). "Investigating Casual Relations by Econometric Models and Cross-Spectral Methods." *Econometrica: Journal of the Econometric Society*, 37(3), 424-438.

Ifft, J., Kuethe, T., & Morehart, M. (2015). *Does Federal Crop Insurance Lead to Higher Farm Debt Use? Evidence from the Agricultural Resource Management Survey*. The Charles H. Dyson School of Applied Economics and Management, Cornell University, Ithaca, NY.

Just, R.E., Calvin, L., & Quiggin, J. (1999). "Adverse Selection in Crop Insurance: Actuarial and Asymmetric Information Incentives." *American Journal of Agricultural Economics*, 81, 834-849.

Katchova, A. (2010). "Agricultural Contracts and Alternative Marketing Options: A Matching Analysis." *Journal of Agricultural and Applied Economics*, 42, 261-276.

Knight, F.H. (1921). *Risk, Uncertainty and Profit*. Boston, MA: Houghton Mifflin.

Kropp, J.D. & Whitaker, J.B. (2011). "The Impact of Decoupled Payments on the Cost of Operating Capital." *Agricultural Finance Review*, 71(1), 25-40.

Laws, F. (2015, April 3). "Rice Subsidy Program Cost Thailand $27Billion." *Farm Progress*. Retrieved October 17, 2021, from https://www.farmprogress.com/rice/rice-subsidy-program-cost-thailand-27-billion

McClung, A.M., Chen, M.-H., Jodari, F., Famoso, A., Addison, C., Linscombe, C., Ottis, B., Moldenhauer, K, Walker, T., Wilson, L., & McKenzie, K. (2019). “Use of Objective Imaging Systems to Assess Subjective Grain Appearance Traits Important to the US Rice Industry.” *Cereal & Grains Chemistry Association*.

Mishra, A.K., Harris, J.M., Erickson, K.W., Hallahan, C., & Detre, J.D. (2012). “Drivers of Agricultural Profitability in the USA: An Application of the Du Pont Expansion Method.” *Agricultural Finance Review*, 72(3), 325-340.

National Agricultural Statistics Service. (2021, March 31). “Prospective Plantings.” *U.S. Department of Agriculture, Agricultural Statistics Board*. Retrieved October 17, 2021, from https://downloads.usda.library.cornell.edu/usda-esmis/files/x633f100h/w6634x823/x633fv29f/pspl0321.pdf

Nganje, W., Hearne, R., Gustafson, C., & Orth, M. (2015). “Farmers’ Preferences for Alternative Crop and Health Insurance Subsidy.” *Review of Agricultural Economics*, 30(2), 333-351.

Outlaw, J.L., Richardson, J.W., & Maisashvili, A. (2016). *Impacts of Brazilian, Chinese, Indian, Thai, Turkish and Vietnamese Rice Support Policies on the Price and Exports of Rice for the U.S. and Selected Countries*. Agricultural and Food Policy Center, Texas Extension Education Foundation, Inc., Texas A&M University, College Station, TX.

Patrick, G.F. (1992, May). “Managing Risk in Agriculture.” *North Central Region Extension Publication No. 406*, City, ST.

Rice Technical Working Group Proceedings. (2020). *U.S. Rice Committee*. Retrieved from https://ucanr.edu/sites/2018RTWG/About_RTWG/

Sherrick, B.J., Barry, P.J., Ellinger, P.N., & Schnitkey, G.D. (2004). “Factors Influencing Farmers’ Crop Insurance Decisions.” *American Journal of Agricultural Economics*, 86(1), 103-114.

Skadberg, K., Wilson, W.W., Larsen, R., & Dahl, B. (2015). “Spatial Competition, Arbitrage, and Risk in U.S. Soybeans.” *Journal of Agricultural and Resource Economics*, 40(3), 442-456.

Statacorp. 2021. *Stata: Statistics/Data Analysis* (Special Edition). College Station, TX: Statacorp, LLC. Available at https://www.stata.com

The Rice Trader (2021, October 25). *The Rice Trader Weekly Report,* 22(39). [Subscribers can access the weekly newsletter at https://thericetrader.com]

Turvey, C.G. & Baker, T.G. (1990). “A Farm-Level Financial Analysis of Farmers’ Use of Futures and Options Under Alternative Farm Programs.” *American Journal of Agricultural Economics*, 72(4), 946-957.

Turvey, C.G. & Baker, T.G. (1989). "Optimal Hedging Under Alternative Capital Structures and Risk Aversion." *Canadian Journal of Agricultural Economics/Revue Canadienne d'agroeconomie,* 37, 135-143.

USA Rice. (2019, February 28). "WTO: China is Guilty of Subsidy Violations on Rice, Corn, and Wheat." *USA Rice*. Retrieved October 17, 2021, from https://www.usarice.com/news-and-events/publications/usa-rice-daily/article/usa-rice-daily/2019/02/28/wto-china-is-guilty-of-subsidy-violations-on-rice-corn-and-wheat

Xouridas, S. (2015). "Agricultural Financial Risks Resulting from Extreme Events." *Journal of Agricultural Economics*, 66, 192-220.

Xu, J.F. & Pu, L.I.A.O. (2014). "Crop Insurance, Premium Subsidy and Agricultural Output." *Journal of Integrative Agriculture*, 13(11), 2537-2545.

Wilson, W.W. & Dahl, B.L. (2008). "Procurement Strategies to Improve Quality Consistency in Wheat Shipments." *Journal of Agricultural and Resource Economics*, 33, 69-86.

Wilson, W.W., Dahl, B.L., & Johnson, D.D. (2007). "Quality Uncertainty and Challenges to Wheat Procurement." *Canadian Journal of Agriculture Economics*, 55(3), 315-326.

World Agricultural Outlook Board. (2021, October). "The World Agricultural Supply and Demand Estimates." *U.S. Department of Agriculture*. Retrieved October 17, 2021, from https://www.usda.gov/oce/commodity/wasde

APPENDIX. TABLES AND FIGURES

Table A1. U.S. Rice: 2020 Planted Acres, by State and by Class (Farm Service Agency, 2021)

State	Medium Grain	Long Grain	Short Grain	Total	5-Year Average
Arkansas	122,328.08	1,312,956.83	176.80	1,435,461.71	1,288,435.10
California	459,461.74	11,194.34	30,076.82	500,732.90	466,484.08
Louisiana	48,963.42	424,115.96	0.00	473,079.38	415,611.49
Mississippi	515.41	164,098.63	0.00	164,614.04	139,590.82
Missouri	3,386.45	207,038.66	0.00	210,425.11	190,973.93
Texas	3,205.92	177,417.70	0.00	180,623.62	164,974.99
Total	638,496.02	2,300,627.85	30,373.83	2,969,497.70	2,670,472.37
5-Year Average	660,060.93	1,983,399.26	27,012.18		
Source: USDA FSA					
Change to 2019	**-8.97%**	**32.73%**	**20.92%**	**20.72%**	
Change to 2018	**-7.05%**	**5.69%**	**9.14%**	**2.70%**	
Change to 2017	**10.66%**	**31.59%**	**17.39%**	**26.29%**	

Table A2. U.S. Rice: 2021 Planted Acres, by State and by Class (National Agricultural Statistics Service, 2021)

State	Medium Grain	Long Grain	Short Grain	Total	5-Year Average
Arkansas	120,000.00	1,130.00	176.80	1,251,000.00	1,285,090.09
California	425,000.00	8,000.00	29,098.28	471,000.00	451,152.54
Louisiana	35.00	410,000.00	-	445,000.00	415,176.15
Mississippi	-	120,000.00	-	120,000.00	139,283.74
Missouri	8,000.00	225,000.00	-	233,000.00	190,378.26
Texas	5,000.00	185,000.00	-	190,000.00	165,386.40
Total	593,000.00	2,300,574.56	29,395.29	2,965,652.52	2,646,467.17
5-Year Average					
Source: USDA FSA					
Change to 2019	**-11.23%**	**-3.62%**	**-15.22%**	**-5.57%**	
Change to 2018	**-16.24%**	**21.12%**	**14.71%**	**9.63%**	
Change to 2017	**-14.43%**	**-4.72%**	**-4.88%**	**-7.03%**	

Table A3. U.S. Long-Grain Rice S&D, USDA WASDE: 2014 to 2021 (The Rice Trader, 2021)

U.S.: RICE SUPPLY & USE -- LONG GRAIN (Rough Equivalent million cwt)										
							2020/21 Est.		2021/22 Proj.	
	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	SEP	OCT	SEP	OCT
Area Harvested (mil. ac.)	2.20	1.85	2.40	1.75	2.18	1.73	2.30	2.30	N/A	N/A
Yield (pounds/acre)	7,407	7,219	6,927	7,314	7,517	7,261	7,422	7,422	N/A	N/A
Production (mil. cwt)	133.4	133.4	166.5	127.9	163.6	125.6	170.9	170.9	144.2	**144.3**
Beginning Stocks	16.2	26.5	22.7	31.0	20.3	32.6	16.9	16.9	29.7	29.7
Imports	21.1	20.8	20.2	23.3	23.4	29.8	27.4	27.4	30.0	**28.0**
Total Supply	200.6	180.7	209.4	182.2	207.3	188.0	215.1	215.1	203.9	**202.0**
Exports	68.0	75.9	76.6	63.2	65.7	64.6	65.1	65.1	65.0	65.0
Domestic Use	106.2	82.1	101.8	98.6	109.0	106.4	120.3	120.3	115.0	**114.0**
Ending Stocks	26.5	22.7	31.0	20.3	32.6	16.9	29.7	29.7	23.9	**23.0**

Table A4. U.S. Medium- & Short-Grain Rice, USDA WASDE: 2016-2021 (The Rice Trader, 2021)

U.S.: RICE SUPPLY & USE -- MEDIUM GRAIN (Rough Equivalent million cwt)										
							2021/21 Est.		2021/22 Proj.	
	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	SEP	OCT	SEP	OCT
Area Harvested (mil. ac.)	0.70	0.74	0.74	0.69	0.63	0.74	0.69	0.69	N/A	N/A
Yield (pounds/acre)	8,270	8,080	8,107	8,311	8,048		8,282	8,282	N/A	N/A
Production (mil. cwt)	58.1	59.6	59.7	57.7	50.4	59.1	56.7	56.7	47.3	47.3
Beginning Stocks	12.2	13.3	20.2	20.9	11.5	10.2	10.7	10.7	11.5	**11.5**
Imports	3.5	3.9	2.3	2.5	6.3	8.5	6.7	6.7	8	**8.0**
Total Supply	73.8	76.1	82.2	81.1	68.2	77.8	74.2	74.2	65.7	**65.7**
Exports	31.4	27.7	31.0	38.2	23.8	29.6	28.8	28.8	26	26.0
Domestic Use	29.1	28.3	30.3	31.4	36.7	37.6	32.4	32.4	32.0	**32.0**
Ending Stocks	13.3	20.2	20.9	11.5	7.6	10.7	11.5	11.5	7.7	**7.7**

Table A5. Global Rice Export Prices, by Country and Quality (The Rice Trader, 2021)

WORLD WEEKLY PRICE TABLE SUMMARY

	100% B	5%		15%	25%	A 1 S	F A 1 S	P 100% S	Hom Mali 92%
Thailand	**$395**	**$385**		**$379**	**$375**	**$353**	**$425**	**$390**	**$675**
Change	$3	$2		$2	$2	-$2	$0	$2	$13
		5% d.p.	10%	15%	25%	Brokens	Jas 5%	Glut 10%	Japonica 5%
Vietnam		**$435**	**$430**	**$425**	**$400**	**$330**	**$580**	**$480**	**$520**
		$5	$5	$5	$0	$0	$5	$10	$0
		5% d.p.	10%	15%	25%	Brokens	Parboiled		
Pakistan		**$355**	**$345**	**$335**	**$330**	**$310**	**$390**		
		-$15	-$15	-$20	-$20	-$5	-$15		
		5%		15%	25%	Brokens	P 5%	P Basmati 2%	P Basmati PB 2%
India		**$360**		**$350**	**$340**	**$285**	**$360**	**$910**	**$860**
		$0		$0	$0	$0	$0	-$20	-$20
								1121 Basm 2%	1121 Basm PB 2%
								$970	**$940**
								-$10	-$10
		5%		15%	25%	A 1 S Brokens			
Cambodia		**$510**		**NA**	**NA**	**NA**			
		-$5		NA	NA	NA			
		5%		15%	25%	B1/2 Sortex			
Myanmar		**$340**		**$330**	**$305**	**$285**			
		-$10		-$10	-$7	-$10			
		#2/4% LG		#3/15% LG	#5/20% LG	#2/4% MG	#1/4% MG bulk ex-spout		
U.S.		**$600**		**$585**	**$540**	**$585**	**$1,125**		
		$0	$0	$0	$10	$0	$25		
		5%	10%						
Uruguay		**$580**	**$570**						
		$0	$0						
		5%	10%						
Argentina		**$610**	**$600**						
		$0	$0						
		5%					PB 5%		
Brazil		**$510**					**$520**		
		$0					$0		
OTHER…									

FOB prices closed today as follows for Oct/Nov Shipment (in 50 kg pp bags)

Table A6. Louisiana Rice Acreage, by Variety, 2020 Variety Survey (Rice Technical Working Group Proceedings, 2020)

Total Acreage	**475,927**	**255,306**	**807**	**46, 124**	**11,532**	**83,124**	**7,252**	**500**	**1,435**	**628**	**55,426**	**24,914**	**7,454**	**16,110**
Percent (of Clearfield)		**100.00**	**0.32**	**18.07**	**4.52**	**32.56**	**2.84**	**0.20**	**0.56**	**0.25**	**21.71**	**9.76**	**2.92**	**6.31**
Percent) of all acres)		**53.64**	**0.17**	**9.69**	**2.42**	**17.47**	**1.52**	**0.11**	**0.30**	**0.13**	**11.65**	**5.23**	**1.57**	**3.38**

Total Acreage			**151,402**								**103,904**			
Percent (of Clearfield)			**59.30**								**40.70**			
Percent (of all acres)			**31.81**								**21.83**			

Table A7. U.S. Rice Export by Country and Region: 2016 to 2021 (The Rice Trader, 2021)

U.S.: EXPORTS TO MAJOR DESTINATIONS (M.R.E., TMT)										
COUNTRY	**2016**	**2017**	**2018**	**2019**	**2020**	**2020 SEP**	**2021 SEP**	**2020 JAN-SEP***	**2021 JAN-SEP***	**% CHG**
Americas	2,257	2,139	2,102	1,942	1,841	64	130	1,104	1,426	29%
Of which:										
Brazil	0	0	1	0	84	0	0	0.12	0.22	77%
Canada	204	204	225	235	230	19	19	172	158	-8%
C. America	606	406	487	435	325	0	0	193	281	46%
Cuba	0	0	0	0	0	0	0	0	0	-1%
Haiti +	419	509	412	452	461	32	15	289	273	-5%
Mexico +	644	674	739	621	459	10	62	290	488	68%
South America	340	281	196	154	287	1	20	110	287	161%
Columbia	123	100	149	112	135	0	0	101	134.92	34%
Venezuela	207	170	42	38	65	0	19	7	65	785%
E.U. + 1/	55	58	2	37	65	3	2	31	45.21	48%
F.S.U. 2/	1.43	3.00	1.68	2.52	2.77	0.12	0.20	1.95	2.60	33%
Middle East	437	391	357	406	281	19	54	210	192	-9%
Of which:										
Iraq +	93	33	157	154	0	0	43	0	43	NA
Jordan	102	147	82	93	89	4	5	64	50	-23%
Saudi Arabia	123	125	96	117	116	11	5	84	64	-24%
Turkey +	70	51	1	3	20	0	0	19.27	0.64	-97%
Africa	177	232	163	141	95	26	3	77	145	89%
Of which:										
Ghana	16	17	5	5	3	0	1	1.35	6.74	399%
S. Africa	1	1	0	0	0	0	0	0.26	0.36	37%
Asia	602	551	479	596	611	21	17	491	453	-8%
Of which:										
Japan	347	303	274	338	314	0	12	244	237	-3%
South Korea	150	138	114	147	196	13	1	175	149	-15%
Taiwan +	57	49	47	61	61	4	3	45	43	-4%
TOTAL	**3,534**	**3,376**	**3,160**	**3,126**	**2,866**	**133**	**206**	**1,929**	**2,265**	**17.39%**

1/ E.U.-28
2/ F.S.U. = Former U.S.S.R. Does not include Baltic states beginning 2004.
+ = With *TRT* adjustments.
*2020/2021 U.S. Census Data through Aug: TRT estimate for Sep
SOURCE: U.S. Census through Jul

Table A8. Review of Rice Subsidies: Environmental Working Group (n.d.)

Program	Total Payments 1995-2020*
Direct Payment-Rice	$4,534,298,901
Production Flexibility-Rice	$2,953,294,339
Price Loss Coverage-Rice	$2,236,332,547
Market Loss Assistance-Rice	$1,562,421,735
Loan Deficiency-Rice	$1,399,643,149
Commodity Certificates-Rice	$945,135,871
Market Gains-Rice	$879,343,835
Deficiency-Rice	$662,753,329
Counter Cyclical Payment-Rice	$596,784,247
Advance Deficiency-Rice	$296,372,225
Agricultural Risk Coverage County-Rice	$20,635,570
ACRE Direct Payments-Rice	$11,325,106
Load Deficiency-Special Rice	$5,286,262
Agricultural Risk Coverage Individual-Rice	$1,262,559
Direct Payment Violation-Rice	$-505
Rice Marketing Expense Payments	$-3,802
Loan Def. Refund-Rice	$-7,012
Denied Market Gain-Rice	$-131,585
Prod. Flex. Refund-Rice	$-418,066
Loan Def. Refund-Rice	$-715,559
Loan Def. Refund-Rice	$-3,134,026
*Data for 2020 includes payments made by USDA through June 30, 2020 and does not include crop insurance premium subsidies.	

Table A9. Stata Lag Tests for Market Share, Subsidy, and Hybrid Percentage

Sample: 2008 thru 2020 Number of obs = 13 * optimal lag								
Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	**-50.5369**				**0.758604**	**8.23644**	**8.20965**	**8.36682**
1	**-29.5403**	**41.993**	**9**	**0.000**	**0.127327**	**6.39082**	**6.28363**	**6.91231**
2	**-18.7636**	**21.554**	**9**	**0.010**	**0.133319**	**6.11747**	**5.92989**	**7.03008**
3	**11.6835**	**60.894**	**9**	**0.000**	**.014989***	**2.81793**	**2.54995**	**4.12166**
4	**1229.61**	**2435.8**	**9**	**0.000**	**.**	**-183.171**	**-183.519**	**-181.476**
5	**1248.77**	**38.325**	**9**	**0.000**	**.**	**-186.119**	**-186.467**	**-184.424**
6	**1262.36**	**27.18***	**9**	**0.001**	**.**	**-188.209**	**-188.558**	**-186.514**
7	**1266.88**	**9.038**	**9**	**0.434**	**.**	**-188.905***	**-189.253***	**-187.21***
8	**1264.67**	**-4.4251**	**9**	**.**	**.**	**-188.564**	**-188.913**	**-186.869**

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	**-87.9293**				**2.88107**	**9.5715**	**9.59674**	**9.72062**
1	**-57.78**	**60.298***	**9**	**0.000**	**.316893***	**7.34527***	**7.44622***	**7.94175***
2	**-49.5933**	**16.374**	**9**	**0.059**	**0.377676**	**7.43087**	**7.60753**	**8.47472**

Log likelihood	=	**-62.52532**	AIC	=	**7.452532**
FPE	=	**0.3517959**	HQIC	=	**7.569158**
Det(Sigma_ml)	=	**0.1042358**	SBIC	=	**8.049971**

Equation	Parms	RMSE	R-sq	F	P > F
Subsidy_Adjusted	**4**	**158.086**	**0.2682**	**1.954661**	**0.1615**
Perc_Hyb	**4**	**0.054201**	**0.9431**	**88.47987**	**0.0000**
MexicoMarketsh~e	**4**	**0.058031**	**0.7444**	**15.5319**	**0.0001**

Table A10. Stata Vector Auto Regression for Market Share, Subsidy, and Hybrid Percentage

	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
Subsidy_Adjusted						
Subsidy_Adjusted L1.	**0.2631847**	**0.2462167**	**1.07**	**0.301**	**-.2587714**	**0.7851408**
Perc_Hyb L1.	**328.6544**	**285.5643**	**1.15**	**0.267**	**-276.7149**	**934.0237**
MexicoMarketshare L1.	**64.87575**	**679.6532**	**0.10**	**0.925**	**-1375.925**	**1505.676**
_cons	**146.0692**	**723.1329**	**0.20**	**0.842**	**-1386.904**	**1679.043**
Perc_Hyb						
Subsidy_Adjusted L1.	**0.0000221**	**0.0000844**	**0.26**	**0.797**	**-.0001569**	**0.000201**
Perc_Hyb L1.	**0.9716826**	**0.0979078**	**9.92**	**0.000**	**0.7641275**	**1.179238**
MexicoMarketshare L1.	**-.1225843**	**0.2330239**	**-0.53**	**0.606**	**-.6165729**	**0.3714044**
_cons	**0.1471675**	**0.2479313**	**0.59**	**0.561**	**-.3784233**	**0.6727584**
MexicoMarketshare						
Subsidy_Adjusted L1.	**-.0001089**	**0.0000904**	**-1.20**	**0.246**	**-.0003005**	**0.0000827**
Perc_Hyb L1.	**-.2693624**	**0.1048268**	**-2.57**	**0.021**	**-.4915853**	**-.0471395**
MexicoMarketshare L1.	**0.3649824**	**0.2494915**	**1.46**	**0.163**	**-.163916**	**0.8938809**
_cons	**0.6846768**	**0.2654524**	**2.58**	**0.020**	**0.1219429**	**1.247411**

Table A11. Stata: Granger Causality Wald Tests

Equation	Excluded	F	df	df_r	Prob > F
Subsidy_Adjusted	Perc_Hyb	**1.3246**	**1**	**16**	**0.2667**
Subsidy_Adjusted	MexicoMarketshare	**0.00911**	**1**	**16**	**0.9251**
Subsidy_Adjusted	ALL	**1.2161**	**2**	**16**	**0.3224**
Perc_Hyb	Subsidy_Adjusted	**0.06827**	**1**	**16**	**0.7972**
Perc_Hyb	MexicoMarketshare	**0.27674**	**1**	**16**	**0.6061**
Perc_Hyb	ALL	**0.24868**	**2**	**16**	**0.7828**
MexicoMarketshare	Subsidy_Adjusted	**1.4505**	**1**	**16**	**0.2460**
MexicoMarketshare	Perc_Hyb	**6.6028**	**1**	**16**	**0.0206**
MexicoMarketshare	ALL	**4.0506**	**2**	**16**	**0.0377**

Table A12. Stata: Lagrange-Multiplier Test

lag	chi2	df	Prob > chi2
1	**5.5823**	**9**	**0.78089**
2	**10.5353**	**9**	**0.30891**

Table A13. Stata: Jarque-Bera Diagnostic Test

Equation	chi2	df	Prob > chi2
Subsidy_Adjusted	**2.091**	**2**	**0.35152**
Perc_Hyb	**0.711**	**2**	**0.70068**
MexicoMarketshare	**2.270**	**2**	**0.32144**
ALL	**5.072**	**6**	**0.53458**

Table A14. The Five Major Global Rice Exporters: Weekly and Yearly Summary, 2018 to 2021 (The Rice Trader, 2021)

WEEKLY EXPORT MOVEMENTS (TMT)												
ORIGIN	PERIOD	PRIOR WEEK	THIS WEEK	% CHG	CUMULATIVE 2018	2019	2020	2021	Yearly CHG	CY 2018 Full Yr	CY 2019 Full Yr	CY 2020 Full Yr
Thai	19-Oct	169	164	**-2.96%**	8,730	6,326	4,616	4,601	**-0.32%**	11,059	7,562	5,669
India	19-Oct	331	325	**-1.81%**	9,540	8,109	10,696	16,457	**53.86%**	11,609	9,811	14,601
Viet	19-Oct	152	156	**2.63%**	5,888	6,182	5,523	4,967	**-10.07%**	6,988	7,327	6,575
Pak	19-Oct	95	94	**-1.05%**	2,351	3,084	3,023	2,948	**-2.48%**	3,258	3,984	4,133
Subtotal		747	739	**-1.07%**	26,509	23,701	23,858	28,973	**21.44%**	33,557	28,915	30,130
U.S.	20-Oct	14	67	**397.78%**	2,385	2,488	2,024	2,345	**15.84%**	3,160	3,113	2,840
Total		**761**	**806**	**6.01%**	**28,894**	**26,189**	**25,882**	**31,318**	**21.00%**	**36,909**	**32,038**	**32,970**

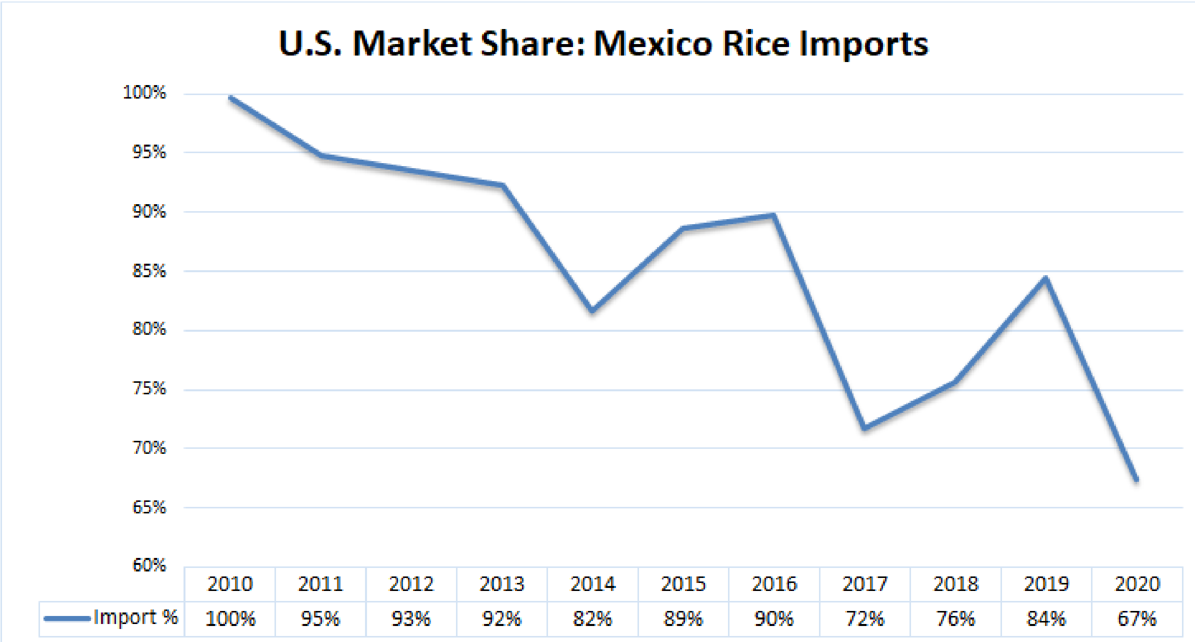


Figure A1. U.S. Export Market Share to Mexico, 2010 -2020 (The Rice Trader, 2021)

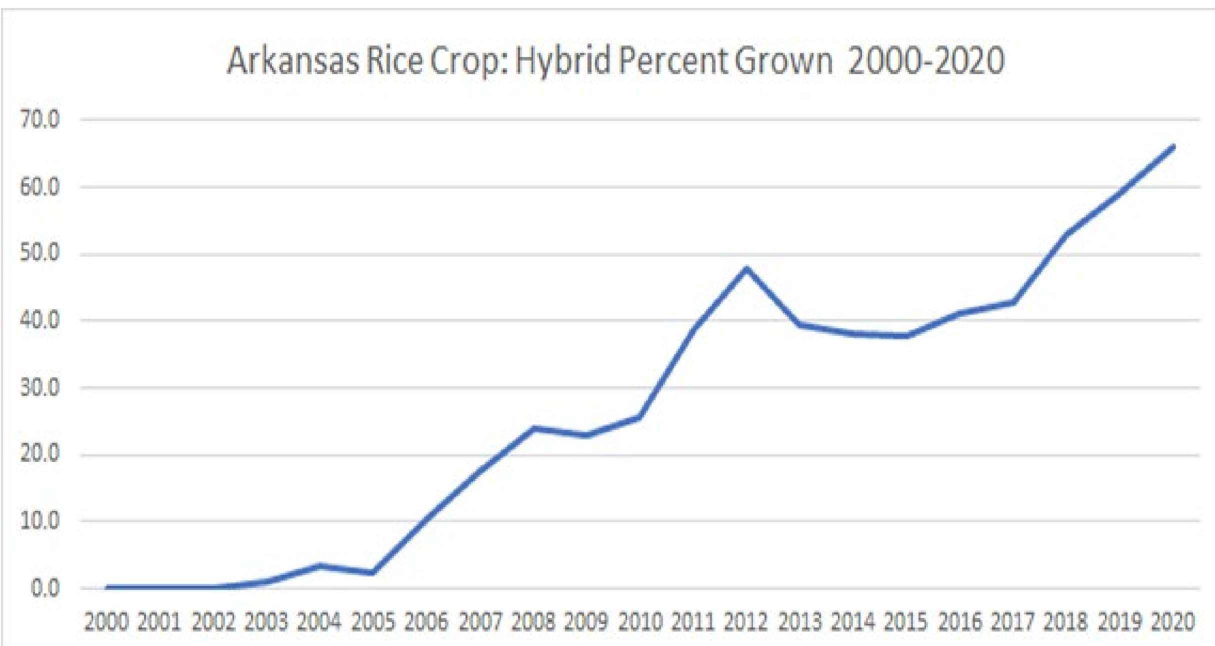


Figure A2. Percentage of Hybrid Rice Production in Arkansas, 2000-2020 (Rice Technical Working Group Proceedings, 2020)

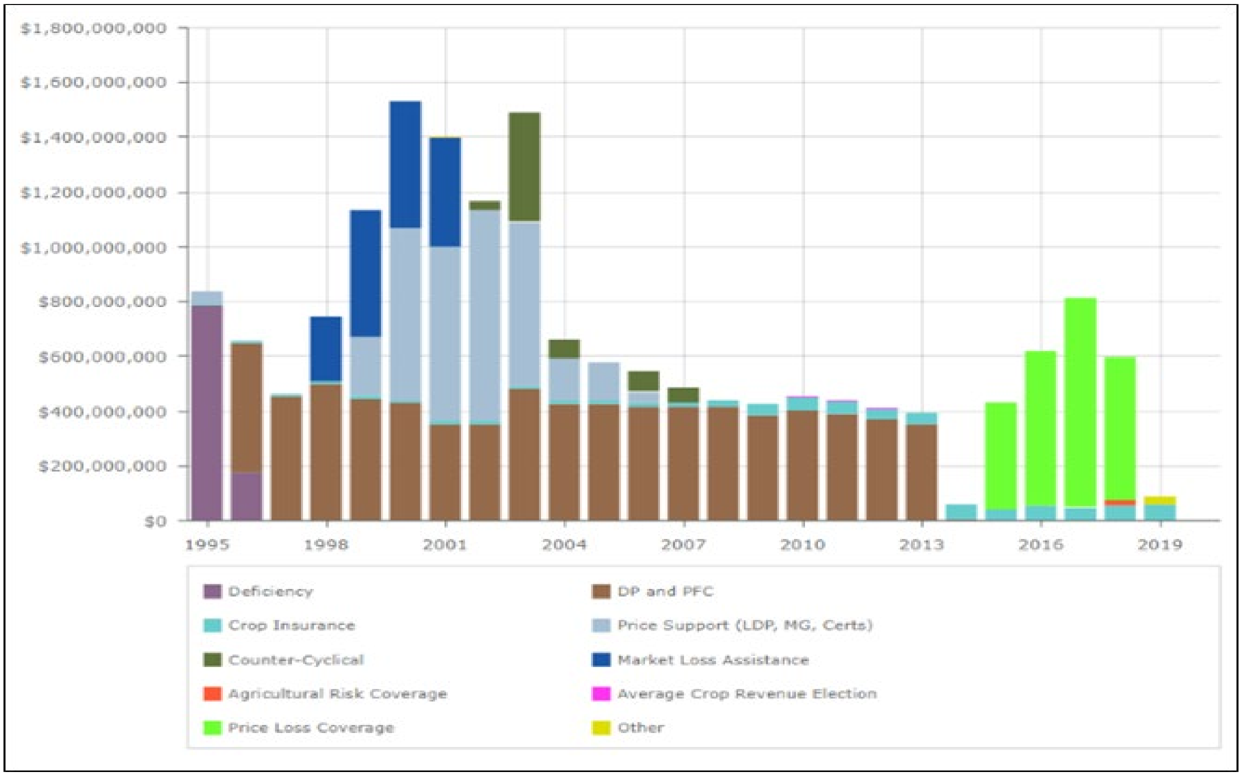
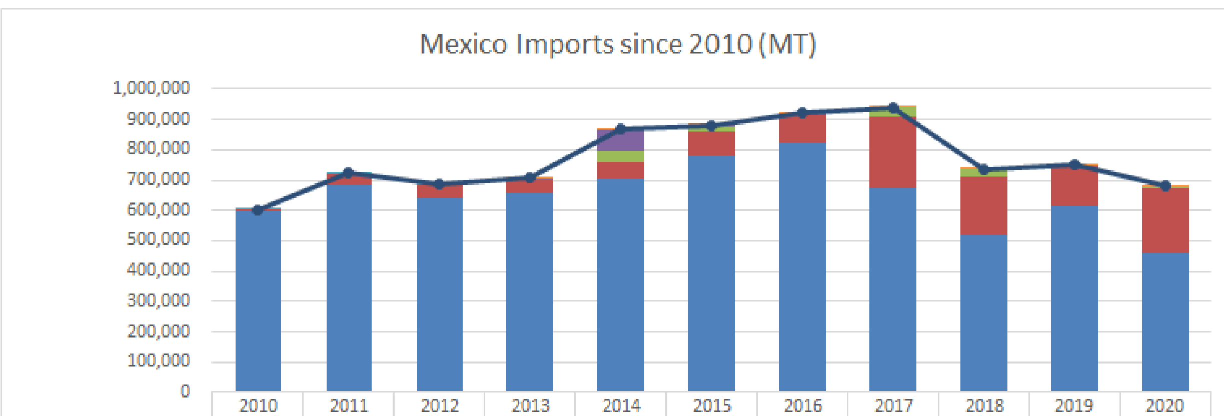


Figure A3. Review of Rice Subsidies: 1995 to 2019 (Environmental Working Group, n.d.)



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
India	0	0	65	5,665	1,598	1,325	336	487	696	1,712	1,696
Pakistan	18	62	1,589	0	0	0	0	0	0	0	0
Vietnam	0	0	0	2,643	66,663	2,237	3,000	0	175	179	720
Thailand	71	83	70	187	40,300	19,071	2,461	28,899	26,382	1,665	4,174
South America	1,569	37,666	43,151	46,728	50,040	76,865	88,533	235,547	189,716	133,486	215,807
U.S.	600,423	683,865	642,374	654,975	707,451	781,574	825,397	674,352	519,212	615,373	458,892
Total Imports	602,181	721,813	687,382	710,374	866,244	881,340	919,963	939,631	736,408	752,415	681,289

Figure A4. Mexico's Rice Imports, by Country, 2010 to 2020 (The Rice Trader, 2021)

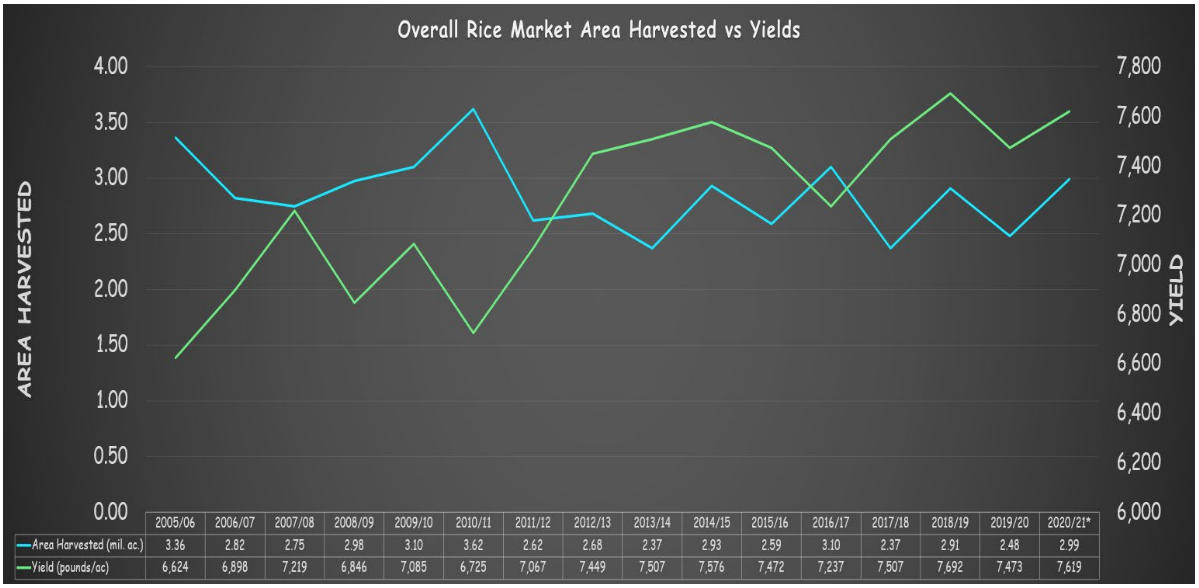


Figure A5. U.S. Rice Harvest and Yield Trends: 2005 to 2021 (The Rice Trader, 2021)

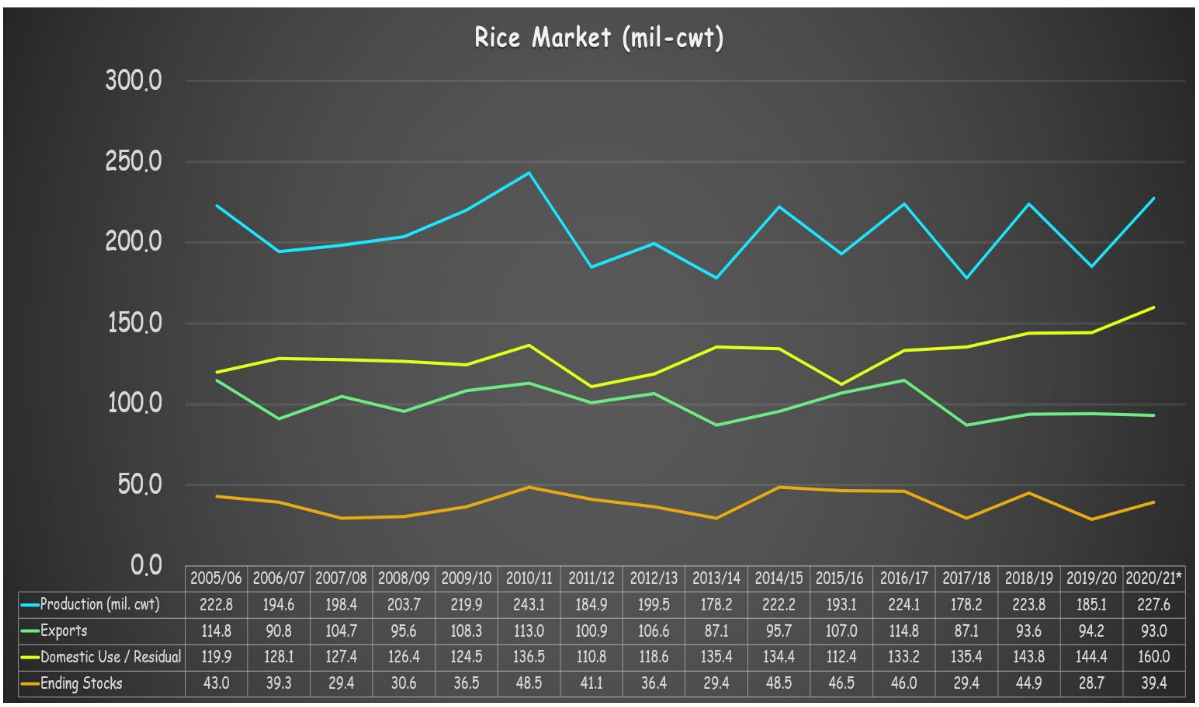
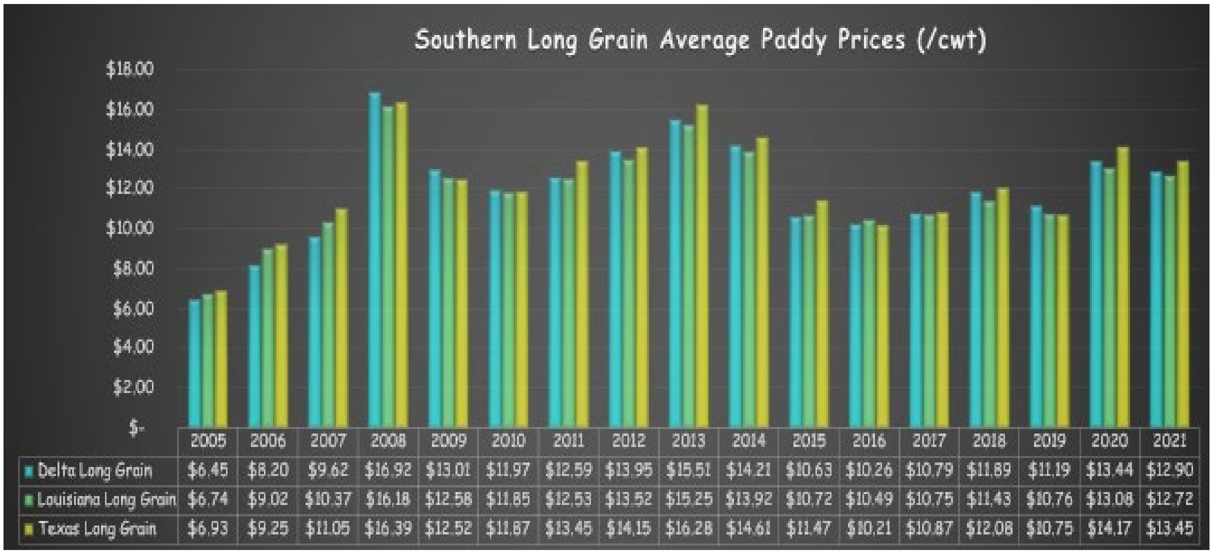


Figure A6. U.S. Rice S&D: 2005 to 2021 (The Rice Trader, 2021)



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Delta Long Grain	$6.45	$8.20	$9.62	$16.92	$13.01	$11.97	$12.59	$13.95	$15.51	$14.21	$10.63	$10.26	$10.79	$11.89	$11.19	$13.44	$12.90
Louisiana Long Grain	$6.74	$9.02	$10.37	$16.18	$12.58	$11.85	$12.53	$13.52	$15.25	$13.92	$10.72	$10.49	$10.75	$11.43	$10.76	$13.08	$12.72
Texas Long Grain	$6.93	$9.25	$11.05	$16.39	$12.52	$11.87	$13.45	$14.15	$16.28	$14.61	$11.47	$10.21	$10.87	$12.08	$10.75	$14.17	$13.45

Figure A7. U.S. Long-Grain Rice Average Paddy Price: 2005 to 2021 (The Rice Trader, 2021)

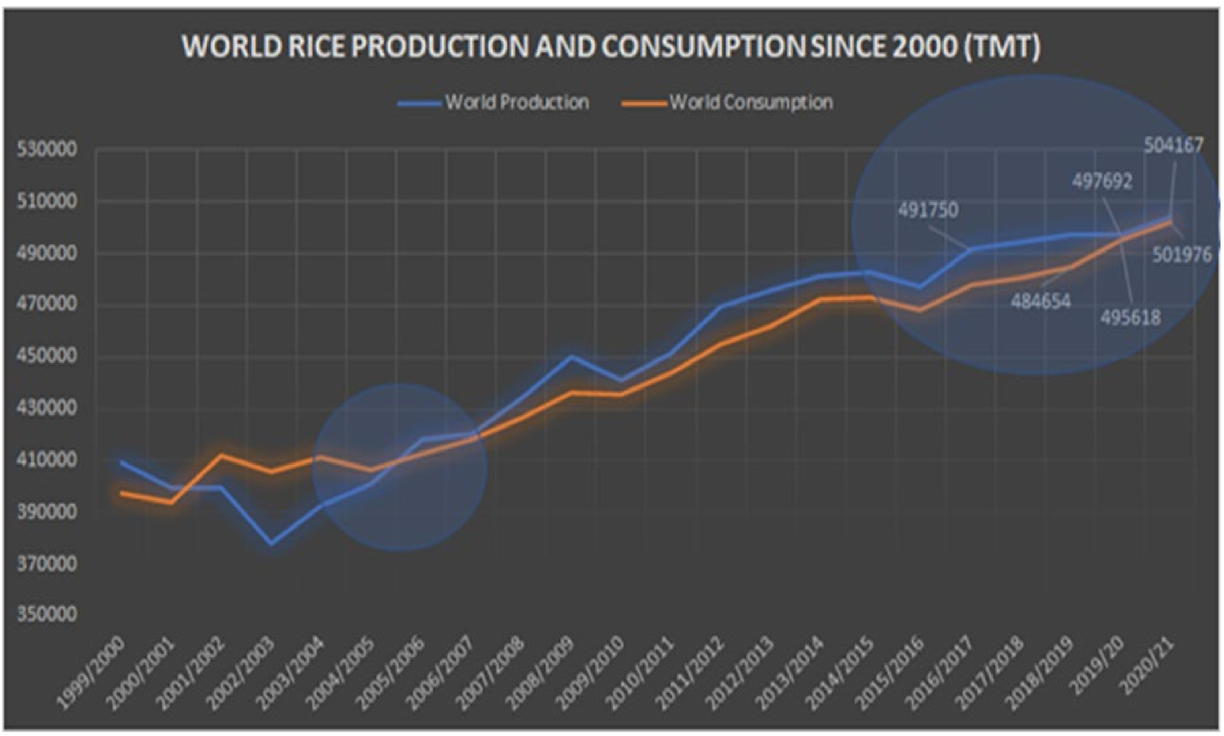


Figure A8. World Rice Production and Consumption: 2000-2021 (The Rice Trader, 2021)

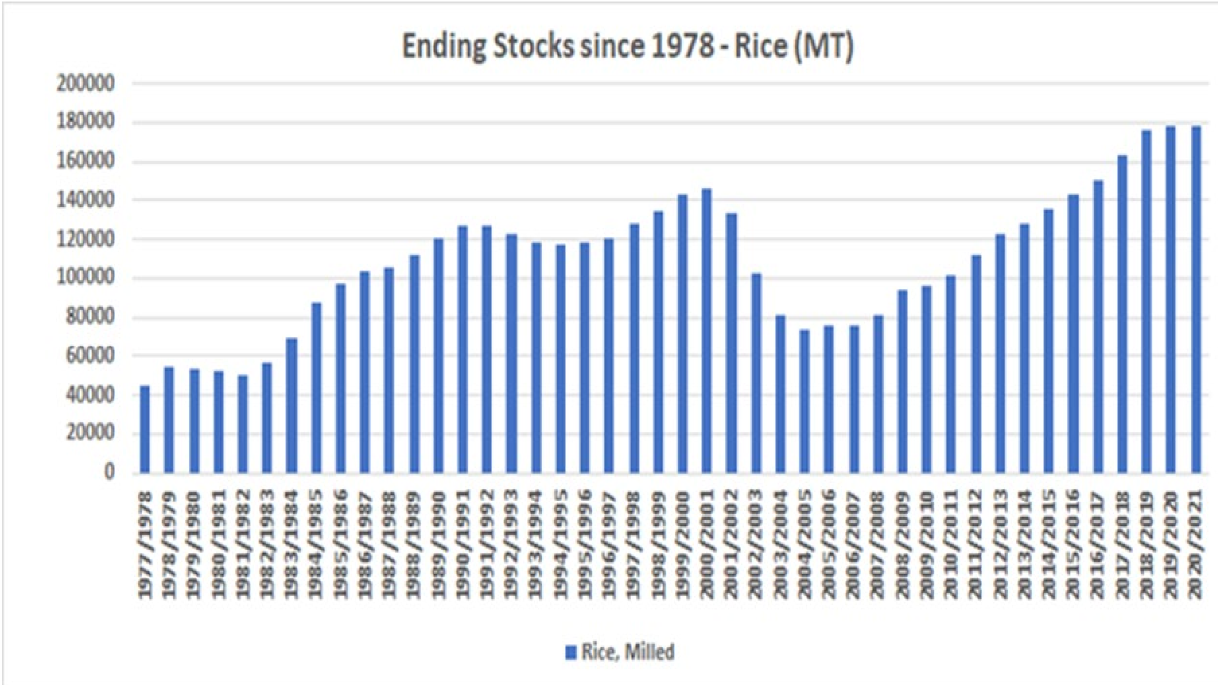


Figure A9. Global Rice Ending Stocks (The Rice Trader, 2021)

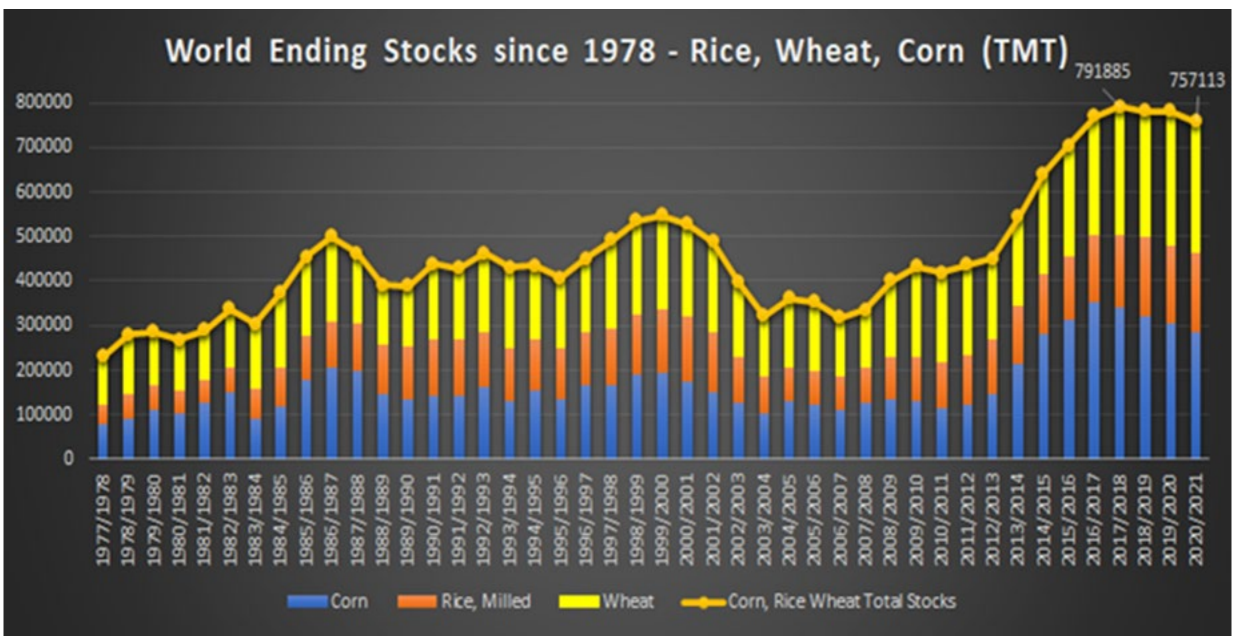


Figure A10. World Ending Stocks: Rice, Wheat, and Corn (The Rice Trader, 2021)

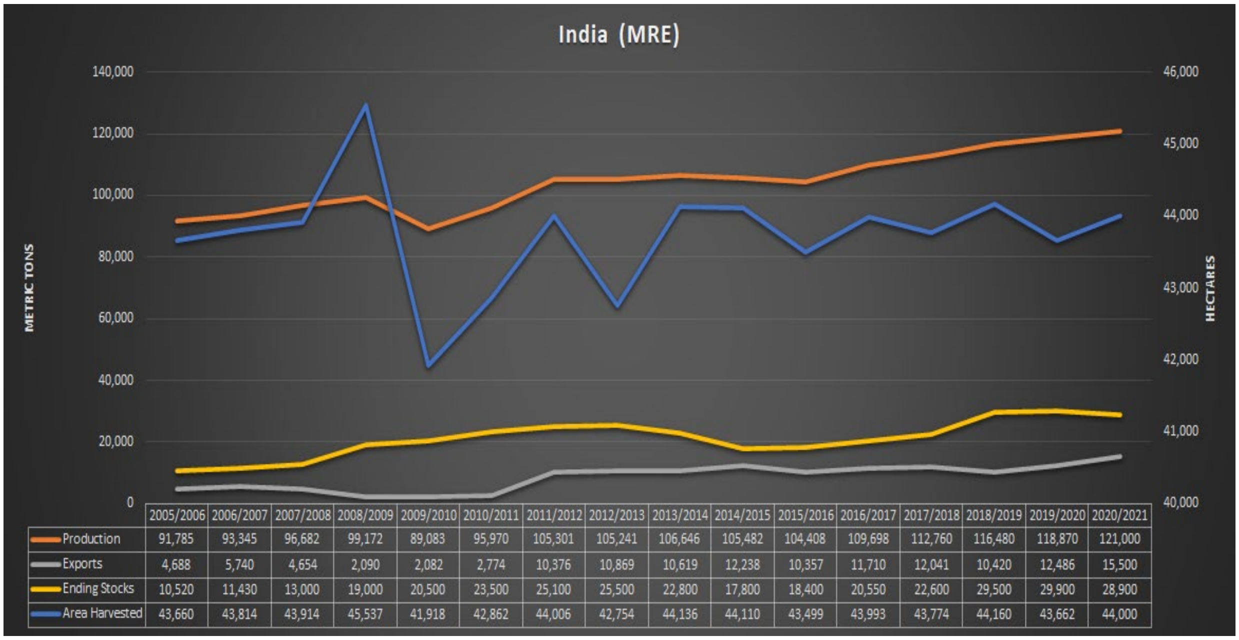


Figure A11. Indian Rice S&D: 2005 to 2021 (The Rice Trader, 2021)

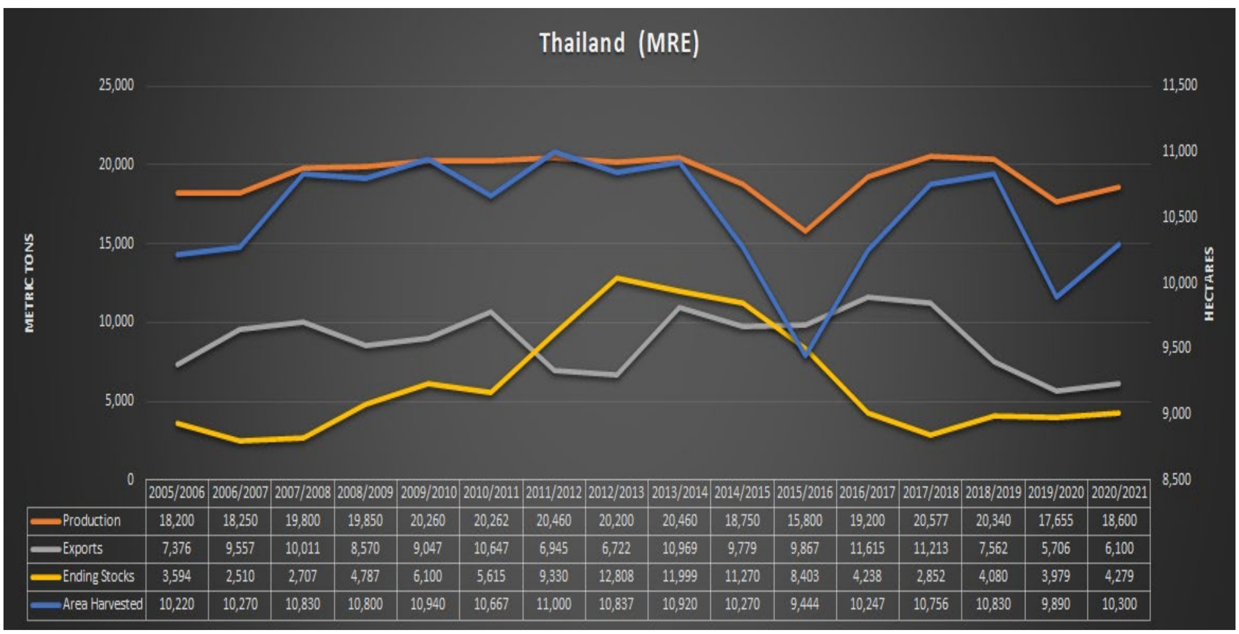
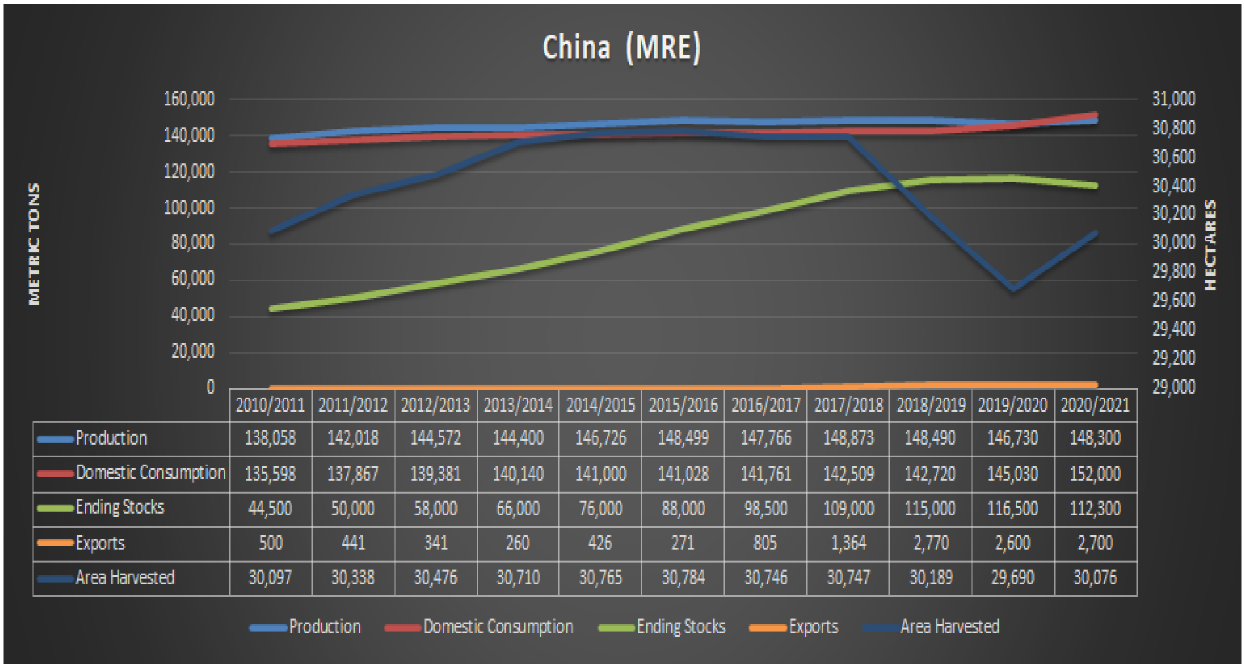


Figure A12. Thailand Rice S&D: 2005 to 2021 (The Rice Trader, 2021)



	2010/2011	2011/2012	2012/2013	2013/2014	2014/2015	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021
Production	138,058	142,018	144,572	144,400	146,726	148,499	147,766	148,873	148,490	146,730	148,300
Domestic Consumption	135,598	137,867	139,381	140,140	141,000	141,028	141,761	142,509	142,720	145,030	152,000
Ending Stocks	44,500	50,000	58,000	66,000	76,000	88,000	98,500	109,000	115,000	116,500	112,300
Exports	500	441	341	260	426	271	805	1,364	2,770	2,600	2,700
Area Harvested	30,097	30,338	30,476	30,710	30,765	30,784	30,746	30,747	30,189	29,690	30,076

Figure A13. Chinese Rice S&D: 2010 to 2021 (The Rice Trader, 2021)

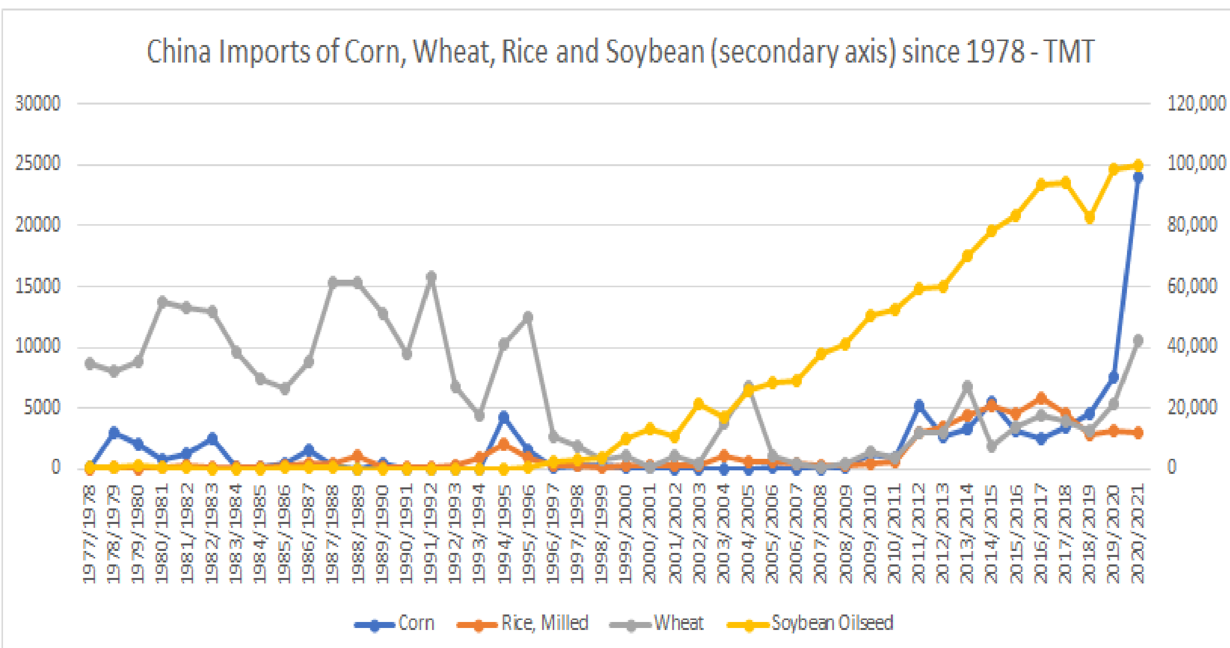


Figure A14. China's Major Grain Imports: 1977 to 2021 (The Rice Trader, 2021)

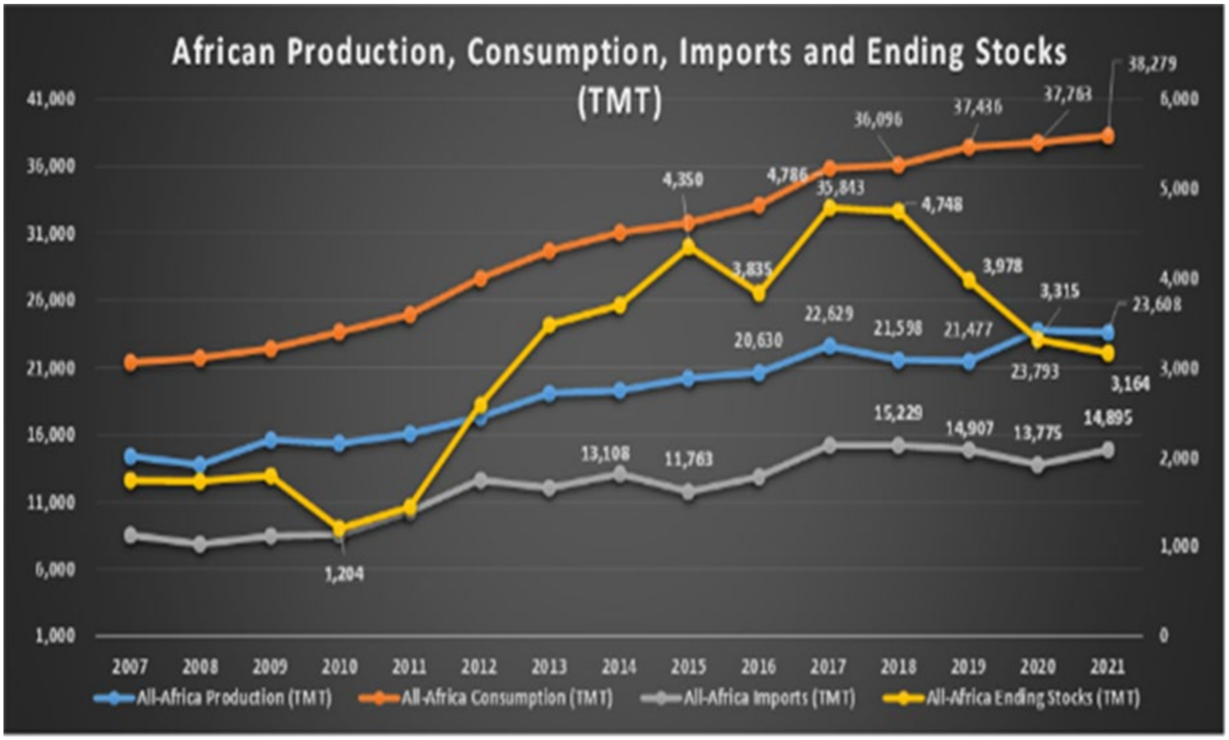
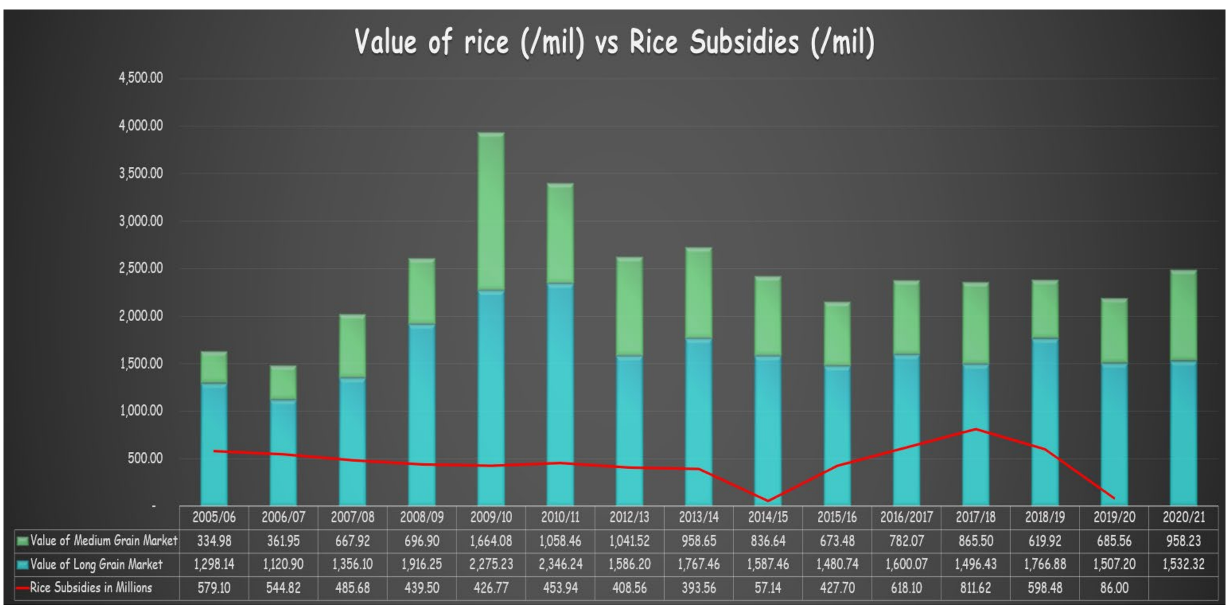


Figure A15. African Rice S&D: 2007 to 2021 (The Rice Trader, 2021)



	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2012/13	2013/14	2014/15	2015/16	2016/2017	2017/18	2018/19	2019/20	2020/21
Value of Medium Grain Market	334.98	361.95	667.92	696.90	1,664.08	1,058.46	1,041.52	958.65	836.64	673.48	782.07	865.50	619.92	685.56	958.23
Value of Long Grain Market	1,298.14	1,120.90	1,356.10	1,916.25	2,275.23	2,346.24	1,586.20	1,767.46	1,587.46	1,480.74	1,600.07	1,496.43	1,766.88	1,507.20	1,532.32
Rice Subsidies in Millions	579.10	544.82	485.68	439.50	426.77	453.94	408.56	393.56	57.14	427.70	618.10	811.62	598.48	86.00	

Figure A16. Value of U.S. vs the Rice Subsidy: 2005 to 2021 (The Rice Trader, 2021)

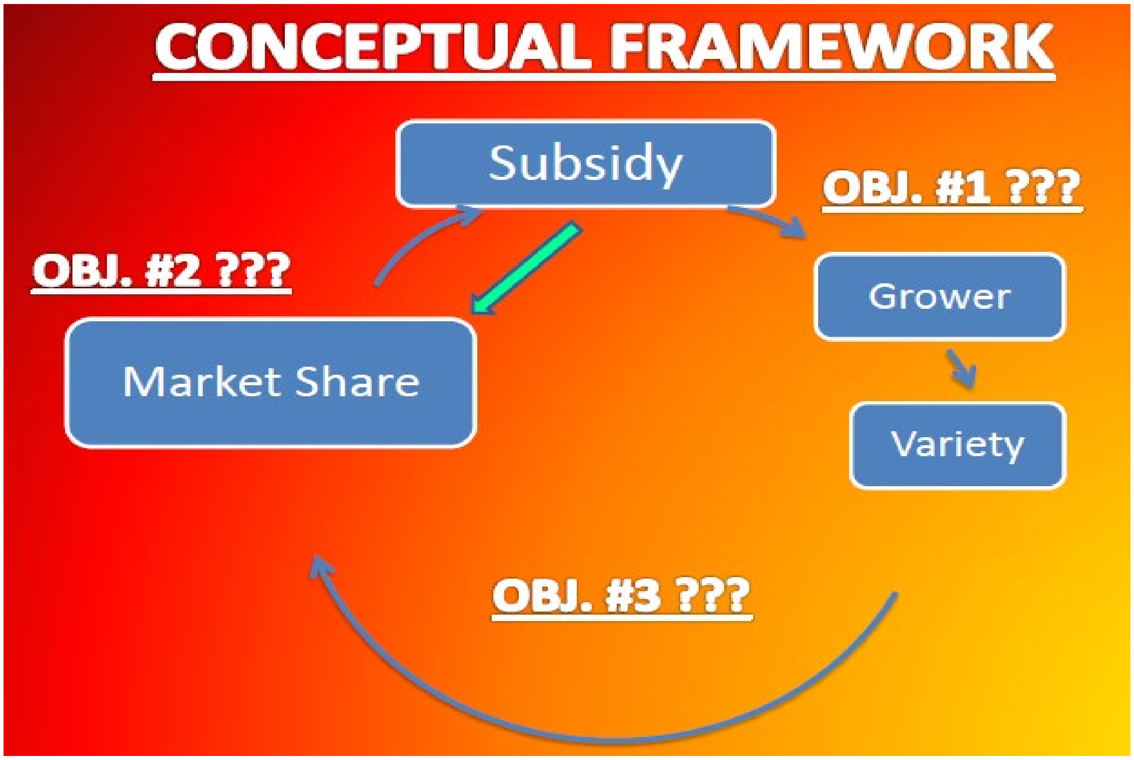


Figure A17. Conceptual Framework for Effects of Subsidy, Variety, and Market Share

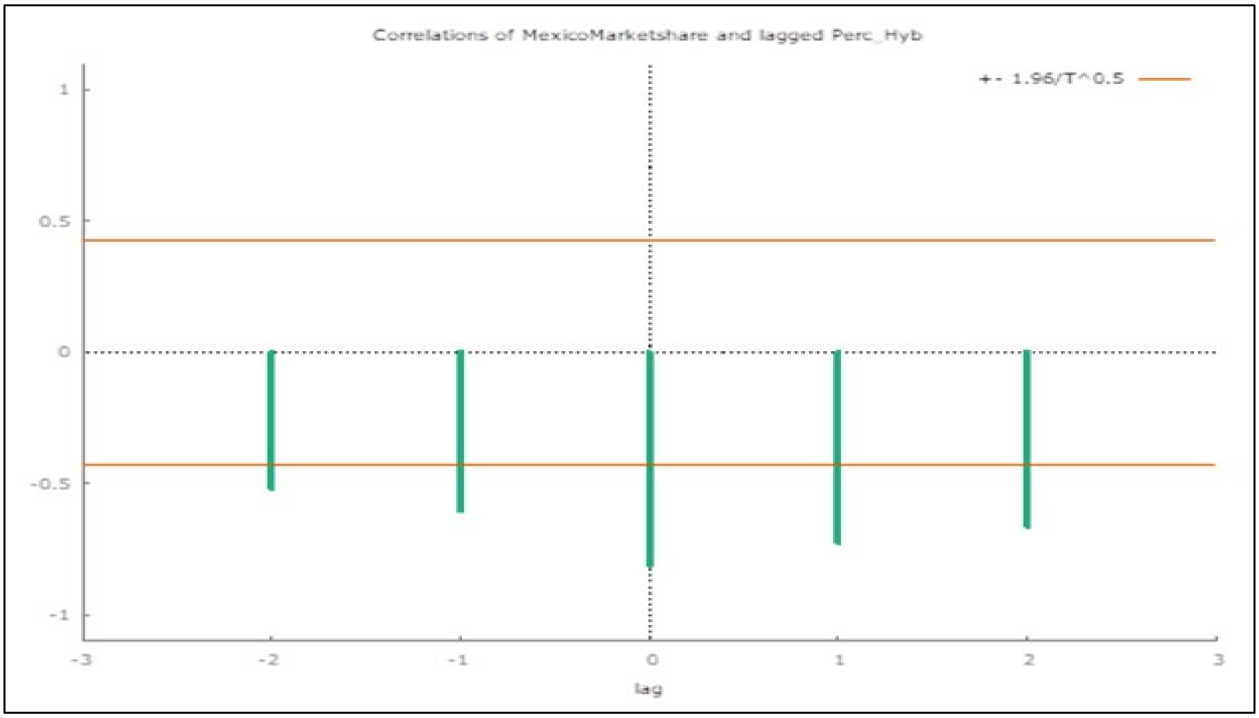


Figure A18. Gretl: Cross-Autocorrelation for Hybrid Rice Production and Mexico’s Market Share